



The Effects of an 8-Week Moderate-Intensity Continuous Running Program on Selected Performance Parameters in National-Level Cross-Country Athletes

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Abstract

Aim: This study aimed to investigate the effects of an 8-week training program centered on moderate-intensity continuous running on key performance parameters in national-level cross-country athletes. The research focused on determining how such training influences aerobic endurance, speed, agility, explosive power, and flexibility—components that play a critical role in the complex physiological and mechanical demands of cross-country running.

Method: A total of 30 national-level cross-country athletes participated in this study. A single-group pre-test/post-test design was used. Athletes completed an 8-week combined training program centered on moderate-intensity continuous running and supported by supplementary exercises, in addition to their regular training routines. Performance assessments included Wingate anaerobic power, 30 m sprint, Illinois agility test, 20 m shuttle run, standing long jump, and sit-and-reach flexibility tests. Pre- and post-training values were compared using paired samples t-tests and Cohen's d effect sizes.

Results: Significant improvements were observed across all performance parameters following the 8-week training program ($p < 0.001$). Athletes demonstrated increases in anaerobic power, aerobic endurance, explosive strength, and flexibility, accompanied by decreases in sprint and agility times. All variables showed very large effect sizes, indicating strong performance adaptations primarily associated with the moderate-intensity continuous running-based training stimulus.

Conclusion: The findings indicate that a training program centered on moderate-intensity continuous running, when supported by supplementary exercises, is an effective and sustainable approach for enhancing multidimensional performance in national-level cross-country athletes. The program produced robust improvements even in high-performance individuals, highlighting the importance of including well-planned moderate-intensity endurance sessions within comprehensive training models.

Key words: Athletics, Endurance, Performance.

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INTRODUCTION

Endurance performance is one of the primary determinants of success in long-distance running and is shaped by physiological components such as aerobic capacity, running economy, and fatigue resistance. In addition to these classical determinants, recent evidence highlights the importance of neuromuscular efficiency, motor unit recruitment patterns, and metabolic regulation in sustaining race pace under prolonged loading conditions. For national-level cross-country athletes, the systematic progression of training loads and the continuous monitoring of adaptive responses are critical for achieving sustainable performance improvements and minimizing excessive fatigue. In cross-country running, which involves prolonged and repetitive locomotion over uneven terrain, moderate-intensity continuous loads have been shown to enhance cardiorespiratory function and exert positive effects on maximal oxygen uptake (VO_{2max}), lactate threshold, and aerobic power, thereby supporting race-specific endurance demands (Jones & Carter, 2000; Seiler, 2010; González-Mariscal et al., 2023).

Another key factor influencing the performance of cross-country runners is weekly training volume and the distribution of training intensity. Moderate-intensity continuous loads, typically characterized by prolonged running durations, play a central role in supporting oxidative energy metabolism, stimulating mitochondrial biogenesis, and strengthening the aerobic endurance base (Laursen & Jenkins, 2002; Granata et al., 2020). Such loads promote both central and peripheral physiological adaptations, including enhanced oxygen transport capacity, improved muscle fiber oxidative potential, and favorable changes in running economy. Importantly, improvements in aerobic metabolism and fatigue resistance have also been shown to indirectly support neuromuscular performance by delaying peripheral fatigue, preserving force production, and enhancing movement efficiency during repeated high-intensity actions. Recent longitudinal and meta-analytic studies have reported that sustained exposure to moderate-intensity endurance training contributes to long-term improvements in competitive performance and

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training sustainability among elite and sub-elite endurance athletes (Galán-Rioja et al., 2023; Mølmen et al., 2025).

Performance in cross-country running is influenced not only by physiological but also by mechanical and neuromuscular factors. The uneven terrain, variable acceleration patterns, and frequent changes of direction inherent to cross-country courses require athletes to effectively utilize and coordinate both aerobic and anaerobic energy systems. Although explosive actions such as sprinting, jumping, and rapid directional changes are primarily supported by anaerobic mechanisms, the ability to repeatedly express these actions during prolonged exercise is closely linked to aerobic energy availability and fatigue tolerance. Moderate-intensity continuous training strengthens the foundational endurance base necessary to cope with this complex structure and enhances athletes' capacity to sustain neuromuscular output, movement quality, and pace throughout the race (Seiler & Tønnessen, 2009).

