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The effect of endurance training combined with creatine monohydrate supplementation on the development of selected physical and motor abilities in advanced taekwondo athletes

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Abstract
It has been observed that the skill performance of Taekwondo athletes declines during the final third of each round, with this effect becoming more pronounced in the last round, thereby negatively impacting motor performance. This reduction in performance endurance limits athletes' ability to compete successfully at both national and international levels.
To address this problem, the researcher designed endurance-based training programs supplemented with creatine monohydrate to evaluate their impact on selected physical and motor abilities in advanced Taekwondo athletes competing in the 54-58 kg weight category.
The aim of this study was twofold: (1) to develop performance endurance through a structured training program supported by creatine monohydrate supplementation, and (2) to identify differences in physical and motor performance variables between two experimental groups. It was hypothesized that the integration of endurance training with creatine monohydrate intake would positively affect the measured variables in both pre- and post-tests.
An experimental methodology was employed with two experimental groups to suit the research objectives. The study sample included 16 players from four clubs (Al-Shorta, Al-Karkh, Al-Amanah, and Al-Kahraba) who participated in the 2024 Iraqi Taekwondo Championship. Players were randomly assigned into two groups of eight athletes each. Following pre-testing, one group received performance endurance training with concurrent creatine monohydrate supplementation throughout the training program. Post-tests were conducted after the intervention, and the results were statistically analyzed.
The findings indicated that endurance training combined with creatine monohydrate supplementation produced significant positive effects on muscle cell adaptation and internal physiological systems, thereby enhancing both physical and motor performance.
The study concludes that implementing endurance training with nutritional supplementation positively develops physical variables and performance endurance in advanced Taekwondo players, particularly improving the execution of back and front circular kicks. The researcher recommends incorporating lactic acid-based dynamic endurance exercises into Taekwondo training curricula, as they are effective in enhancing both skill execution and physical capacity.

Keywords: Taekwondo, creatine monohydrate, endurance training, physical abilities, motor performance, back kick, front circular kick

Introduction
Scientific research represents one of the fundamental pillars upon which societies rely for progress in various fields, including sports. By exploring and harnessing the physiological and physical capacities endowed to humans, research contributes to maximizing the benefits of applying modern scientific theories in sports training. This process serves to prepare athletes holistically physically, functionally, technically, tactically, educationally, and cognitively—toward achieving the highest performance levels and international accomplishments. Attaining elite sporting achievements is not a matter of coincidence but rather the outcome of adopting advanced training methods and techniques grounded in scientific principles and consistent with the rules of sports training.
With the remarkable global development in the field of sports, training processes across both individual and team competitions have undergone significant advancements. This progress is reflected in enhanced physical and technical capabilities of athletes, leading to notable achievements on the international stage.

Such development is largely attributed to systematic planning processes that improve athletic performance and ensure optimal results. Among these sports, Taekwondo has witnessed remarkable global expansion due to its dynamic, exciting nature and the diversity of its fundamental skills. Consequently, experts and coaches have emphasized the importance of precise preparation, planning, and the implementation of scientifically structured training programs to elevate athletes' physical and technical capacities [1].

In parallel, nutritional supplementation has received increasing attention from specialists in recent years. Derived from natural food sources, these supplements play a vital role in creating a favorable physiological environment for enhancing energy production. Specifically, creatine monohydrate has been shown to boost muscular energy output, influence key biochemical processes, and delay fatigue, thereby enhancing physical performance. When combined with endurance-based training, creatine monohydrate supplementation may further improve certain physical and motor variables, particularly for athletes in physically demanding sports such as Taekwondo. Moreover, understanding the physiological responses associated with endurance training in the special preparation phase is essential for coaches, as these responses reflect the effectiveness of the training methods employed [2].

The predominant energy system in Taekwondo during the special preparation stage is the anaerobic lactic system. Therefore, monitoring the degree of adaptation and development of this system is considered one of the essential objectives of sports training. Modern Taekwondo training focuses on improving both physical and functional variables, emphasizing endurance training during the special preparation phase to achieve peak performance. Enhancing aerobic capacity has been shown to positively influence anaerobic performance, which is critical for executing offensive and defensive skills under competitive conditions. Hence, well-designed training programs that target relevant physiological adaptations are necessary [3].

From this perspective, the importance of the current study emerges: Investigating the combined effects of creatine monohydrate supplementation and performance endurance exercises on improving physical and motor abilities of advanced Taekwondo athletes.

Research Aims

- To design performance endurance exercises supported by creatine monohydrate supplementation aimed at developing selected physical and motor abilities in advanced Taekwondo players.
- To identify differences in physical, motor, and skill-related variables between two experimental groups.

