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The Effect of Combined Sprinting and Plyometric Training With Modified Circuits on Strength Endurance, Terminal Velocity, Aerobic Capacity, and 400m Performance in Under-20 Years

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Abstract: *The specificity of the 400m race requires runners to run at speeds close to their maximum. This places a significant role on the central nervous system, which is responsible for the continuous mobilization of muscle fibers when a large amount of lactate accumulates. Consequently, it must improve the efficiency of the nervous system to increase the mobilization of fast-twitch muscle fibers during high lactate accumulation within the muscles. This must also increase the ability of these fibers to generate the energy they need by removing and breaking down lactate during intensive training and competition. This is the key to developing a runner's ability to tolerate and handle lactate accumulation and produce high speed despite the large accumulation, which is a high indicator of the efficiency of the body's functional organs and systems. The study aimed to: 1. Identify the effect of combined running and plyometric exercises using modified circuits on strength endurance, final speed, aerobic capacity, and the 400m completion rate for under-20years. 2. Identify the superiority of the effect between the experimental and control groups in developing research variables. The researchers used the experimental approach, designing two equivalent groups: control and experimental, to suit the research objectives and hypotheses. The research population consisted of 16 runners from the Middle Euphrates Governorates (Karbala, Babil, Najaf, Diwaniyah) and the capital, Baghdad, in the 400m under-20 competition. The researcher randomly selected the 10 runners for his research sample, representing 62.5% of the research population. The most important conclusions of the researchers were:*

Keywords: *Sprinting, Plyometric, Training, Strength, Endurance.*

Introduction

Athletics is a widely popular sport worldwide. What distinguishes it from other sports is the variety of its competitions, each one distinct from the next. The 400m race is one of the most exciting, thrilling, and competitive athletic events, requiring runners to run the entire race distance at speeds close to their maximum. "The uniqueness of this event places a significant burden on the body's various functional systems due to the increased accumulation of lactate during training and competition, as this competition falls within the framework of the lactic system. Since the uniqueness of this competition requires runners to run at speeds close to their maximum, this places a significant role on the central nervous system, as it is responsible for the continuous mobilization of muscle fibers when a large amount of lactate accumulates. Athletic performance is influenced by several physiological

processes related to the nervous system's ability to regulate the activities of the body's various systems and organs. Enhancing the central nervous system's ability to recruit fast-twitch muscle fibers during high muscle lactate buildup and increasing its ability to generate the necessary energy by removing and breaking down lactate during intense training or competition is a key factor in developing a runner's ability to withstand lactate buildup and maintain high speeds despite elevated lactate levels. This is an important indicator of the efficiency of the body's functional systems and organs."

Using a combination of sprint training and plyometric exercises within modified training circuits aims to enhance the central nervous system's ability to recruit fast-twitch muscle fibers under conditions of high muscle acidity, contributing to the development of muscle endurance, terminal velocity, and aerobic capacity, thus improving overall athletic performance.

Methodology

Research Problem:

Clarifying the true relationship between the central nervous system and endurance racing remains complex and challenging. Runners who specialize in this type of competition possess powerful nervous systems that play a pivotal role in determining the success or failure of both training and competition. The nervous system contributes to regulating running speed during endurance training and racing and can also be a major cause of fatigue. Based on this concept, which is part of recent developments in training science, and through field observations by researchers with extensive practical training experience, a clear decline in athletic achievement has been observed. This is attributed to the weakness of training programs designed to enhance the nervous system's ability to recruit fast-twitch muscle fibers to function under conditions of lactate accumulation. It has also been shown that many coaches focus on training that targets speed and strength separately, adopting training methods that enhance only one physical characteristic without combining exercises specifically designed to develop the nervous system's ability to function under challenging conditions. Accordingly, researchers have developed a modern training program that focuses on enhancing the efficiency of the nervous system, which positively impacts the development of the physical qualities and abilities associated with this type of sporting activity.

Research Objectives:

1. Identify the effect of combined running and plyometric exercises with modified circuits on strength endurance, final velocity, aerobic capacity, and 400m completion for under-20s.
2. To identify the differences between the two groups in developing the research variables under study.

Research Hypotheses:

1. Combined running and plyometric exercises with modified circuits have effects on strength endurance, final velocity, aerobic capacity, and 400m completion for under-20s.
2. Identify the superiority of the effect between the experimental and control groups in developing the research variables.

