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Improvement of functional and special physical fitness of 11–12-year-old swimmers using aquafitness and interval hypoxic training

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Abstract

Background and Study Aim. The introduction of aquafitness elements and interval hypoxic training into the training process of young swimmers aged 11–12 years, in accordance with their age-related and morphofunctional characteristics, may enhance the effectiveness of functional and special physical fitness without increasing the volume of traditional physical loads. Such an approach reduces the risk of maladaptive responses and functional disturbances of the cardiovascular system. The aim of the study was to scientifically substantiate and develop a swimming training programme incorporating aquafitness elements and interval hypoxic training to improve the functional and special physical fitness of swimmers aged 11–12 years.

Material and methods. The following research methods were applied: theoretical analysis and synthesis of scientific literature; pedagogical methods (observation and experiment); testing of special physical fitness; physiological research methods (cycle ergometry, heart rate monitoring, chronometry, Stange and Genchi breath-holding tests); and methods of mathematical statistics.

Results. The study presents data on the effects of swimming training sessions incorporating aquafitness elements and interval hypoxic training on the functional and special physical fitness of swimmers aged 11–12 years.

Conclusions. The combined application of interval hypoxic training and aquafitness elements contributes to a significant improvement in special physical and functional fitness of swimmers (boys and girls) aged 11–12 years. This approach optimises adaptive processes in young athletes and reduces the risk of overload. The obtained results confirm the feasibility of implementing this methodology in the training process and open prospects for further research aimed at its improvement.

Keywords: swimmers; physical fitness; functional capacity; boys; girls.

Анотація

Удосконалення функціональної та спеціальної фізичної підготовленості 11-12 річних плавців засобами аквафітнесу та інтервального гіпоксичного тренування

Передумови та мета дослідження. Впровадження в тренувальний процес юних плавців 11–12 років елементів аквафітнесу та інтервального гіпоксичного тренування, що відповідають віковим і морфофункціональним можливостям організму, сприятиме підвищенню ефективності функціональної та спеціальної фізичної підготовленості без необхідності збільшення обсягів традиційних фізичних навантажень, знижуючи ризик порушення адаптаційних процесів та функціонального стану серцево-судинної системи. Мета дослідження: науково обґрунтувати та розробити програму тренувальних занять із плавання із використанням елементів аквафітнесу та інтервального гіпоксичного тренування для удосконалення функціональної та спеціальної фізичної підготовленості плавців 11-12 років.

Матеріал і методи. В роботі використано такі методи дослідження: теоретичний аналіз і узагальнення даних наукових джерел; педагогічні (спостереження та експеримент), тестування спеціальної фізичної

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підготовленості, фізіологічні методи досліджень (велоергометрія, пульсометрія, хронометрія, проби Штанге, Генча); методи математичної статистики.

Результати. У статті представлено дані впливу тренувальних занять із плавання із використанням елементів аквафітнесу та інтервального гіпоксичного тренування на функціональну та спеціальну фізичну підготовленість плавців 11-12 років.

Висновки. Комплексне застосування інтервального гіпоксичного тренування з елементами аквафітнесу сприяє підвищенню спеціальної фізичної та функціональної підготовленості плавців (хлопців та дівчат) 11–12 років. Такий підхід оптимізує адаптаційні процеси організму спортсменів та знижує ризик перевантажень. Отримані результати підтверджують доцільність упровадження цієї методики у тренувальний процес і відкривають перспективи подальших досліджень щодо її вдосконалення.

Ключові слова: плавці, фізична підготовка, функціональні можливості, хлопці, дівчата.

Introduction

In contemporary sport, there is a steady tendency towards increasing performance at international competitions, which, according to researchers, is largely driven by the implementation of innovative technologies in athletes' training systems [1]. This trend is particularly evident in swimming, especially at the early stages of long-term athlete development, where the focus is placed on achieving an optimal balance between training loads and age-related functional capacities of the developing organism [2–4]. Recent studies have confirmed the effectiveness of incorporating aquafitness elements and interval hypoxic training into training programmes for swimmers aged 11–12 years. These methodologies significantly improve indicators of aerobic and anaerobic endurance without excessive physiological strain, thereby reducing the risk of overloading the growing organism [5–8].