Research Hypotheses

- The endurance training program combined with creatine monohydrate supplementation will have a significant positive effect on the studied variables in the pre- and post-tests of both research groups.
- The endurance training program combined with creatine monohydrate supplementation will have a significant positive effect on the studied variables in the post-tests of both research groups.

Methods and Procedures

Participants: The research sample consisted of 16 advanced Taekwondo athletes (weight category: 54-58 kg) representing four Iraqi clubs: *Al-Shorta, Al-Karkh, Al-Amanah, and Al-Kahraba*. To ensure group equivalence, homogeneity was tested using Levene's test for equality of variances. The calculated *F* value was compared against the significance level (α=0.05). Following confirmation of homogeneity, the athletes were randomly divided into two experimental groups of equal size (N=8 per group; 50% of the total sample), using the lottery method.

Research Design

The study employed an experimental design with two experimental groups. Both groups underwent performance endurance training; however, only one group additionally received creatine monohydrate supplementation. Pre-tests were administered before the intervention, and post-tests were conducted upon completion of the training program to assess differences in physical and motor performance variables.

Instruments and Equipment

The following tools and equipment were employed in data collection and testing: [4]

- Questionnaire
- Direct observation
- Structured interviews
- Standardized testing and measurement tools
- Data registration forms
- iPhone 6 (for video recording and performance documentation)
- HP electronic calculator
- CDs (for data storage)
- Taekwondo mats
- Multi-height markers
- Rubber bands and weights
- Masking tape and stationery (papers, pens)
- Taekwondo dummy
- Kick pads (N=12)
- Rings (diameter: 60 cm)
- Linen tape measure (40 meters)
- Whistles (2)
- Stopwatches (2)
- Electronic protectors and operating system
- Medical weighing scale
- Official Taekwondo uniforms

Tests and Measurements

Physical Abilities

A. Endurance of the front roundhouse kick (Dolio Chagi Test) [5]

- **Objective:** To assess the player's ability to repeatedly execute the front roundhouse kick (right × left) over 40 seconds.
- **Equipment:** Taekwondo dummy (with support base), head protector, whistle, Taekwondo mat, stopwatch, tape.
- **Performance Specifications:** The player assumes a Taekwondo ready stance behind the designated line and performs continuous front roundhouse kicks with one leg. Each kick must be executed with accuracy and power, striking the correct target area with the instep of the foot. The player must return to the ready stance after each kick.

- **Conditions:** Performance must be continuous without interruption. Only kicks landing accurately on the head protector with the correct part of the foot are counted.
- **Scoring:** The total number of correct kicks within 40 seconds is recorded.

B. Endurance of the Back Kick (Dwi Chagi Test) [6]
- **Objective:** To assess the player's ability to repeatedly execute the back kick (right × left) over 40 seconds.
- **Equipment:** Taekwondo dummy (with support base), whistle, Taekwondo mat, stopwatch, tape.
- **Performance Specifications:** From the ready stance, the athlete executes continuous back kicks with one leg, striking the head protector with the instep.
- **Conditions:** Kicks must be executed with accuracy and strength, returning to the ready stance after each attempt, without interruptions.
- **Scoring:** The number of correct kicks delivered within the 40-second duration is recorded.

C. Speed-Strength Test (Hopping Test) [7]
- **Test Name:** "The Partridge Flies" Test
- **Objective:** To measure speed-strength of the leg muscles.
- **Equipment:** Stopwatch, whistle, tape measure, recording form.
- **Performance Specifications:** The athlete begins behind a marked line and, upon the whistle, hops forward on one leg (of their choice) along a straight path for 10 seconds.
- **Conditions:** Only one attempt is permitted. If the player loses balance, changes leg, or falls, the test is repeated.
- **Scoring:** The total distance covered within 10 seconds is measured from the starting line to the final point reached.

Motor Abilities [8]
- **Coordination (Compatibility)**
- **Dynamic Balance**

(Note: You may provide the detailed test protocols for these motor ability assessments if you wish me to expand them to the same level as the physical ability tests).

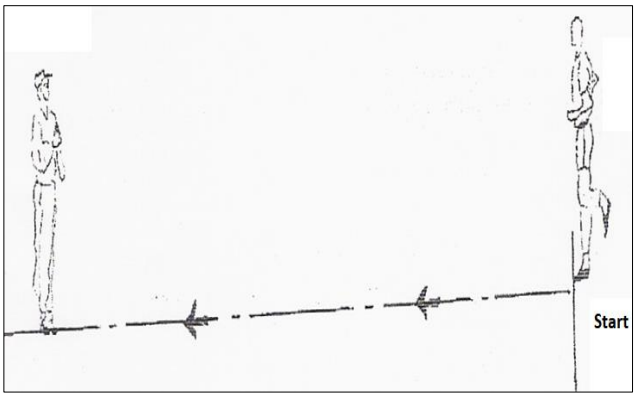

Fig 1: Bar chart showing distance covered in the 10-second hopping test for speed-strength assessment

Maximum Distance Test in 10 Seconds
This test evaluates **speed-strength of the lower limbs** by measuring the maximum distance an athlete can cover through repeated single-leg hops within a duration of 10 seconds. The distance is recorded from the start line to the final landing point.

