

# Effect of Circuit-Based Strength-Endurance Training on Biomechanics and 800m Performance in Junior Female Athletes

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DOI:

<https://doi.org/10.47134/jpo.v3i1.2023>

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Received: date

Accepted: date

Published: date



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**Abstract:** The purpose of this study was to examine the impact of long-term circuit strength-endurance training in running on selected biomechanical variables and performance in women 800 m young runners. Eight weeks with two sessions per week were applied to a sample of five athletes of the National Talent Center in Athletics in training exercises to the muscles which play a role in running. Running speed, step length, step frequency, lap time and total 800-m performance were assessed during both pre- and post-test after a series of video and biomechanical analysis tests. Results demonstrated significant enhancements at lap levels including running speed for all laps, step length, lap time, and total race time ( $p < 0.05$ ). It is concluded that the utilized training program results in muscular endurance and biomechanical efficiency which are suitable for 800 meter running. Emphasis on sustained, progressive overload and short rest periods of the circuit training method resulted in improved anaerobic and aerobic capacities. Better pacing strategies and running mechanics were also detected, which are fundamental for achieving peak performance at the 800 m race. The findings emphasize the need to incorporate scientifically-based sport-specific training strategies to elicit neuromuscular adaptations and endurance responses in young athletes. Further investigation is warranted on the larger sample and different training intensities Customary to confirm and generalize these findings.

**Keywords:** Strength-Endurance Training, Circuit Training, Biomechanics, 800-Meter Running

## Introduction

Advances in training science in sport have steadily improved human performance in all sports. However, middle-distance regions like the 800m still have physiological and biomechanical requirements which need additional specific studies (Haugen et al., 2021; Llanos-Lagos et al., 2024). Nevertheless, performance maximization of these events remains largely dependent on the systematic use of training interventions supported by scientific evidence that target the specific physiological determinants of performance associated with participants (Barnes & Kilding, 2015).

Of these capacities, strength-endurance capacity is an important factor in maintaining economical running mechanics during a race (Prieto-González & Sedlacek, 2022). The 800m is a mixed event, i.e., both aerobic and anaerobic contributions of energy, and imposes a considerable amount of stress upon the musculoskeletal and metabolic

systems. Since athletes must keep up an effective stride mechanics and pacing with a growing fatigue, strength-endurance is essential for ultimate success (McArdle et al., 2010). Circuit training, in particular, as structured in a consecutive and consecutive manner has been presented as an effective and efficient means of enhancing strength- endurance (Kravitz, 2006; Suniga et al., 2025). This technique consists of series of sets of different muscles (legs, arms and core and without inter-repetitions interval) at moderate resistances in order to simulate specific work-race muscles (Rodriguez-Barbero et al., 2025). It also has to do with reaching a physiological steady state where blood supply equals oxygen consumption during exercise (Lacour & Bourdin, 2015; Menier & Pugh, 1968) which would allow for a sustained performance.

Due to its advantages, lower limbs strength-endurance training using circuits has been applied to enhance running economy and stride variables (i.e., step length, frequency and cycle efficiency) (Bachero-Mena et al., 2021; Balsalobre-Fernández et al., 2016). These biomechanical components are crucial for controlling pace, reducing race-related fatigue and executing a stable technique during an 800m race (Greene, 1982; Taipale et al., 2010).

According to experts, circuit training involves a series of simple exercises executed over a series of stations, in order to simultaneously improve several physical capacities within a short amount of time while maintaining structure (Alcaraz et al., 2008). This is particularly true for sports that require the activation of both, the anaerobic and aerobic energy systems, such as the double 800-meter run, which energy contribution reached 65% anaerobic and 35% aerobic (Haugen et al., 2021; McArdle et al., 2010).

## **Methodology**

### **Study Design**

This study employed a randomized controlled experimental design with two experimental groups, each subjected to pre- and post-testing. The goal was to assess the effects of circuit-based strength-endurance training versus conventional endurance training on selected kinematic variables and 800-meter performance among junior female runners.

### **Participants**

The participants were selected purposively from the National Center for Sports Talent Development in Athletics (Baghdad, Iraq). The initial sample consisted of six junior female 800-meter runners, aged 16–17 years. One participant withdrew due to non-study-related reasons, resulting in a final sample of five athletes. All participants were healthy, injury-free, and engaged in regular training. Written informed consent was obtained from all athletes and their legal guardians.

### **Tools and Equipment**

The following tools and equipment were used for biomechanical and performance assessment:

Stopwatches Rhythm® Digital Stopwatch (Model RH-108, Rhythm Co., Ltd., Tokyo, Japan), precision to 0.01 seconds (×4 units). Video Camera: Sony HDR-CX405 HD Handycam (Sony Corporation, Minato, Tokyo, Japan), used for motion capture and kinematic analysis. Tripod-mounted cameras for fixed-position video acquisition during

running trials. Standardized 400-meter outdoor athletics track under consistent weather conditions. Custom-coded video analysis software for step counting and stride analysis.