Research Areas:

- Human Area: 400m runners under 20 years of age in the Middle Euphrates and Baghdad clubs for the 2025 season.
- Time Area: From January 11, 2025 to April 24, 2025.
- Spatial Area: Karbala Olympic Stadium track, Hilla Stadium track, Najaf Stadium track, and Baghdad Ministry of Youth Stadium track.

Research Methodology:

The research methodology is determined by the nature of the problem to be studied. Since the research problem is experimental in nature, requiring the implementation of a specific training program, the researchers relied on the experimental approach by designing two equivalent groups: a control group and an experimental group, in line with the research objectives and hypotheses.

Research Population and Sample:

The research population was determined from 14 runners from the Middle Euphrates Governorates (Karbala, Babil, Najaf, Diwaniyah) and the capital, Baghdad, for the 400m under-20 race. The researchers randomly selected their sample of 10 runners, representing 71% of the research population. The sample was divided in the same manner into two groups: a control group and an experimental group, each comprising five runners.
The researchers performed a homogeneity process on the research sample members, using the variables of height, mass, and training age, and analyzed them statistically using Levene's law for the aforementioned variables, as shown in Table (1).

Table 1. Shows the homogeneity of the research sample members

Variables	Units	Degrees of freedom between groups	Degrees of freedom within groups	Levene's value of the mean	Morale level	Type of statistical significance
Height	Cm	1	8	1.100	.376	Sig.
Mass	Kg	1	8	.148	.741	Sig.
Training Age	Month	1	8	.638	.469	Sig.

It is clear from Table (1) that the level of significance for the test for all variables was greater than the significance level (0.05), which indicates the absence of significant

differences between the individuals of the research sample, which indicates their homogeneity in these variables.

Methods, devices, and tools used in the research:

- Observation.
- Personal interview.
- Questionnaire.
- Tests and measurements.
- Chinese medical scale.
- (2) Japanese Sony cameras.
- ACER electronic calculator.
- (2) Chinese whistles.
- 2 m long leather measuring tape.
- (4) Chinese stopwatches.
- (4) 30 cm high cones.

Field Research Procedures:

Identifying Tests for the Variables:

After reviewing sources, references, theses, and scientific frameworks, the researchers identified the following tests to measure the research variables:

- Strength endurance was measured using the Bosco test[2]—jumping up onto a strength platform from a half-squat position for 60 seconds.
- Final velocity was measured using the achievement test, where the time for the last 60 meters of the race was measured.
- Measuring aerobic capacity using the Bruce test.

Test Description:[3]

First: Bosco test, 60 seconds.

- Test objective: Measuring strength endurance.
- Test requirements: Strength measuring platform - computer - whistle - stopwatch.
- Test description: "The test consists of jumping on a strength measuring platform for 60 seconds. After completing the warm-up requirements properly, the test begins with the subject standing on the strength measuring platform with their hands on their waists (waist position). When ready for the test, the timer blows a whistle to begin the test. The subject jumps up from a half-squat position and continues jumping until the 60 seconds are complete. After that, the timer blows a whistle to stop the test. All research sample members complete the test in the same manner."
- Recording: Data were recorded using a computer, then entered and processed using Excel.

Second: Final velocity:

- Test objective: Measuring the final velocity of the research sample members.

- Test requirements: Athletics track - computer - Whistle, Stopwatch, Indicators
- Test Description: The last 60m of the athletics track was marked. Indicators were placed on the fields, and a camera was installed to record the time of the last 60m. The time was analyzed using the Kinovea program, in addition to manual timing by setting a special timer to record the time of the last 60m.
- Recording: The times are recorded by analyzing the test using the aforementioned program and then statistically processing.

Third: Bruce Test:

- Test Purpose: Measuring aerobic capacity.
- Test Requirements: Fitmate Pro system:
    - A Life Fitness stationary bike with a capacity of 9700, American-made, mechanical (hand and foot), with a screen to monitor speed and determine the resistance of each test subject.
    - Hygienic paper for cleaning respirator masks/Antiseptic solution for sterilizing respirator masks.
    - A personal electronic scale measuring (kg) and its parts.
- Test Description: Before starting the test, the test administrator cleans the respirator mask used to measure capacity. The airway is sterilized with a disinfectant solution, the parts of the Fitmate Pro device are connected together, the pulse belt is secured to the tester's chest, and the Bluetooth pulse signal receiver is installed in the device. This is followed by entering the tester's information into the device, including name, date of birth, gender, height, weight, and the type of test required, which is aerobic capacity. The breathing mask is then securely fastened using its straps, ensuring that no air is leaking from the mask. The tester then climbs onto a stationary bicycle with a push-feet function. The tester gradually increases the speed, with the test administrator instructing the user to control the speed of the machine by gradually increasing the speed and monitoring it from (2.5) to (7) km/h. This differs from the treadmill in that it determines the speed and engages the body's muscles during the exercise. The device contains a small screen with a bar chart showing the pulse and aerobic capacity, along with the percentages of each, which are monitored by the assessor. Recording: The Fitmate Pro device provides a comprehensive reading of the measurements for aerobic capacity in milliliters/kg/h. Minutes, and compared to the objective standard issued by the device to determine the individual's rate of improvement.

Fourth: 400m Test:

- Purpose of the Test: Measuring the achievement of the research sample members
- Test Requirements: Legal athletics track, stopwatches, timers, whistle, starter, scoring form, recorder.

- Test Description: Each pair of research sample members is tested. The two test subjects stand near the starting line, each in their designated area. Upon hearing the starter's signal, they move around, and each sits in the low starting position. The starter then gives the "Get Ready" signal. The starter then gives the start signal, and the two test subjects set off to complete a full lap as far as possible. Upon crossing the finish line, the timers stop their watches and record them on the scoring form. The rest of the test subjects complete the test in the same manner.

Pre-tests:

Before beginning the exercises designed by the researchers, pre-tests were conducted on the research sample over two consecutive days, separated by one rest day. This interval was intended to avoid fatigue from the athletes' excessive testing, thus ensuring the accuracy of the results obtained. These tests included measuring strength, terminal velocity, and aerobic capacity, in addition to a 400-meter completion test. The tests were conducted on the Karbala Olympic Stadium track, with the exception of the strength and aerobic capacity tests, which were conducted in the laboratory of the College of Physical Education and Sports Sciences/University of Karbala using a force platform and a FitTM Pro device.
On the first day of testing, the researchers measured and recorded the mass and height, as well as the chronological and training age of the sample members. The researchers ensured that all testing conditions were standardized, including the location of the test, the performance mechanism, and the support team, to ensure consistent post-test conditions. The tests were distributed as follows:

- Day One: Sunday, January 19, 2025
    1. 9:00 AM / Strength Endurance Test
    2. 11:00 AM / Aerobic capacity test.
- Day Two: Tuesday, January 21, 2025
    1. 9:00 AM / 400m run achievement test
    2. 2-4-4 Equivalence Procedures:

To enable the researchers to identify the differences between "the two independent groups, the control and the experimental, and attribute these differences to the experimental factor, the researchers conducted an equivalence process between the two groups in the variables of strength endurance, final speed, aerobic capacity, and achievement. The parametric statistical law (t-test) was used for two independent samples of equal number, based on the results of the pre-measurements and tests, as shown in Table (2)".

Table 2 . shows the equivalence of the control and experimental groups in terms of the variables studied.

Variables under study	Units	Control group		Experimental group		t value	Moral level	Statistical significance
		Mean	Std	Mean	Std			

Strength Endurance	Newtons	2129.700	24.406	2177.30	85.884	-1.191	0.267	Non sig.
Terminal Velocity	seconds	9.1160	0.0658	9.0860	0.05273	0.796	0.449	Non sig.
Aerobic Capacity	milliliters/kg/minute	43.6640	0.53379	43.6500	0.79847	.033	0.975	Non sig.
Achievement	seconds	54.0150	0.29345	53.9950	0.09955	0.158	0.878	Non sig.

Table (2) shows that all significance level values were greater than (0.05), indicating that there were no statistically significant differences between the control and experimental groups in the variables under study, which confirms their equivalence.