Recent studies have demonstrated that 6–12-week structured endurance training programs significantly improve aerobic performance in elite athletes, with submaximal and moderate-intensity loads being particularly effective in inducing long-term physiological and metabolic adaptations (Stöggl & Sperlich, 2014; González-Mariscal et al., 2023). From a practical perspective, enhanced aerobic capacity and improved metabolic efficiency may contribute not only to endurance performance but also to secondary gains in speed, agility, and explosive power by reducing fatigue-related decrements during high-intensity efforts. In this context, examining the effects of an 8-week systematic moderate-intensity continuous training program on aerobic performance indicators in national-level cross-country athletes addresses a noteworthy gap for both researchers and practitioners. Given the limited number of studies directly evaluating the effects of moderate-intensity continuous loads on national-level cross-country runners, the present research has the potential to contribute meaningfully to the existing literature (Galán-Rioja et al., 2023). Therefore, the purpose of this study was to investigate the effects of an 8-week moderate-intensity continuous running program on aerobic performance parameters in national-level cross-country athletes.

METHOD

Research model

This study was structured within a quantitative research framework and conducted using a single-group pretest–posttest quasi-experimental design. In quasi-experimental designs, although the independent variable is applied in a controlled manner, full random assignment of participants is not feasible; therefore, such designs are more limited than true experiments yet offer greater adaptability to field conditions (Karasar, 2020). Pretest–posttest applications allow for the statistical examination of differences between measurements taken before and after the intervention, as well as for determining the magnitude of change (Büyüköztürk, 2018). Accordingly, the present study can be characterized as a quantitative, applied, and quasi-experimental design aimed at evaluating the effects of a specific training protocol over time (Creswell & Creswell, 2018).

Population and sample

The population of the study consisted of elite national-level cross-country athletes actively competing under the Turkish Athletics Federation. The sample included a total of 30 athletes (14 women and 16 men) between the ages of 18 and 30, all of whom volunteered to participate in the study. Every athlete had achieved at least a Balkan Championship–level ranking, possessed international competition experience, and met the inclusion criteria such as a minimum of five years of continuous long-distance training, a habitual weekly training volume of at least 60 km, and being free from cardiopulmonary or orthopedic disorders. Athletes with acute or chronic injuries, cardiopulmonary diseases, performance-affecting medication use, or recent training interruptions were excluded from the sample.

Data collection tools

Anaerobic Power Test: The athletes' anaerobic power and capacity levels were assessed using the Wingate Anaerobic Power Test under laboratory conditions. The test was performed on a calibrated Monark-type cycle ergometer (e.g., Monark, Sweden) and consisted of a 30-second maximal pedaling protocol. The resistance load was adjusted according to each athlete's body weight based on

standardized percentage values. Peak power, mean power, and fatigue index were calculated automatically via the test software.

Sprint Speed Test: To evaluate sprint performance, a 30 m sprint test was administered. Following a standardized warm-up, athletes performed an all-out sprint on a 30-meter straight track. Running times were recorded with 0.01-second precision using an electronic photocell timing system positioned at the start and at the 30-meter mark. Each athlete completed two attempts, and the best performance was used for analysis.

Agility Test: Agility performance was assessed using the Illinois Agility Test, a widely utilized and validated protocol in field-based sports. The test course was set up according to standard dimensions, preserving its directional-change, acceleration, and deceleration characteristics. Test times were recorded with millisecond precision using photocell timing gates placed at the start and finish lines. Athletes were briefed on the test procedures beforehand, completed one familiarization trial, and then performed one maximal trial, which was included in the analysis.

Endurance Test: Aerobic endurance was evaluated using the 20 m Shuttle Run (Beep) Test, a widely accepted and valid field test. The test was conducted between two 20-meter lines using standard pre-recorded audio signals delivered via a speaker system connected to a computer or mobile device. Athletes increased their running speed in accordance with the auditory cues, and the test was terminated when the participant failed to reach the line on two consecutive signals. The final completed stage and corresponding running speed were used to estimate VO_2max via the relevant predictive equation.

The 8-week training program consisted of four sessions per week and all testing procedures were conducted under the supervision of a qualified coach.