Despite the availability of published data, several important issues remain unresolved. In particular, there is no unified approach to determining the optimal duration and frequency of interval hypoxic training sessions when combined with aquafitness exercises. Moreover, the long-term effects of such training methods on the development of young swimmers have not been sufficiently investigated. There is also a lack of comparative analysis of physiological responses to hypoxic training models in comparison with traditional training approaches.

Research hypothesis: The integrated application of aquafitness and interval hypoxic training in the preparation of swimmers aged 11–12 years will significantly enhance functional (aerobic and anaerobic) and special physical capacities without increasing the overall training volume, compared with traditional training programmes.

Purpose of the study: To scientifically substantiate and develop a swimming training programme incorporating aquafitness elements and interval hypoxic training aimed at improving the functional and special physical fitness of swimmers aged 11–12 years.

Material and methods

Participants

The study involved 83 swimmers (42 boys and 41 girls) aged 11–12 years. The mean age of the participants was 11.4 ± 0.02 years. All athletes had a third sports qualification level. Informed consent to participate in the study was obtained from both the athletes and their parents or legal guardians.

Procedure

Swimmers in the control and experimental groups trained according to the standard curriculum for Children and Youth Sports Schools (CYSS) and Specialised Children and Youth Olympic Reserve Schools (SCYORS), which included six training sessions per week, each lasting 120 minutes. The structure of each session comprised a warm-up, a main part, and a cool-down.

A distinctive feature of the training process in the experimental groups was the implementation of interval hypoxic training using the *Endogenic-01* device. This training was performed before each swimming session during the preparatory part of the workout and lasted throughout 24 weeks of the preparatory period of the annual macrocycle.

Prior to the introduction of interval hypoxic training, athletes were instructed in diaphragmatic breathing techniques. In a supine position, with palms placed on the chest and abdomen, swimmers practised controlled breathing by focusing on the movement of the hands. Subsequently, athletes were familiarised with the structure of the device and the rules for its safe and effective use.

Breathing through the *Endogenic-01* device created internal resistance, resulting in the formation of a gas mixture with a reduced oxygen concentration (~18%) and an increased carbon dioxide concentration (~3%). This induced a state of moderate hypoxia and hypercapnia, stim-

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ulating the functional capacities of the respiratory system and promoting bronchial dilation. Particular attention was paid to slow and controlled exhalation, which was regulated by monitoring the position of the float inside the device.

Before each session, athletes independently prepared the device by filling it with water to a prescribed level and installing the appropriate float. The duration of inhalation, exhalation, pauses, water volume, and the total duration of each session were recorded in individual monitoring cards.

In addition, to enhance strength-related qualities, strength training sessions conducted on land ("dry swimming") in the experimental groups were replaced three times per week with water-based training incorporating aquafitness elements. Each session lasted 20 minutes. Exercises were progressively modified in terms of coordination complexity, intensity, tempo, and number of repetitions, taking into account individual levels of physical and functional fitness.

The following equipment was used during aquafitness sessions: aqua belts, water gloves, small and large dumbbells, elastic resistance bands, kickboards, and other auxiliary devices. The combination of interval hypoxic training with aquafitness exercises enhanced the overall effectiveness of the training process, optimised functional fitness, and improved the adaptive capacity of young swimmers.

Research Methods: The study employed the following methods: theoretical analysis and synthesis of scientific and methodological literature; pedagogical methods (observation and experiment); testing of special physical fitness; physiological research methods (cycle ergometry, heart rate monitoring, chronometry, Stange and Genchi breath-holding tests); and methods of mathematical statistics [9].