Numbered Circuit Test [9]
- **Purpose:** To assess eye-foot coordination through rapid and accurate movement across designated points.
- **Equipment:** Stopwatch, chalk or tape to draw circles on the ground (8 circles, each with a 60 cm diameter), numbered sequentially (see Figure 12).
- **Performance Description:** The athlete begins inside circle (1). At the starting signal, the athlete jumps with both feet together into circle (2), then continues sequentially through circles (3), (4)…up to circle (8), moving at maximum possible speed.
- **Scoring / Recording:** The total time taken to complete the circuit of eight circles is recorded using a stopwatch. Faster completion times indicate better coordination ability.

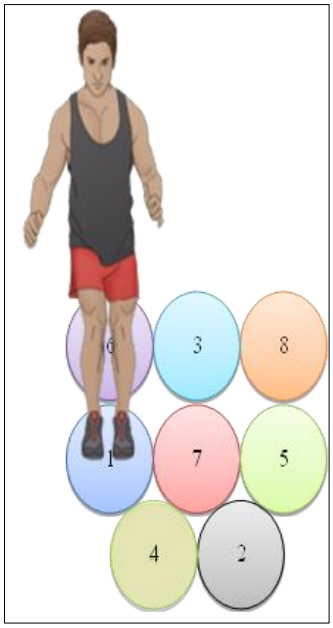

Fig 2: Diagram of the numbered circuit test used to measure eye–foot coordination

The numbered circuit test
This figure illustrates the movement sequence across eight numbered circles, designed to assess eye-foot coordination through rapid bilateral jumps.

Motor Balance Test [10]
- **Test Name:** *Modified Bass Motor Balance Test*
- **Purpose:** To assess dynamic balance during and immediately following movement.
- **Equipment:** Stopwatch, tape measure, and 11 ground markers.
- Performance Specifications: The subject begins at the starting line, balancing on the right foot. The first action is to jump and land with the instep of the left foot on mark (1), ensuring the foot fully covers the mark and remains stable. Next, the subject jumps to mark (2), landing with the instep of the right foot, and continues alternately until reaching the final mark.
  The distance from the starting line to the first mark is 1 meter, and subsequent marks are positioned as illustrated in Figure 5.

- **Scoring:** Each successful jump-landing-balance sequence is awarded 10 points. The final score is the sum of points across all attempts, reflecting the subject's motor balance ability.

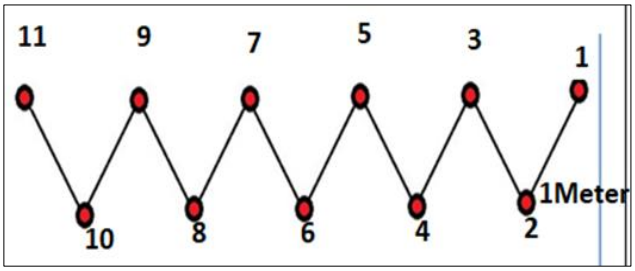

Fig 3: Layout of the modified Bass test assessing dynamic balance and stability

The motor balance test

Pre-Tests

Prior to administering the physical and motor tests for the Taekwondo athletes, the researcher organized the participants and categorized them into their respective groups. The names were recorded accordingly. Together with the assistant research team, the researcher explained the test procedures, demonstrated them, and ensured the participants were familiar with the tasks before performing them. The pre-tests for both experimental groups were conducted on Wednesday and Thursday, December 25-26, 2024.

Performance endurance training and nutritional supplementation

The endurance training program was designed and implemented by the researcher, incorporating performance-based endurance exercises supported by creatine monohydrate supplementation. These exercises were included in the main portion of the training units for Taekwondo athletes in the (54-58 kg) weight category. Exercise variety and progression were carefully considered to align with the athletes' abilities, with emphasis on applying the exercises to skill-related aspects of performance. Training elements included agility ladders, sports benches, resistance bands, and weights, all structured to simulate competition-like conditions while enhancing motivation, enjoyment, and engagement.

Key considerations in the design of the endurance training program included: [11]

- Alignment with the objectives of the preparation phase specific to Taekwondo athletes.
- Suitability to the physical and motor characteristics of Taekwondo practitioners.
- Adaptation to the available training tools and facilities.
- Variation and flexibility in exercise selection to enhance effectiveness and training outcomes.