Standing Long Jump Test: Horizontal jump performance was assessed using a standard Long Jump Test Mat / Jump Board commonly employed in international literature. Measurements were obtained with the Takei Physical Fitness Test Jump Meter (Takei Scientific Instruments, Japan) with centimeter accuracy. Athletes were given at least 1 minute of rest between attempts, and the best score from two trials was used for analysis.

Flexibility – Sit-and-Reach Test: Flexibility was assessed using the Sit-and-Reach Box, which is widely utilized in sports science research. Measurements were performed with the Baseline Sit-and-Reach Flexibility Box (Fabrication Enterprises Inc., USA). Following a warm-up, athletes completed three trials in the test position, and the highest value was recorded

Training Program

Table 1. The 8-week combined training program including moderate-intensity continuous running and supplementary exercises applied to the athletes

Week	Moderate-Intensity Continuous Running (Duration)	Regular Exercise: Sprint / Anaerobic Power	Regular Exercise: Agility – Plyometric	Regular Exercise: Flexibility / Mobility
Week 1	40 min × 2	6 × 10 s uphill sprint	Technical Illinois + low-intensity plyo	10 min static stretching
Week 2	40 min × 2	6–7 × 10 s sprint	3 × 15 squat jumps, 3 × 15 m bounding	12 min PNF + static
Week 3	45 min × 2	7 × 10 s sprint + 2 × 30 m acceleration	Illinois (1 maximal) + increased plyometrics	12–13 min mobility
Week 4	45 min × 2	7–8 × 10 s sprint	3 × 20 m bounding, 3 × 8 lateral hop	15 min PNF
Week 5	50 min × 2	8 × 10 s sprint + 3 × 30 m	Increased Illinois intensity	15 min posterior chain mobility
Week 6	50 min × 2	8 × 10 s sprint	Increased plyometric load (3 × 12 squat jumps)	15 min combined mobility
Week 7	55 min × 2	8 × 10 s sprint + acceleration series	Maximal Illinois + change-of-direction	15–18 min flexibility
Week 8	55–60 min × 2	8 × 10 s sprint (maximal)	Peak plyometric loading	15–18 min PNF + static

The combined training program centered on moderate-intensity continuous running and supplementary exercises applied to the athletes.

Data analysis

The data obtained from the study were analyzed using the SPSS 26.0 statistical software package. The distribution characteristics of the variables were assessed with the Shapiro–Wilk test, and since the assumption of normality was met, parametric statistical methods were employed. To determine the pre-test and post-test differences for male athletes, female athletes, and the whole group, paired samples t-test, Cohen’s d effect size, and percentage change (%Δ) were calculated. Cohen’s d effect size was interpreted as follows: $d < 0.20$ very small, $0.20–0.49$ small, $0.50–0.79$ medium, $0.80–1.19$ large, and ≥ 1.20 very large. To examine differences between male and female athletes, an independent samples t-test was performed, and the homogeneity of variances was verified using Levene’s test. Bonferroni correction was applied in comparisons involving multiple variables to reduce the likelihood of Type I error. The results were presented as $\bar{X} \pm SD$ (mean \pm standard deviation), and the level of statistical significance was set at $p < 0.05$.

RESULTS

Table 2. Demographic characteristics of the athletes

Variable	Male (n = 16) $\bar{X} \pm SD$	Min–Max	Female (n = 14) $\bar{X} \pm SD$	Min–Max	Total (n = 30) $\bar{X} \pm SD$	Min–Max
Age (years)	24.19 \pm 3.85	18–30	23.71 \pm 3.89	18–30	23.97 \pm 3.81	18–30
Height (cm)	179.81 \pm 3.64	174–186	164.93 \pm 3.75	159–171	172.87 \pm 8.38	159–186
Body weight (kg)	74.50 \pm 4.76	67–82	57.29 \pm 3.45	52–63	66.47 \pm 9.66	52–82
Athletic experience (years)	9.25 \pm 2.08	6–12	7.71 \pm 1.90	5–11	8.53 \pm 2.11	5–12

Examination of the demographic distribution presented in Table 2 indicates that the study sample displays a highly consistent and high-performance profile in terms of age, anthropometric characteristics, and athletic background. The higher mean values observed in male athletes for height, body weight, and athletic experience compared to female athletes align with well-documented sex-based physiological differences that influence endurance- and strength-related performance outcomes in the literature.