### Training Protocol

The experimental group 1 underwent circuit-based strength-endurance training, while experimental group 2 followed conventional continuous endurance training. The intervention lasted 8 weeks, with 2 training sessions per week (total of 16 sessions).

The circuit protocol was structured as follows:

- Four exercise stations targeting major muscle groups:
  1. Lower limbs (e.g., bodyweight squats or lunges)
  2. Upper limbs and shoulders (e.g., push-ups or resistance band rows)
  3. Abdominal core (e.g., sit-ups or planks)
  4. Back musculature (e.g., superman holds or resistance band pull-downs)
    1. Duration: 30 seconds per station
    2. Rest between stations: 10 seconds
    3. Five rounds per session
    4. Rest between rounds: 2 minutes
    5. Progressive overload: resistance/intensity increased biweekly based on athlete performance
    6. Session duration: 45–60 minutes
    7. Warm-up and cool-down: 10 minutes each

The control group performed traditional endurance training such as steady-state runs and tempo intervals of equivalent duration and frequency.

### Data Collection

**Pre-tests:** Conducted on January 2, 2025, including:

1. 800-meter timed run
2. Video recording of each trial
3. Stride analysis: using video footage to calculate:

1. Step count (per 100 m segment, especially during the second 100 m of each 200 m)
2. Step frequency and step length
3. Average speed per lap
4. Total race time (performance)

**Post-tests:** Conducted on March 2, 2025, under the same conditions as pre-tests.

Data were extracted by two independent experts in biomechanics using frame-by-frame analysis of recorded footage to ensure reliability.

### Statistical Analysis

Data were analyzed using SPSS version 26.0 (IBM). Descriptive statistics (mean  $\pm$  SD) were calculated for all variables. A paired samples t-test was used to assess within-group differences between pre- and post-tests, while independent samples t-tests were applied to assess between-group differences. The level of statistical significance was set at  $p < 0.05$ .

Reliability of observational data (step count, stride metrics) was assessed using inter-rater correlation coefficients (ICC). All assumptions for parametric testing (normality, homogeneity of variances) were tested prior to analysis.

## Result and Discussion

The comparative analyses of the pre-test and post- test measurement of the physical and bio-mechanical variables as it related to the 800m run among these subjects are depicted in table-1. We found for each score a statistically significant improvement from the macro training condition.

More notably, the mean running velocity over the second 100-m of both the first and the second laps were significantly reduced post-training (from  $15.80 \pm 0.10$  to  $14.17 \pm 0.14$ , and  $18.40 \pm 0.29$  to  $16.75 \pm 0.14$  s, respectively), with t-values of 3.70 ( $p = 0.006$ ), and 4.82 ( $p < 0.001$ ), respectively.

Also, step length was significantly higher for both laps (Lap 1:  $1.27 \pm 0.23$  m to  $1.35 \pm 0.13$  m; Lap 2:  $1.19 \pm 0.77$  m to  $1.23 \pm 0.31$  m), but it may indicate improved biomechanical efficiency in the stride mechanics ( $t = 4.30$ ,  $p < 0.001$ ;  $t = 3.12$ ,  $p < 0.001$ , respectively).

The time taken to complete a lap was significantly less following the intervention (Lap 1:  $76.00 \pm 2.64$ s vs  $69.00 \pm 1.21$ s, Lap 2:  $87.00 \pm 2.15$ s vs  $75.00 \pm 0.98$ s) indicating improved endurance and pacing ( $t = 3.86$ ,  $p = 0.001$ ;  $t = 3.38$ ,  $p = 0.002$ ).

In general, the overall 800-meter completion time significantly decreased from  $163.00 \pm 12.00$  to  $144.00 \pm 8.00$  seconds from pre- to post-testing, validating the success of the implemented intervention program ( $t = 4.31$ ,  $p < 0.001$ ).

All the observed differences reached  $p < 0.05$  with degrees of freedom = 4, indicating meaningful 24 improvement in the physical capacities and biomechanical parameters that are relevant for performance of middle-distance running.