Following the pre-tests, the endurance training program combined with creatine monohydrate supplementation was applied over eight weeks, with three training sessions per week (Saturday, Monday, Wednesday), for a total of 24 training sessions. Each training session lasted 100 minutes: 15 minutes were allocated for warm-up, 75 minutes for the main training segment (which incorporated the endurance exercises using the high-intensity interval training method), and 10 minutes for cool down activities. Each training unit included five structured exercises.

Post-Tests

Upon completion of the training program, post-tests were conducted by the researcher and the assistant team on Saturday, February 20, 2025. The testing procedures followed the same sequence and conditions as the pre-tests to ensure consistency and reliability of the results.

Statistical Methods

To achieve the research objectives, the following statistical techniques were employed:-

- Arithmetic mean
- Median
- Standard deviation
- Coefficient of skewness
- Pearson's correlation coefficient
- T-Test for correlated samples
- T-Test for independent samples
- Chi-square test
- Standard error

Results and Discussions

Presentation, analysis, and discussion of results

- **Results of physical abilities in the two experimental groups:** Results of physical abilities in the first experimental group (Pre- and Post-Measurement)

Table 1: Results of the arithmetic means, standard deviations, and t-values for the physical abilities of the first experimental group in the pre- and post-tests

Variables	Unit of Measurement	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	T-Value	Sig. (P)	Significance
Performing the front roundhouse kick	Number	20.50±1.41	25.75±1.03	-7.000	0.000	Significant
Performing the backflip	Number	18.87±1.24	21.75±2.12	-4.709	0.002	Significant
Power characterized by speed	(Tha)	7.73±0.61	7.17±0.35	2.877	0.024	Significant

Interpretation

The results presented in Table 1 indicate statistically significant improvements in the performance of the first experimental group across all tested variables in the post-test compared with the pre-test. Specifically, the mean scores for performing the front roundhouse kick and backflip increased significantly, as evidenced by negative *t*-values and highly significant *p*-values ($p<0.01$). Similarly, performance in the "power characterized by speed" variable showed a statistically significant difference, confirming the positive impact of the endurance training program combined with creatine monohydrate supplementation [12].

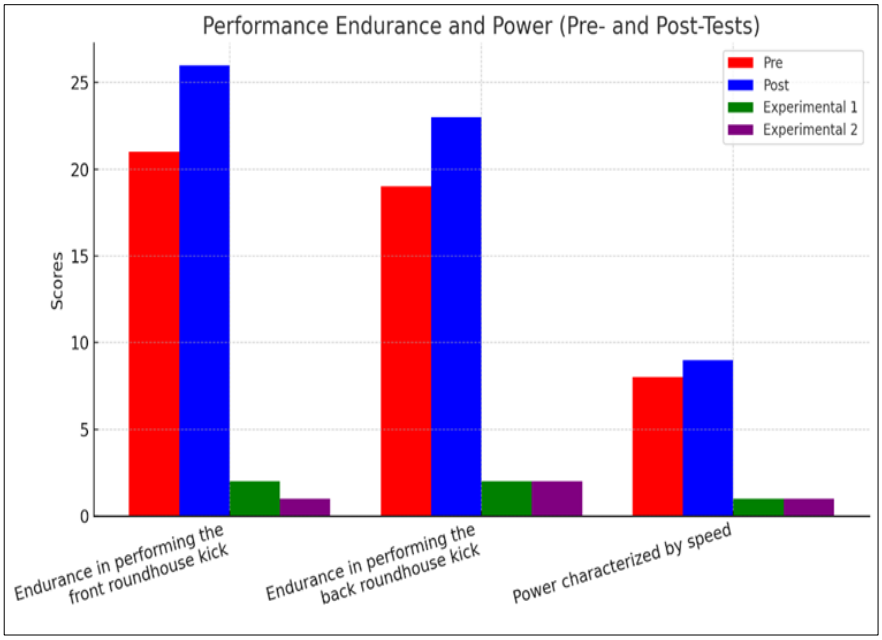

Chart 1: Comparison of the results of arithmetic means and standard deviations to assess the development of physical abilities of the first experimental group in the pre- and post-tests

- **Presentation and analysis of the results of the physical abilities of the second experimental group (pre- and post-tests)**

Table 2: Results of the arithmetic means, standard deviations, and *t*-values for the physical abilities of the second experimental group in the pre- and post-tests

Variables	Unit of Measurement	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	T-Value	Sig. (P)	Significance
Performing the front roundhouse kick	Number	20.62±1.50	23.37±2.38	-2.543	0.039	Significant
Performing the backflip	Number	19.25±1.38	19.75±0.88	-0.882	0.407	Not significant
Power characterized by speed	(Tha)	7.33±0.46	7.85±0.14	-3.261	0.014	Significant

Interpretation

The results presented in Table 2 and Chart 2 indicate significant improvements in two of the tested variables for the second experimental group. The mean performance of the front roundhouse kick and the variable of power characterized by speed both showed statistically significant development ($p<0.05$). However, the backflip performance did not demonstrate a significant difference between pre- and post-tests ($p>0.05$), suggesting that this specific skill may require a longer training duration, different supplementary methods, or greater skill-specific emphasis to achieve measurable improvement [13].