The lower height and body weight values recorded in female athletes correspond to the expected anthropometric profile of elite long-distance runners. The similarity in age distribution between the two groups demonstrates that the sample is developmentally homogeneous, reducing the likelihood of age acting as an external confounding factor on performance variables. Additionally, the high athletic experience averages for both male and female athletes indicate that participants possess extensive training histories, which represents a methodological advantage for evaluating the targeted performance parameters of the study. Overall, the table demonstrates that the research was conducted with a well-trained, high-performance elite sample suitable for examining endurance and anaerobic performance outcomes.

Table 3. Pre-test and post-test performance values of male athletes (n = 16)

Variable	Pre-Test (M \pm SD)	Post-Test (M \pm SD)	t	df	p	Cohen’s d	%Δ
Wingate (W)	748.38 \pm 43.48	790.00 \pm 41.58	39.785	15	.001***	9.95	+5.60
30 m Sprint (s)	4.30 \pm 0.10	4.19 \pm 0.11	-41.849	15	.001***	-10.46	-2.99
Illinois agility test	16.20 \pm 0.24	15.88 \pm 0.25	-55.308	15	.001***	-13.83	-2.32
20 m Shuttle Run (laps)	102.00 \pm 12.64	111.75 \pm 13.53	53.562	15	.001***	13.39	+9.66
Standing Long Jump (cm)	244.50 \pm 10.35	253.62 \pm 10.61	45.273	15	.001***	11.32	+3.79
Flexibility (cm)	28.06 \pm 3.24	33.13 \pm 3.55	42.485	15	.001***	10.62	+17.34

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; $0.20–0.49$ = small effect; $0.50–0.79$ = medium effect; ≥ 0.80 = large effect; %Δ = percent change

When Table 3 is examined, it is observed that the male athletes demonstrated statistically significant and consistent improvements across all performance parameters ($p < 0.001$). In particular, the 5.60% increase observed in the Wingate anaerobic power test indicates the development of pronounced neuromuscular adaptations in response to high-intensity training stimuli. Consistently, the exceptionally high Cohen’s d value of 9.95 shows that the change in anaerobic power represents not only a statistically significant difference but also a practically and clinically substantial effect.

The reductions in post-test times for the sprint and agility assessments (–2.99% and –2.32%, respectively) indicate improvements in speed and change-of-direction ability. Along with the negative

percentage changes, the extremely large effect sizes (-10.46 and -13.83 , respectively) demonstrate that the speed and agility components responded strongly to the training protocol. These findings support the notion that even small percentage improvements in sprint and agility performance can translate into meaningful competitive advantages for high-level athletes. The 9.66% increase in the 20 m shuttle run test, a key indicator of endurance, demonstrates robust aerobic capacity adaptations. The very large effect size ($d=13.39$) further supports the conclusion that the athletes experienced substantial improvements in cardiorespiratory function. The 3.79% increase in standing long jump performance indicates a meaningful enhancement in lower-limb explosive strength. The extremely large effect size ($d=11.32$) highlights the strong impact of the strength-oriented elements of the training program. Similarly, the 17.34% improvement recorded in flexibility, accompanied by a very large effect size ($d=10.62$), shows notable improvements in range of motion, muscle elasticity, and functional mobility. Overall, the table demonstrates that the training program generated highly potent stimuli across multiple performance domains (anaerobic power, speed, agility, endurance, flexibility, and explosive strength) in male athletes. The fact that all statistical changes were supported by exceptionally large effect sizes strongly indicates that the applied training protocol is a highly effective and performance-enhancing method.

Table 4. Pre-test and post-test performance values of female athletes ($n = 14$)

Variable	Pre-Test (M \pm SD)	Post-Test (M \pm SD)	t	df	p	Cohen's d	% Δ
Wingate (W)	551.57 \pm 78.50	592.71 \pm 77.54	49.115	13	.001***	13.13	+7.63
30 m Sprint (s)	4.71 \pm 0.12	4.59 \pm 0.12	-47.836	13	.001***	-12.79	-2.70
Illinois (s)	16.82 \pm 0.29	16.45 \pm 0.31	-54.285	13	.001***	-14.52	-2.20
20 m Shuttle Run (laps)	93.64 \pm 8.89	101.93 \pm 8.85	63.402	13	.001***	16.95	+8.85
Standing Long Jump (cm)	195.50 \pm 13.59	204.21 \pm 13.93	69.551	13	.001***	18.59	+4.47
Flexibility (cm)	32.71 \pm 4.50	37.57 \pm 4.72	50.047	13	.001***	13.38	+15.02