Main Experiment:

"The researchers prepared combined running and plyometric exercises with modified circuits to develop the studied research variables. They relied on their own field training experience and expertise, consulting the opinions of specialists in the field of training science and consulting Arab and foreign scientific sources on training and physiology. The exercises were characterized by the following":

- The exercises were implemented in the last quarter of the baseline period and continued until the end of the special preparation period.
- The exercises included in the training program for the experimental group sample began on Sunday, January 26, 2025.
- The exercises continued for (8) weeks.
- The number of training units per week (two training units).
- The days for implementing the training units were Saturday and Wednesday.
- The total number of training units was (16) training units (*).
- The training time for the modified circuits varied according to the goals and requirements of each, and their location in the planning. It ranged between (30-45) minutes.
- The intensity used in running exercises ranged between (85% - 115%) of the maximum 5 km stride for the research sample, which was standardized according to the (5-Tier System) theory for multi-step training and the four-second rule of the Italian coach Frank Horwill. As for the intensity used in plyometric exercises and running technique exercises, the intensity ranged between (80% - 90%) of the maximum distance for performing each exercise.
- As for training methods, the researcher used the continuous training method to implement the exercises within the circuit.

- The researchers, in agreement with the trainers, ensured that training for the remaining days of the week was as equal as possible for all members of the experimental research sample in terms of training load components, physical characteristics, and abilities.
- The implementation of the exercises prepared in the training program concluded on Wednesday, March 26, 2025.

Post-tests:

Using the same procedures used for the pre-tests, the researchers conducted the post-tests for the research sample for the control and experimental groups after completing the exercises for the experimental group on Sunday, March 30, 2025, and Tuesday, April 1, 2025. The researchers were committed to providing the same conditions and requirements in terms of time, place, and tools used in the pre-tests, as much as possible.

Statistical Methods:

The researchers chose relevant statistical methods to compare the results of the pre- and post-tests, using the Statistical Package for Statistics (SPSS).

Result and Discussion

- **Presentation, Analysis, and Discussion of Results:**

This section includes a presentation and analysis of the results of the pre- and post-tests for the variables of strength endurance, terminal velocity, aerobic capacity, and the 400-meter completion test for both the control and experimental groups, in addition to a discussion.

1. **Presentation and Analysis of the Results of the Pre- and Post-tests for the Variables of Strength Endurance, Terminal Velocity, aerobic capacity, and the 400-meter completion test for the Control Group**

Table 3. shows the mean values, standard deviations, mean differences, standard errors of the differences, calculated t-value, significance level, and type of statistical significance for the pre- and post-tests for the studied research variables for the control group

Variables	Test	Mean	Std	Mean diff.	Std diff.	T value	Morale level	Statistical significance
Strength Endurance Terminal Velocity	**Pre**	2129.800	24.407	-98.600	14.834	-6.647	0.003	**Sig.**
	Post	2228.400	28.711					
Aerobic Capacity	**Pre**	9.1160	0.06580	0.18000	0.01732	10.392	0.000	**Sig.**
	Post	8.9360	0.03847					
Strength Endurance Terminal Velocity	**Pre**	43.6640	0.53379	-1.17400	0.24647	-4.763	0.009	**Sig.**
	Post	44.8380	0.70804					
Aerobic Capacity	**Pre**	54.0150	0.29345	0.74000	0.35180	5.152	0.004	**Sig.**
	Post	53.2750	0.11606					

Table (3) shows the statistical indicators for the results of the pre- and post-tests for the "variables of strength endurance, maximum speed, aerobic capacity, and completing the 400-meter run, which were conducted on members of the control group who applied the exercises prescribed by the trainers. The results showed that the arithmetic means were better in the post-test according to the measurement levels of the variables under study. The significance levels confirmed, through the use of the statistical law (t-test for related samples), that all of these variables were less than the significance level of (0.05), indicating the presence of statistically significant differences between the two tests in favor of the post-tests".

2. **"Presentation and analysis of the results of the pre- and post-tests for the variables of strength endurance, maximum speed, aerobic capacity, and completing the 400-meter run for the experimental group".**

Table 4. shows the mean values, standard deviation, mean differences, standard errors of the differences, calculated t-value, significance level, and type of statistical significance for the pre- and post-tests for the variables of the experimental group

Variables	Test	Mean	Std	Mean diff.	Std diff.	T value	Morale level	Statistical significance
Strength Endurance Terminal Velocity	**Pre**	2177.400	85.894	-157.400	21.533	-7.310	0.002	**Sig.**
	Post	2334.800	50.919					
Aerobic Capacity	**Pre**	9.0860	0.05273	0.32600	0.02159	15.102	0.000	**Sig.**
	Post	8.7600	0.04000					
Strength Endurance Terminal Velocity	**Pre**	43.6500	0.79847	-2.54800	0.39015	-6.531	0.003	**Sig.**
	Post	46.1980	0.47452					
Aerobic Capacity	**Pre**	53.9950	0.09955	1.82667	0.13003	34.412	0.000	**Sig.**
	Post	52.1683	0.05742					