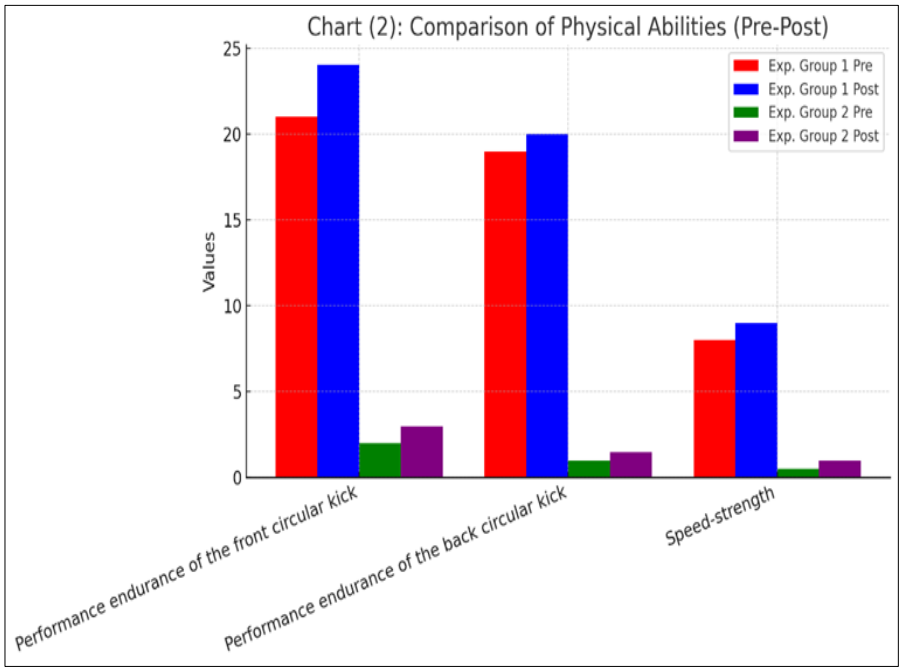

Chart 2: Comparison of the results of arithmetic means and standard deviations to assess the development of physical abilities of the second experimental group in the pre- and post-tests.

- **Presentation and analysis of the results of the physical abilities of the two research groups in the post-test**

Table 3: Arithmetic means, standard deviations, and *t*-values for the physical abilities of the two experimental groups in the post-test

Variables	Unit of Measurement	First Experimental Group (Mean ± SD)	Second Experimental Group (Mean ± SD)	T- Value	Sig. (P)	Significance
Performing the front roundhouse kick	Number	25.75 ± 1.04	23.37 ± 2.39	2.582	0.022	Significant
Performing the backflip	Number	21.75 ± 2.12	19.75 ± 0.89	2.460	0.027	Significant
Power characterized by speed	(Tha)	7.17 ± 0.35	7.85 ± 0.14	-5.096	0.000	Significant

Interpretation

The post-test results reveal significant differences between the two experimental groups across all measured physical abilities. The first experimental group demonstrated superior performance in the execution of the front roundhouse kick and backflip ($p<0.05$), highlighting the effectiveness of the endurance training program with creatine supplementation in enhancing skill-based motor performance. Conversely, the second experimental group showed higher mean values in power characterized by speed, with a highly significant difference ($p<0.001$). These findings suggest that while creatine-supported endurance training improves skill execution, the second group's training program may have been more effective in developing speed-related power capacities [14].