Based on the theoretical analysis and generalisation of scientific and methodological sources, the relevance and purpose of the study were determined, and the working research hypothesis was formulated.

Pedagogical observation was conducted to define the direction of the research and to monitor the organisation of the training process for swimmers aged 11–12 years throughout the entire experiment.

The pedagogical experiment consisted of two stages: a baseline (ascertaining) stage and a formative stage.

At the **baseline stage**, the initial level of physical fitness was assessed, and training programmes incorporating aquafitness elements and interval hypoxic training were developed. The formative stage involved evaluating the effectiveness of the developed programmes in terms of their impact on physical and functional fitness.

Physiological testing of young swimmers (11–12 years) was conducted in the first half of the day (10:00–13:00), 1–1.5 hours after meals, under controlled environmental conditions (relative humidity ≤ 80%, air temperature +19 to +21 °C). The testing area was well ventilated.

A comprehensive assessment of the effects of swimming training combined with aquafitness elements and interval hypoxic training on functional fitness was performed. The testing protocol included cycle ergometer workloads to analyse aerobic and anaerobic performance, resistance to hypoxia, and the rate of cardiovascular recovery following graded physical exercise.

Aerobic performance was assessed using the PWC170 index (power output at a heart rate of 170 beats·min^{-1}), determined by a two-load test (1 and 2 W·kg^{-1}) on a cycle ergometer at a pedalling rate of 60 rpm with 3-minute stages. If the difference in heart rate between the two workloads was less than 40 beats·min^{-1}, a third workload (2.5 W·kg^{-1}) was applied, and calculations were based on the first and third stages. Maximal oxygen uptake (VO_2max) was calculated using the formula:

$VO_2max = 1{,}7 \cdot PWC170_{абс} + 1240$, причому використовували як абсолютні, так і відносні значення (мл·хв$^{-1}$·кг$^{-1}$). with both absolute and relative values (ml·min^{-1}·kg^{-1}) reported.

Anaerobic performance was assessed using two approaches:

ShögyCherebetin test: submaximal workload for 1 minute (225 W), followed by determination of the maximal number of pedal revolutions. The maximal external mechanical work (MEMW) was calculated and expressed in kgm·min^{-1}.

VanT10/VanT30 tests: following a warm-up (5 minutes at 60 W), athletes performed 4–5 accelerations lasting 5–6 s at maximal pedalling frequency. After a 4-minute recovery period, a 30-second maximal effort at 225 W was completed. Pedal revolutions over 10 and 30 seconds were recorded to calculate power output of the anaerobic alactic (VanT10) and anaerobic lactic (VanT30) energy systems.

Cardiovascular function was evaluated during 5-minute workloads (1 and 2 W·kg^{-1}, 60 rpm), with measurements of heart rate and arterial blood pressure taken after each workload and at 1–3 minutes of recovery.

The ability of participants to tolerate arterial hypoxaemia and hypercapnia was assessed using functional hypoxic tests with breath-holding after inhalation (Stange test) and after exhalation (Genchi test).

Special physical fitness was assessed using swimming test exercises performed in different intensity zones, corresponding to the capabilities

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of energy supply systems:

a) Anaerobic alactic zone: 25 m freestyle swim at maximal speed.

b) Anaerobic lactic zone: interval test of 4 × 50 m freestyle with 15 s rest intervals.

c) Aerobic zone: 800 m freestyle swim at the highest possible pace.

d) Speed qualities: number of 25-m repetitions performed at maximal intensity at a heart rate of 150–170 beats·min^{-1}, with rest intervals of 2–4 minutes.

Heart rate values exceeding 170 beats·min^{-1} indicated work in the anaerobic lactic zone. An increase in the number of 25-m repetitions performed at a heart rate of 150–170 beats·min^{-1} was considered an indicator of increased power of the anaerobic alactic energy system.

Statistical analysis.