Table (4)" shows the statistical indicators for the results of the pre- and post-tests for the variables of strength endurance, final velocity, aerobic capacity, and completion of the 400-meter run, which were administered to members of the experimental group, who used combined sprinting and plyometric exercises within modified training circuits. The results showed that the arithmetic means were better in the post-test according to the measurement levels of the variables under study. The significance levels, using the statistical law (t-test for linked samples), confirmed that all values were less than the significance level of (0.05), indicating the presence of statistically significant differences between the two tests, in favor of the post-tests".

3. **"Presentation, analysis, and discussion of the results of the post-tests for the variables of strength endurance, final velocity, aerobic capacity, and completion of the 400-meter run for the control and experimental groups".**

Table 5. shows the arithmetic means, standard deviations, calculated t-values, significance levels, and statistical significance types for the post-tests between the two groups regarding the research variables under study

Variables	Groups	Mean	Std	T value	Morale level	Statistical significance
Strength Endurance Terminal Velocity	Control	2228.400	28.711	-4.070	0.004	**Sig.**
	Experimental	2334.800	50.919			
Aerobic Capacity	Control	8.9360	0.03847	7.091	0.000	**Sig.**
	Experimental	8.7600	0.04000			
Strength Endurance Terminal Velocity	Control	44.8380	0.70804	-3.568	0.007	**Sig.**
	Experimental	46.1980	0.47452			
Aerobic Capacity	Control	53.2750	00.11606	20.935	0.000	**Sig.**
	Experimental	52.1683	0.05742			

Table (5) shows the statistical indicators for the post-test results for the variables of strength endurance, final velocity, aerobic capacity, and 400-meter completion, which were administered to members of the control and experimental groups. The results showed that the average strength endurance variable was higher for members of the experimental group compared to the control group, given that this variable is measured in Newtons, and the higher its value, the better the performance. The results also showed that the average final velocity and completion variables were lower for the experimental group compared to the control group, given that this variable is measured in time, and the lower the value, the better the performance. "The aerobic capacity variable, measured in ml/kg/min, had a higher average for the experimental group compared to the control group, indicating a better performance level for this group.
Significance levels, using the statistical law (t-test for independent samples), confirmed that all variables were less than (0.05), indicating the presence of statistically significant differences between the two groups in favor of the experimental group".

Discussion:

Tables (3,4) show that there are significant differences in the pre- and post-tests, and for the control and experimental groups, in favor of the post-test, for the studied variables. The researchers attribute the significant differences for the control group to the effectiveness of the exercises developed by the trainers and implemented by the group members and good planning. This is what (Ahmed Youssef) indicated: “Planning is one of the procedures that depend on many studies of reality, taking into consideration the available potential and moral and material capabilities and what can be provided to achieve the set goal, which is preparing athletes to reach the highest levels of achievement” .[4] This agrees with (Jamal Sabry): “Proper training planning is helping athletes reach the highest level of physical, skill and psychological readiness to use during training and competition and maintain this level for the longest possible period through regular training” .[5] As for the experimental group, the researchers were keen to implement combined running and plyometric exercises in modified circuits that were appropriate to the specificity and requirements of the competition. These exercises were characterized by diversity within the modified circuit, as well as changes in the intensity of running and jumping steps, as well as changes in intensity, volume, and rest between circuits. Majid Ali emphasized, “To achieve the requirements of the training program or circuit in a manner consistent with the training objectives at each stage, the relationship between the degree of load and the rest period must be taken into account when