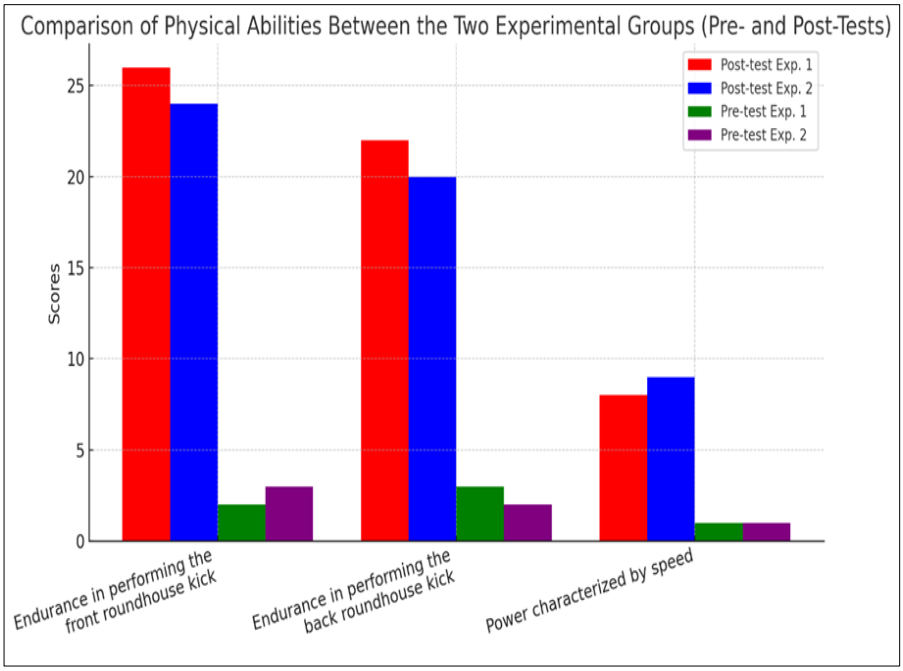

Chart 3: Comparison of the arithmetic means and standard deviations illustrating the development of the physical abilities of the two experimental groups in the post-test.

Discussion of physical abilities results

In order to adequately interpret the results, it is essential to first review the descriptive statistical indicators, both in terms of mean values and the differences observed between pre- and post-tests. As shown in Tables 1 and 2, the results of the post-test measurements revealed significant improvements in the performance endurance of the front roundhouse kick, the performance endurance of the back roundhouse kick, and power characterized by speed. These differences were particularly evident between the first and second experimental groups, favoring the first experimental group [15].

This outcome can be attributed to the training design, where performance endurance exercises were combined with creatine monohydrate supplementation. The program emphasized sport-specific exercises aimed at developing the endurance required to repeatedly execute front and back roundhouse kicks under conditions of fatigue, while also targeting power characterized by speed. The results demonstrated that the applied training protocol was effective for both groups, although its impact was more pronounced in the first experimental group [16].

These findings are consistent with the perspective of Abu Al-Ala Ahmed, who emphasized that improvements in athletes' physical performance depend largely on the use of competition-related exercises and specific drills tailored to the activity of specialization. Similarly, Mufti Ibrahim highlighted that the development of speed-strength relies on rapid muscle contractions performed under resistance conditions that closely resemble the speed of actual performance. Peen also confirmed that speed-strength improves through systematic and regular training interventions. The present study supports these viewpoints, as the endurance exercises combined with supplementation resulted in measurable enhancements in speed-strength [17].

The superior development observed in the first experimental group can be explained by the content and organization of the training program applied. Experts have long stressed that training programs yield optimal outcomes only when they are prepared according to a structured and scientifically grounded methodology. The exercises in this study promoted

neuromuscular coordination by engaging multiple muscle groups simultaneously during motor tasks. This neuromuscular efficiency is crucial for improving physical abilities, as it involves the coordinated activation of a large number of motor units during execution. Such targeted neuromuscular development aligns with the observations of Juan Carlos (2016), who affirmed that specialized training can increase strength capacity without a corresponding increase in body weight a desirable outcome for weight-class athletes such as Taekwondo practitioners.

Furthermore, the researcher attributes part of the improvement in motor performance to enhanced motor transition speed, particularly in the rapid motor responses of the legs. This was achieved by optimizing the coordination between muscular contraction and relaxation cycles, enabling athletes to execute movements more efficiently, fluidly, and consistently. Such regulation of muscular work plays an essential role in refining skill execution and enhancing overall competitive performance.

- **Presentation and analysis of the results of the motor abilities of the first experimental group in the pre- and post-tests**

Table 4: Arithmetic means, standard deviations, and *t*-values for the motor abilities of the first experimental group in the pre- and post-tests

Variables	Unit of Measurement	Pre-Test (Mean ± SD)	Post-test (mean ± SD)	T Value	Sig. (P)	Significance
Compatibility	(Tha)	6.39 ± 0.35	5.51 ± 0.41	3.798	0.007	Significant

Interpretation

The results in Table 4 demonstrate a statistically significant improvement in the compatibility variable of the first experimental group, as evidenced by the decrease in mean scores from the pre-test (6.39) to the post-test (5.51), with a t-value of 3.798 (P=0.007). This suggests that the endurance training program combined with creatine monohydrate supplementation contributed positively to enhancing motor coordination and compatibility, aligning with the objectives of the intervention.