**Table 1.** Pre- and Post-Test for the Experimental Group in 800m Running

Variable	Pre-test M $\pm$ SD	Post-test M $\pm$ SD	Mean Diff.	SD Diff.	t-value	Sig. (p)
Speed – 100 m (2nd half, Lap 1)	$15.80 \pm 0.10$	$14.17 \pm 0.14$	1.63	0.44	3.70	0.006*
Speed – 100 m (2nd half, Lap 2)	$18.40 \pm 0.29$	$16.75 \pm 0.14$	1.65	0.34	4.82	0.000*
Avg. Step Length – Lap 1	$1.27 \pm 0.23$	$1.35 \pm 0.13$	0.08	0.02	4.30	0.000*
Avg. Step Length – Lap 2	$1.19 \pm 0.77$	$1.23 \pm 0.31$	0.04	0.012	3.12	0.000*
Time – Lap 1	$76.00 \pm 2.64$	$69.00 \pm 1.21$	7.00	1.81	3.86	0.001*
Time – Lap 2	$87.00 \pm 2.15$	$75.00 \pm 0.98$	12.00	3.55	3.38	0.002*
800m Completion Time	$163.00 \pm 12.00$	$144.00 \pm 8.00$	19.00	4.40	4.31	0.000*

\*: significance level  $\leq 0.05$

## Discussion

The present findings indicate the positive effect of the strength-endurance training implemented on the participants to enhance physical capabilities and the 800 m running performance. The scientific nature of the training program led to the improvement of the athletes' physical qualities, eliciting favorable adaptations in the important variables due to the specific and reasoned manner of the training load.

In particular, improvements in the 100m sprint segments of each lap and an increase in propulsive endurance (longer step lengths at a reduced lap time) were indicative of

enhanced biomechanical efficiency and endurance capacity. These results highlight the suitability of the implemented training protocol in specifically challenging working muscles continuously, with a balanced dose of intensity and volume with subsequent rest allowed, in agreement with evidence emphasizing specific endurance and strength adaptations to middle-distance running (Abdulkareem & Ali Hassan, 2025; Llanos-Lagos et al., 2024).

The physiological adaptations observed are reinforced by the idea that the majority of training responses happen in the first weeks of structured programs, at approximately 6–8 weeks (Remaud et al., 2010). It is this timeline that coincides with the duration of the intervention in the present study.

Improved anaerobic and aerobic power was reflected in the post-test data, resulting in better 800 meter running performance. This is accordant with the well-known fact that the middle-distance race is based on the combination of these two energy systems and that programs for the development of speed resistance and resistance are determining for the success (Busso & Chatagnon, 2006; Ramos-Campo et al., 2025).

The beneficial impact of training on the training protocol can be ascribed to high muscular demands reflecting performance-specific applications, with progressive overload and strategic format of training intervals contributing to the adaptations in sport-specific muscular endurance (Henselmans & Schoenfeld, 2014). These adaptations are important in maintaining high intensity over the race distance and improving running economy (Doma & Deakin, 2013).

Circuit training produced marked neuromuscular adaptations in muscles involved in the workloads, promoting fatigue resistance and muscular endurance at time periods similar to the race, suggesting multiple high-intensity efforts (Sonchan et al., 2017). The focus on sport specific movement patterns interspersed with on maximal effort allowed for better step mechanics and race specificity (O'Leary et al., 2017).

Given the requirement to consider racing strategy, particularly in terms of both as bursts and racing start position, and many would argue that athletes must be encouraged to concurrently develop the ability to produce force rapidly and their ability to sustain higher levels of muscular endurance. Evidence of these relationships are provided by studies showing that adaptations in the running cadence and speed descend from strength development and the capacity to keep producing force over time (Beattie et al., 2014; Trowell et al., 2020).

In summary, middle-distance runners must meter their running pace very accurately, setting off at a pace that allows the output of maximum force and leaves some reserves for both an acceleration of speed in the final part of the race. Biomechanical efficiency when racing is a key element in performing at the peak level, an untrained effect that was specifically trained in the applied circuit training in this investigation, indicated by the enhanced pre- to post-test results.

## Conclusion

This study demonstrates that circuit-based strength-endurance training is an effective method for improving physical performance and biomechanical efficiency in

highly trained junior female 800 m specialists. The periodized program, characterized by structured progression, sustained muscular engagement, and controlled recovery intervals, contributed to significant improvements in anaerobic and aerobic capacities, running kinematics, and pacing strategies. These findings provide practical implications for coaches and practitioners, suggesting that the systematic integration of circuit strength-endurance training into middle-distance training plans can optimize race-specific adaptations, enhance fatigue resistance, and promote efficient force application during competition.

From a practical standpoint, coaches are encouraged to adopt training models that concurrently develop strength, endurance, and biomechanical efficiency, with careful management of training intensity and recovery to maximize adaptations. At the same time, athletes may benefit from targeted interventions aimed at improving both propulsive power and energy conservation strategies across different race segments.

Future research should expand on these findings by examining the long-term effects of circuit strength-endurance training across different age groups, competition levels, and genders. Additionally, incorporating physiological markers such as lactate thresholds, muscle activation patterns, or hormonal responses could provide deeper insights into the mechanisms underlying the observed adaptations. Investigating the interaction between strength-endurance protocols and other training modalities (e.g., plyometric or interval training) may further refine evidence-based guidelines for middle-distance running performance optimization.

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