forming or sequencing the amounts of training loads in training units and weekly circuits, up to monthly and then annual ones. The adaptation process requires training at high levels of load, but it is not possible to continue using the same high load every day, as this leads to a drop in level and the appearance of symptoms of overload." Researchers believe that through the above, we can say that the reason for the development in the post-tests for both the control and experimental groups is the systematic and continuous use of training curricula, because the training process is an organized process that aims to raise the level of athletes and reach the highest levels. This is what was confirmed by (Eddington and Edgerton) "that organized training results in an increase in the individual's performance capacity as a result of performing physical exercises for several days, weeks, or months, by imprinting the body's systems on the optimal performance of those exercises".[6] When we want to develop or improve a variable, we must take into account the extent to which training and exercises are related to the nature and specificity of this variable, and to what extent they can affect it, relying on the opinions of specialists in the relevant field, as well as relying on scientific sources and related studies. From this standpoint, researchers confirm that the combined exercises between running and plyometrics, which were prepared in modified circuits that suit the requirements and specificity of the 400m competition, had a major role in improving the studied research variables, as these circuits were characterized by combining running training and plyometric exercises. As we mentioned previously, these exercises helped increase the ability of muscle fibers, especially fast-twitch fibers, to resist fatigue during training and competition, which in turn contributed to the development of muscle strength endurance, as the high level of strength endurance is linked to the ability of muscles to accept lactate and endure fatigue, and to the efficiency of the central nervous system, as the latter bears the greatest burden of controlling performance and resisting fatigue under training and competition conditions. This is what Saleh Shafi confirmed: "Special endurance (which represents "Power endurance is part of it) and is not integrated except with the development of the efficiency of the central nervous system, the cardiovascular system, and the muscles, and the readiness of these systems to perform at distinct rates" .[7] This is on one hand. The other aspect is that the exercises contributed significantly to developing the final speed of the individuals in the experimental research sample, as the exercises imposed on the nervous system a high mobilization of fast-twitch muscle fibers with a high degree of fatigue. The combination of running and plyometrics aims to develop the ability of the central nervous system to produce speed despite fatigue. These conditions are similar to what happens at the end of a race. After the runner has covered two-thirds of the distance, he needs to decide the end of the race as much as possible. Here, the nervous system is forced to mobilize fast fibers with a high accumulation of lactate. Final speed expresses the relationship between endurance and speed. From here, its importance for the runner to run the race distance quickly despite the accumulation of lactate in his muscles and blood, which helps to develop the completion time, and this is what Canova (Renato) indicated: "Every event is a speed event because the winner is always the fastest athlete at the end of the race, but most of the training is strength-endurance training, where strength is the speed that each athlete can maintain for about 3/4 of the distance, and endurance is training to maintain the same speed for the entire competition distance" .[8] The method adopted by researchers in executing the exercises played a major role in the development of aerobic capacity. Researchers adopted the 5 km pace as a standard for the intensity of running exercises, as we mentioned previously, which contributed greatly to controlling the rate of lactate accumulation during training. Many studies have confirmed that training at the 5 km pace helps in the economy of running as well as the economy of training, which helps the muscles and functional systems of the runner's body quickly get rid of lactate accumulation during physical effort and delay fatigue, and allows the runner to race at a percentage higher than

his maximum capacity. Jack Daniels confirmed that the intensity of training at the (5-10 km) pace seems particularly necessary for developing the economy of running and the economy of training [9]. Training at this intensity plays a major role in improving anaerobic energy and the speed of getting rid of lactate, and this is closely linked to improving the metabolic process and the activity of enzymes within the muscle cell. It also helps in a large mobilization of type I muscle fibers (slow). (The uprising), and this is what (Jamal Sabry) pointed out, the 5 km step training leads to an improvement in the anaerobic threshold and the elimination of lactate, and this is related to the percentage of type I muscle fibers and the activity and concentrations of aerobic enzymes of mitochondria. It is also related to the size and density of mitochondria and the density of capillary blood vessels in the muscle and the improvement of the metabolism of fatty acids. Because type I muscle fibers have the greatest advantage in the concentrations of aerobic enzymes of mitochondria - the mobilization of type I muscle fibers reaches its peak at this speed and thus improves aerobic capacity .[10] The development of the variables we mentioned contributed significantly to the development of achievement, as these exercises helped to integrate the qualities and capabilities associated with the specificity of this competition and increase the acceptance of the individuals of the experimental research sample for exercises, the result of which was the development of achievement.

Conclusion

1. The exercises designed by the researchers and implemented within modified training circuits clearly contributed to enhancing the efficiency of the central nervous system by enabling it to recruit a greater number of fast-twitch muscle fibers under highly acidic conditions. This positively impacted the development of strength endurance and terminal velocity, which helped significantly improve performance.
2. Standardizing circuit running exercises based on the 5 km pace helped improve aerobic capacity.

Recommendations:

1. The researchers recommend adopting the exercises used in the study as components of training programs for specialists in the 400m running event, as they contributed to developing the variables associated with event performance.
2. Applying these exercises to other competitions and different age groups, while studying different variables.

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