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; 0.20–0.49 = small effect; 0.50–0.79 = medium effect; ≥ 0.80 = large effect; % Δ = percent change

When Table 4 is examined, it is observed that the female athletes demonstrated statistically significant improvements across all performance parameters ($p < 0.001$). The 7.63% increase in Wingate anaerobic power outputs indicates notable anaerobic power adaptations in response to high-intensity loading. The reductions in post-test sprint and agility times (-2.70% and -2.20% , respectively) correspond to meaningful improvements in speed and change-of-direction performance, and the magnitude of the Cohen's d values shows that these improvements are both statistically and practically strong. The 8.85% increase observed in the 20 m shuttle run test, which represents the endurance component, indicates a marked enhancement in cardiorespiratory capacity. Similarly, the 4.47% increase in standing long jump performance demonstrates effective improvements in lower-limb explosive strength. The 15.02% improvement in flexibility, supported by a very large effect size, reflects significant enhancements in functional range of motion and mobility. Overall, the findings show that the improvements observed in female athletes are both statistically robust and highly effective in terms of applied performance. These results indicate that the implemented training protocol holistically and effectively enhanced aerobic, anaerobic, strength, speed, agility, and flexibility components in female athletes.

Table 5. Pre-Test and Post-Test Performance Values of All Athletes ($n = 30$)

Variable	Pre-Test (M \pm SD)	Post-Test (M \pm SD)	t	df	p	Cohen's d	% Δ
Wingate (W)	644.37 \pm 110.52	685.13 \pm 110.21	61.736	29	.001***	11.27	+6.54
30 m Sprint (s)	4.50 \pm 0.23	4.38 \pm 0.22	-62.943	29	.001***	-11.49	-2.85
Illinois (s)	16.49 \pm 0.37	16.14 \pm 0.38	-73.731	29	.001***	-13.46	-2.12
20 m Shuttle Run (laps)	98.27 \pm 11.90	106.40 \pm 12.27	84.927	29	.001***	15.51	+8.27
Standing Long Jump (cm)	219.67 \pm 25.90	228.60 \pm 26.29	70.760	29	.001***	12.92	+4.10
Flexibility (cm)	30.00 \pm 4.76	34.80 \pm 5.00	64.622	29	.001***	11.80	+16.26

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; 0.20–0.49 = small effect; 0.50–0.79 = medium effect; ≥ 0.80 = large effect; % Δ = percent change

When Table 5 is examined, it is observed that all athletes showed statistically significant improvements across all performance parameters ($p < 0.001$). The 6.54% increase in Wingate anaerobic power outputs indicates that the high-intensity training protocol produced strong adaptations in anaerobic capacity and intramuscular energy production mechanisms. This finding is supported by the very large Cohen's d value, demonstrating that the change has an extremely strong practical effect. The reductions in sprint and agility times (-2.85% and -2.12% , respectively) reflect clear improvements in speed, reaction ability, and change-of-direction performance. These decreases indicate enhancements that are both statistically robust and meaningful for competitive performance on the field. The 8.27% increase in the

20 m shuttle run test, an indicator of endurance, demonstrates notable improvements in aerobic capacity and cardiorespiratory function. The 4.10% improvement in standing long jump performance indicates enhanced lower-limb explosive strength, while the 16.26% increase in flexibility reveals substantial gains in functional range of motion. Overall, the results obtained from all athletes show that the applied training protocol produced holistic and high-level improvements in anaerobic power, speed, agility, endurance, strength, and flexibility. The fact that all effects were supported by very large Cohen's *d* values confirms that these performance enhancements were extremely strong both statistically and practically.

DISCUSSION

The findings of this study indicate that the applied training protocol produced significant improvements in the multidimensional physiological and motor abilities of high-performance athletes. The results show that the protocol provided effective stimuli in key performance components, including anaerobic power, speed, agility, endurance, explosive strength, and flexibility. Although the sports science literature frequently emphasizes that achieving performance enhancement in elite athletes is more limited, the broad improvements observed in this study support the notion that well-structured endurance-based training can create strong adaptation potential even at the elite level. Furthermore, the large effect sizes observed across all parameters indicate that the improvements obtained are not only statistically meaningful but also highly significant in practical terms, demonstrating that the training approach provides a real performance benefit in competitive settings.