The research data were processed using methods of mathematical statistics. Statistical analysis was performed using *Statistica for Windows* (version 8.0). Measures of central tendency and variability were calculated to summarise and describe empirical data. The normality of data distribution was assessed using Pearson's chi-square (χ^2) test. After confirming normal distribution, the significance of differences between mean values was evaluated using Student's *t*-test. Differences were considered statistically significant at $p < 0.05$.

Results

The application of aquafitness elements combined with interval hypoxic training in swimming sessions with boys and girls aged 11–12 years significantly enhanced the development of aerobic and anaerobic performance.

As shown in **Table 1**, after 16 weeks of training in the experimental groups, boys demonstrated a statistically significant increase in both absolute and relative PWC170 values (by 21.47% and 17.16%, respectively), as well as in VO_2max (by 8.28% and 3.89%, respectively; $p < 0.05$).

In girls, significant improvements were observed earlier. After 8 weeks of training, absolute PWC170 and VO_2max increased by 4.36% and 1.63%, respectively ($p < 0.05$). After 16 weeks, both absolute and relative values of PWC170 increased by 7.80% and 8.28%, while VO_2max increased by 5.97% and 2.92%, respectively ($p < 0.05$).

No statistically significant changes in aerobic or anaerobic performance indicators were record-

Table 1. Ability to work in the zone of aerobic and anaerobic energy supply of boys (n=21) and girls (n=21) of the main groups at different stages of the study

Indicators	Gender of athletes	Before starting training	After 8 weeks	After 16 weeks	After 24 weeks
PWC170, kgm·min^{-1}	Guys	458.01±11.46	481.90±14.54	556.33±11.58*	558.52±11.58*
	Girl	437.22±5.75	456.27±6.71*	471.31±5.75*	487.62±8.57*
PWC170, kgm·min^{-1}·kg^{-1}	Guys	11.38±0.11	11.81±0.18	13.33±0.17*	13.38±0.17*
	Girl	11.04±0.13	11.41±0.13	11.70±0.11*	12.09±0.16*
VO2max, ml·min^{-1}	Guys	2018.62±19.48	2059.23±24.71	2185.76±19.69*	2189.49±19.69*
	Girl	1983.27±9.78	2015.66±11.41*	2041.22±9.78*	2068.96±14.58*
VO2max, ml·min^{-1}·kg^{-1}	Guys	50.52±0.77	50.73±0.76	52.48±0.54*	52.56±0.53*
	Girl	50.17±0.39	50.48±0.25	50.76±0.25	51.38±0.32*
VANT10, kgm·min^{-1}	Guys	889.43±29.28	973.00±35.32	1031.43±35.32*	1051.14±35.32*
	Girl	844.57±35.14	920.14±25.56	943.43±33.01*	944.43±33.01*
VANT10, kgm·min^{-1}·kg^{-1}	Guys	22.57±1.06	24.14±1.06	24.86±0.89	25.29±0.89
	Girl	21.29±0.71	23.00±0.53	23.43±0.71*	23.43±0.71*
VAnT30, kgm·min^{-1}	Guys	876.33±34.19	936.38±30.64	976.19±31.12*	976.43±33.42*
	Girl	808.71±30.2	858.00±32.48	889.86±25.20*	904.71±25.20*
VANT30, kgm·min^{-1}·kg^{-1}	Guys	22.14±1.01	23.19±0.89	23.52±0.89	23.52±0.89
	Girl	20.38±0.65	21.43±0.71	22.10±0.59	22.43±0.59*
MEMW, kgm·min^{-1}	Guys	840.76±32.82	878.73±29.48	919.68±31.70	937.36±31.70*
	Girl	800.26±29.66	839.88±28.16	876.97±24.42	881.33±24.42*
ICMR, kgm·min^{-1}·kg^{-1}	Guys	21.30±1.08	21.87±0.96	22.22±0.91	22.65±0.94
	Girl	20.19±0.67	20.99±0.61	21.77±0.55	21.86±0.55
Body weight, kg	Guys	40.24±0.89	40.81±0.89	41.76±0.59	41.76±0.59
	Girl	39.57±0.23	39.95±0.30	40.24±0.30	40.29±0.30