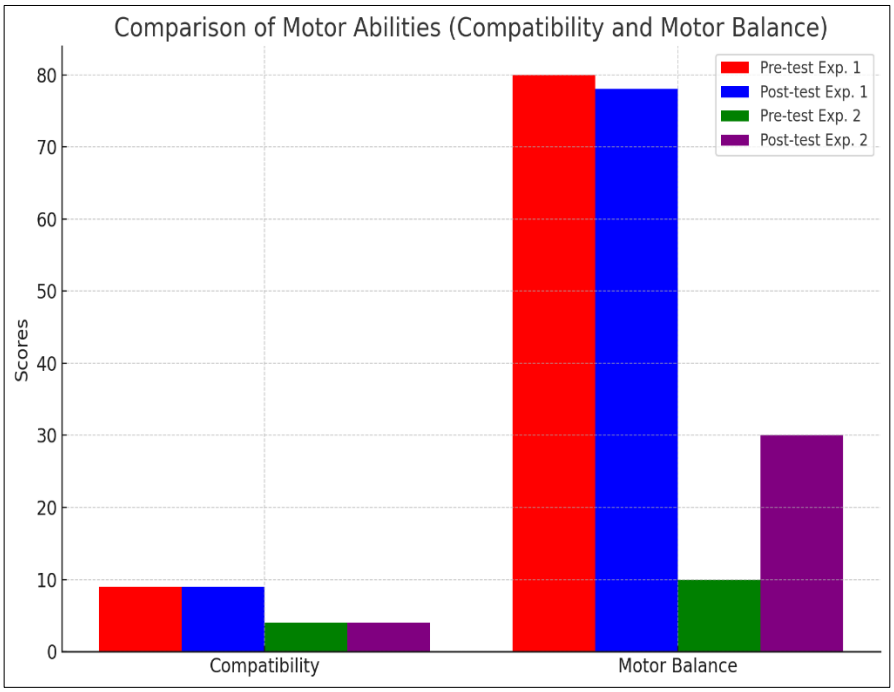

Chart 4: Comparison of the arithmetic means and standard deviations illustrating the development of the motor abilities of the first experimental group in the pre- and post-tests.

- **Presentation and analysis of the results of the motor abilities of the second experimental group in the pre- and post-tests**

Table 5: Arithmetic means, standard deviations, and t-values for the motor abilities of the second experimental group in the pre- and post-tests

Variables	Unit of Measurement	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	T Value	Sig. (P)	Significance
Compatibility	(Tha)	6.39 ± 0.36	5.34 ± 0.25	6.207	0.000	Significant
Kinetic Balance	(Degree)	75.00 ± 11.95	67.50 ± 35.75	0.655	0.534	Not significant

Interpretation

The results in Table 5 indicate a statistically significant improvement in compatibility for the second experimental group ($p<0.001$), suggesting that the training program contributed positively to motor coordination. However, the variable of kinetic balance did not show a statistically significant difference between pre- and post-tests ($p>0.05$). This may imply that balance-related abilities require either a longer training duration, a different type of exercise intervention, or greater specificity in training methods to yield measurable improvements.

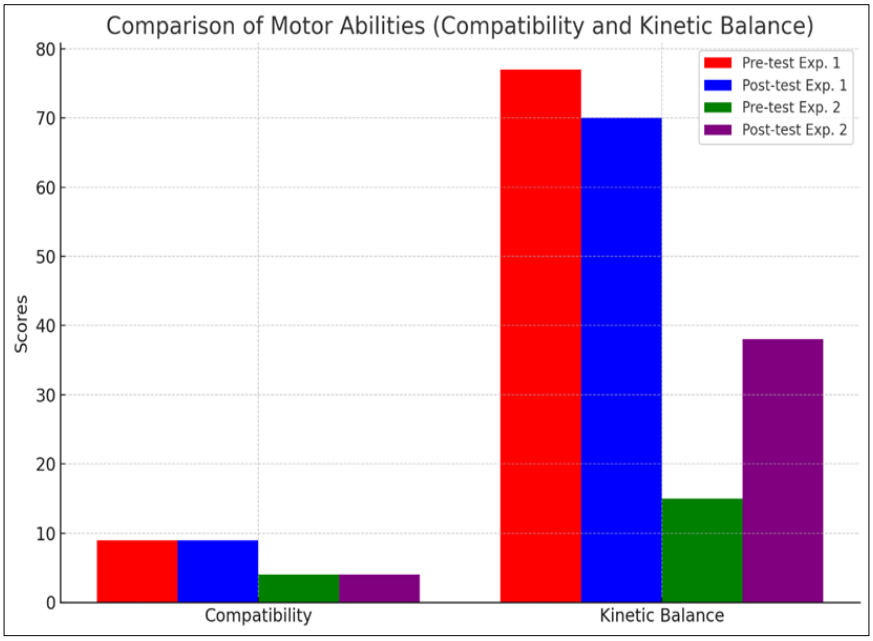

Chart 5: Comparison of the arithmetic means and standard deviations illustrating the development and analysis of the motor abilities of the second experimental group in the pre- and post-tests