*Note. Data are presented as mean ± standard error of the mean (M ± m). * — statistically significant differences relative to the initial data (p < 0.05).*

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Table 2. Indicators of Hypoxia Tolerance at Rest in Boys and Girls Aged 11–12 Years at Different Stages of the Study

Hypoxic functional tests	Average values, x̄±S			
	Baseline	After 8 weeks	After 16 weeks	After 24 weeks
Control group of boys (n=21)				
Stange test, s	50.90±1.72	51.71±1.48	52.90±1.54	54.71±1.12
Genchi test, s	27.52±1.42	28.14±1.24	29.29±1.42	30.00±1.36
Main group of guys (n=21)				
Stange test, s	50.43±1.72	55.05±1.36*	60.76±0.89*	61.81±0.83*
Genchi test, s	27.48±1.18	32.00±0.83*	34.76±0.65*	35.29±0.77*
Control group of girls (n=20)				
Stange test, s	48.80±1.78	50.80±1.54	53.20±1.29	53.70±1.35
Genchi test, s	27.05±1.35	28.80±1.05	29.60±0.92	29.90±0.80
Main group of girls (n=21)				
Stange test, s	48.10±1.77	54.81±1.30*	60.86±1.06*	61.90±1.18*
Genchi test, s	26.90±1.24	32.29±0.89*	34.86±0.53*	34.90±0.35*

Note. Values are presented as mean ± SD. * Statistically significant difference compared with baseline ($p < 0.05$).

ed in the control groups of boys and girls after either 8 or 16 weeks of training.

After 24 weeks of training, boys in the experimental group exhibited a significant increase in absolute PWC170 by 21.95% and relative PWC170 by 17.59% ($p < 0.05$). Absolute VO_2-max increased by 8.46%, while relative VO_2max increased by 4.05% ($p < 0.05$). In girls, absolute and relative PWC170 increased by 11.53% and 9.50%, respectively, while VO_2max increased by 4.32% and 2.42% ($p < 0.05$).

In contrast, in the control groups, 24 weeks of training according to the standard youth swimming programme resulted in smaller, though statistically significant, increases in absolute PWC170 (boys: 10.74%; girls: 5.12%) and absolute VO_2-max (boys: 4.16%; girls: 1.95%; $p < 0.05$).

At the same time, after completion of the 24-week training programme incorporating aquafitness elements and interval hypoxic breathing in swimming sessions, absolute values of $VanT_{10}$ and $VanT_{30}$ increased in both boys and girls. In boys, $VanT_{10}$ increased by 18.18% ($p < 0.05$) and $VanT_{30}$ by 11.42% ($p < 0.05$), while in girls the corresponding increases were 11.82% ($p < 0.05$) and 11.87% ($p < 0.05$), respectively. In addition, girls demonstrated statistically significant increases in relative values of $VanT_{10}$ (by 10.05%) and $VanT_{30}$ (by 10.06%).

Furthermore, an increase in both absolute and relative indicators of maximal external mechanical work (MEMW) was recorded. In boys, MEMW increased by 11.49% ($p < 0.05$) in absolute terms and by 6.34% ($p < 0.05$) in relative terms, while in girls the corresponding increases were 10.13% ($p < 0.05$) and 8.27% ($p < 0.05$). These changes indicate an enhancement of the capacity of anaerobic lactic energy supply processes.

In both boys and girls of the control groups, no statistically significant changes in $VanT_{10}$, $VanT_{30}$, or MEMW were recorded over the 24-week training period conducted according to the standard programme for children and youth sports schools.

The combined use of aquafitness elements and interval hypoxic training during swimming sessions accelerated the positive dynamics of Stange and Genchi test indicators in both boys and girls of the experimental groups (Table 2).