- **Presentation and analysis of the results of the motor abilities of the two experimental groups in the post-test**

Table 6: Arithmetic means, standard deviations, and t-values for the motor abilities of the two experimental groups in the post-test

Variables	Unit of Measurement	First Experimental Group (Mean ± SD)	Second Experimental Group (Mean ± SD)	T Value	Sig. (P)	Significance
Compatibility	Tha	5.505 ± 0.414	5.336 ± 0.246	0.990	0.339	Non-significant
Kinetic balance	Degree	76.25 ± 27.22	67.50 ± 35.75	0.551	0.591	Non-significant

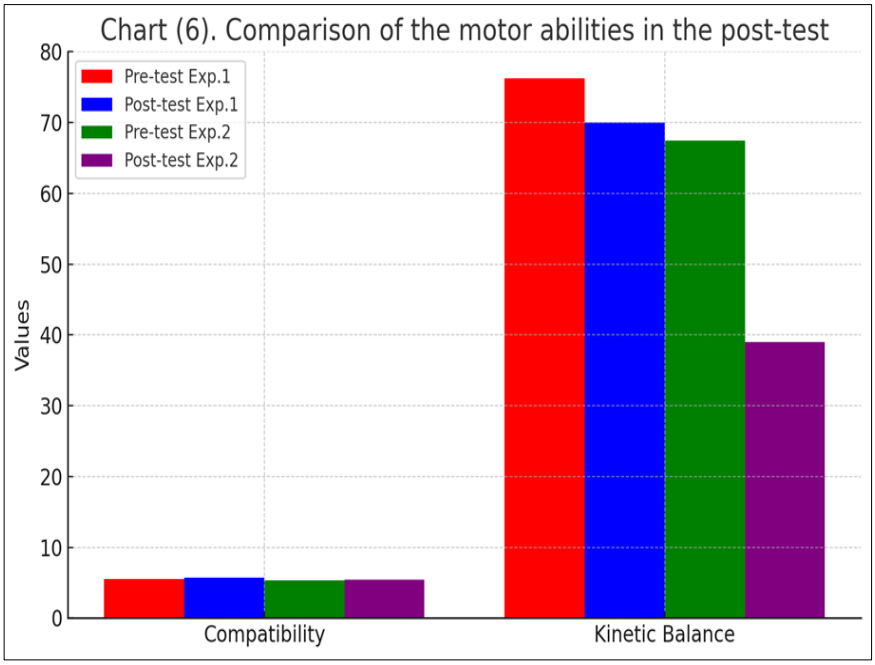

Chart 6: It shows a comparison of the results of the arithmetic means and standard deviations to determine the development of the motor abilities of the two research groups in the post-test

Discussion of motor abilities results

The results presented in Tables 4, 5, and 6 indicate that there were no statistically significant differences in either coordination or motor balance when calculating the *t*-value for the post-tests between the two experimental groups. The calculated *t*-values were lower than the critical values in the table. The researcher attributes this finding to the equivalent effect of the performance endurance exercises applied to both groups, as both the first and second experimental groups underwent similar training interventions. Hence, no superiority in effect was observed between the groups [18].

The researcher emphasizes that the proper planning, scientific structuring of exercises, and the standardization of training load components had a notable influence on developing the

motor abilities of the participants in the second experimental group. This aligns with the view of *Jamal Sabry Farag*, who affirms that:

"Correct training planning enables the athlete to achieve the highest level of physical, motor, technical, and psychological readiness to employ during competitions, and to maintain this level for the longest possible period through organized training [19].

Conclusions

- Performance endurance exercises accompanied by nutritional supplementation in the first experimental group contributed significantly to the development of physical abilities, particularly endurance of front and back circular kicks and speed-strength.
- Both experimental groups demonstrated noticeable improvements in the performance of front and back circular kicks among Taekwondo players.

Recommendations

- Incorporating the researcher's prepared performance endurance exercises with nutritional supplements into training program design, given their positive effect on enhancing selected physical and motor abilities as well as endurance of the studied kicks among advanced Taekwondo athletes.
- Conducting similar experimental studies on different samples of Taekwondo players to validate and generalize the findings.

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