In both sexes, statistically significant changes were already observed after 8 weeks of training. In boys, mean breath-holding time during inhalation increased by 9.16% ($p < 0.05$), and during exhalation by 16.45% ($p < 0.05$). After 16 weeks, these indicators increased by 20.48% ($p < 0.05$) and 26.49% ($p < 0.05$), respectively. After 24 weeks of training, the increases reached 22.57% ($p < 0.05$) during inhalation and 28.42% ($p < 0.05$) during exhalation.

In girls, after 8 weeks of training, breath-holding time during inhalation increased by 13.95% ($p < 0.05$), and during exhalation by 20.03% ($p < 0.05$). After 16 weeks, the increases amounted to 26.53% ($p < 0.05$) and 29.59% ($p < 0.05$), respectively. After 24 weeks of training, breath-holding time increased by 28.70% ($p < 0.05$) during inhalation and by 29.74% ($p < 0.05$) during exhalation. No statistically significant changes were observed in the control groups.

The results of the study on the effects of the combined application of aquafitness elements and interval hypoxic training in swimming sessions with swimmers aged 11–12 years showed that, already after 16 weeks from the beginning of the formative experiment, a marked improvement in indicators of special physical fitness was observed.

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In particular, the time required to complete the tests "800 m freestyle swimming" and "25 m freestyle swimming at maximal speed" decreased by 2.81% and 4.13%, respectively. In addition, during the "4 × 50 m freestyle swimming with 15 s rest intervals" test, a reduction in the time to complete the first and second segments was recorded by 5.11% and 5.00%, respectively.

After 16 weeks of training, athletes of the same group also demonstrated a statistically significant increase in the number of 25 m repetitions performed at maximal intensity (within a heart rate range of 150–170 beats·min^{-1}), amounting to 21.15%.

Further results obtained after 24 weeks from the beginning of training according to the proposed programme indicated that boys in the experimental group exhibited significant improvements in work capacity: by 5.66% ($p < 0.05$) in the aerobic energy supply zone and by 9.26% in the anaerobic alactic energy supply zone.

In addition, the power of the anaerobic alactic energy system, as assessed by the test "number of 25 m maximal-effort repetitions", increased by 38.46%. Performance in the first and second segments of the 4 × 50 m freestyle test also improved by 9.48% and 6.23%, respectively.

The combined application of aquafitness elements and interval hypoxic training during swimming sessions over a 16-week period in girls of the experimental group resulted in statistically significant improvements in indicators of special physical fitness. In particular, the time required to complete the "800 m freestyle swimming" test decreased by 3.23% ($p < 0.05$), while performance in the "25 m freestyle swimming at maximal speed" test improved by 4.57% ($p < 0.05$). During the "4 × 50 m freestyle swimming with 15 s rest intervals" test, the time to complete the first segment was reduced by 5.43% ($p < 0.05$). In addition, the number of 25 m maximal-intensity repetitions (within a heart rate range of 150–170 beats·min^{-1}) increased by 33.33%, indicating enhanced functional endurance in female swimmers.

After 24 weeks of swimming training incorporating aquafitness elements and interval hypoxic training, girls in the experimental group demonstrated further statistically significant improvements in test performance. The time for the "800 m freestyle swimming" test decreased by 5.94%. During the "4 × 50 m freestyle swimming with 15 s rest intervals" test, performance improved in the first, second, and fourth segments by 9.16%, 4.66%, and 5.46%, respectively. Performance in the "25 m freestyle swimming at maximal speed" test improved by 10.97%. Furthermore, the number of 25 m freestyle repetitions performed at a heart rate of 150–170 beats·min^{-1} increased by 43.75%, confirming the effectiveness of the applied training programme for the development of speed-strength and endurance qualities in young female swimmers.

Comparative analysis of special physical fitness indicators between boys in the experimental and control groups demonstrated that athletes in the experimental group achieved statistically significantly better results across all assessed tests. Specifically, work capacity in the aerobic energy supply zone (as determined by the 800 m freestyle swimming test) was higher by 2.85% compared with the control group.

Work capacity in the anaerobic alactic energy supply zone, assessed by performance in the first and second segments of the 4 × 50 m freestyle test with 15 s rest intervals, exceeded control group values by 5.18% and 4.65%, respectively. Work capacity in the anaerobic lactic energy supply zone (according to the "25 m freestyle swimming at maximal speed" test) was higher by 7.21%, while the power of anaerobic energy supply systems (as indicated by the number of 25 m freestyle repetitions performed at a heart rate of 150–170 beats·min^{-1}) was higher by 20.00%.

Similarly to the findings observed in boys, girls in the experimental group demonstrated substantially higher indicators of special physical fitness compared with the control group. After 24 weeks of training, work capacity in the aerobic energy supply zone was higher by 2.43%, work capacity in the anaerobic lactic energy supply zone by 6.67%, and the power of anaerobic energy supply systems increased by 21.69%. In addition, improvements were noted in aerobic work capacity (by 2.31%) and in the power of anaerobic energy supply systems (by 15.00%).

Discussion

The assessment of functional and special physical fitness confirmed the effectiveness of combining aquafitness elements with interval hypoxic training in the preparation of swimmers aged 11–12 years.

In modern sports science, increasing attention is being paid to improving the efficiency of the training process at the early stages of long-term athlete development. Researchers emphasise that the enhancement of athletic performance in young swimmers can be achieved through the use of additional training means that intensify the effects of traditional physical loads [10–13]. This necessitates the optimisation of training structure, particularly in strength development, which directly influences special performance in swimming [14-16].

However, it has been demonstrated that increasing land-based strength training does not always lead to improvements in speed-strength

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qualities in water. Some studies report a temporary decline in swimmers' "feel for the water" following gym-based training sessions [1]. Furthermore, excessive land-based strength loads may negatively affect the functional state of the cardiovascular system in young athletes [6, 7].

In this context, the use of water-based strength exercises is considered more appropriate, as they reduce mechanical stress on the musculoskeletal system while simultaneously promoting the development of strength, endurance, and coordination [17, 18]. The beneficial effects of aquatic exercises are associated with gravitational unloading, tonic stimulation of the cardiovascular and respiratory systems, and a general conditioning effect. The integration of aquafitness elements allows for targeted strength development under conditions closely resembling the specific demands of swimming [19, 20, 21].

In recent years, hypoxic training methods, particularly interval hypoxic breathing, have gained increasing popularity in sports practice. Their effectiveness lies in stimulating adaptive mechanisms of the cardiorespiratory system and enhancing aerobic and anaerobic performance without a substantial increase in training volume. This is especially important when working with young athletes [22, 23].

The results of the present study confirm the feasibility and effectiveness of incorporating aquafitness elements and interval hypoxic training into the training process of both male and female swimmers aged 11–12 years. After 24 weeks of training, significant improvements were observed in most indicators of functional and special physical fitness, highlighting the high adaptive potential of the proposed approach at the stage of preliminary basic training.

Thus, as a result of the present study, scientific concepts concerning the possibilities for improving the functional and special physical fitness of swimmers aged 11–12 years have been further developed.

The findings expand existing knowledge on the positive effects of artificially induced hypoxia and hypercapnia on the aerobic capacity of male and female swimmers aged 11–12 years.

For the first time, the positive impact of using aquafitness exercises in combination with artificially induced hypoxia on the special physical and functional fitness of both male and female swimmers aged 11–12 years has been demonstrated.

Conclusions

The combined application of interval hypoxic training and aquafitness elements contributes to an improvement in the special physical and functional fitness of swimmers (boys and girls) aged 11–12 years. This approach optimises adaptive processes in the athletes' bodies and reduces the risk of overload. The obtained results confirm the feasibility of implementing this methodology in the training process and open prospects for further research aimed at its improvement.

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Conflict of interest
The authors declare that there is no conflict of interest.

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