In this study, after 8 weeks of moderate-intensity continuous running training, significant increases were observed in Wingate anaerobic power outputs: 5.60% in men, 7.63% in women, and 6.54% in the total group. The very large Cohen's *d* values indicate that the observed improvements represent a highly strong effect not only statistically but also in terms of practical performance (Cohen, 1988). The literature suggests that endurance-based training loads may support performance during short-duration high-intensity efforts by improving metabolic efficiency and the ability to sustain power output under fatigue (Jones & Carter, 2000; Laursen & Jenkins, 2002). While Barnes and Kilding (2015) reported that strengthening the aerobic base can indirectly contribute to anaerobic performance through faster phosphocreatine resynthesis, Midgley et al. (2007) emphasized that training-induced central and peripheral adaptations in endurance athletes may positively influence short-duration power expression. Accordingly, the significant improvements in anaerobic power observed in the present study are thought to be primarily related to training-induced adaptations such as enhanced fatigue tolerance, improved pacing ability, and more efficient utilization of available energy during maximal efforts, rather than direct structural changes at the muscular level, enabling athletes to sustain higher power outputs during the Wingate test.

Following the analysis of the study results, significant improvements were observed in 30 m sprint times after 8 weeks of moderate-intensity continuous running training, with reductions of -2.99% in men, -2.70% in women, and -2.85% in the total group. The very large accompanying Cohen's *d* values indicate that the improvement in speed performance created a strong practical effect in addition to being statistically meaningful. Recent literature emphasizes that sprint performance is closely related to spatiotemporal parameters such as stride length, stride time, and ground reaction force, which are influenced by overall running efficiency and neuromuscular coordination. Although the present training program did not specifically target acceleration-phase mechanics, improvements in aerobic support, fatigue tolerance, and movement efficiency may have indirectly contributed to the observed enhancements in sprint performance. Seidl et al. (2021) reported that parameters associated with the maximum velocity phase shape 100 m sprint performance, while Martín-Fuentes et al. (2022) demonstrated that foot/ankle angular kinematics are significantly associated with 50 m sprint time. Similarly, Bustamante-Garrido et al. (2024) and Karadenizli et al. (2025) found that 30 m sprint performance is closely related to lower-limb mechanical characteristics and anthropometric profile. While these findings highlight the importance of sprint-specific mechanical determinants, the present study did not include training interventions directly targeting sprint mechanics or acceleration-phase technique. Therefore, the significant improvement in 30 m sprint time observed in the present study is more likely attributable to indirect adaptations associated with prolonged moderate-intensity continuous running, such as improvements in running economy, fatigue tolerance, and the ability to maintain

neuromuscular coordination under repetitive loading, rather than to direct mechanical or kinematic changes.

After 8 weeks of moderate-intensity continuous running training, the Illinois agility times of the participating athletes improved significantly, with reductions of -2.32% in men, -2.20% in women, and -2.12% in the total group. The very large Cohen's *d* values indicate that these improvements have not only strong statistical significance but also a substantial practical impact on field performance. Recent literature emphasizes that the Illinois Agility Test is a valid and reliable field test for evaluating agility and change-of-direction speed (Ilham et al., 2025). Current studies show that agility performance depends on multiple biomechanical and neuromuscular determinants such as lower-limb strength, braking and propulsive forces, ground contact time, and trunk control (Dos' Santos et al., 2021; Pérez-Ifrán et al., 2023). Furthermore, training that incorporates speed, agility, and quickness (SAQ) components has been reported to improve Illinois agility performance significantly (Sun et al., 2025). Although the present training program did not directly target anaerobic glycolytic capacity or specific change-of-direction biomechanics, the Illinois Agility Test requires repeated accelerations, decelerations, and directional changes under conditions of progressive fatigue. Accordingly, the observed improvements are thought to be primarily related to enhanced aerobic support, improved fatigue tolerance, and the ability to maintain neuromuscular control and trunk stability during the later stages of the test, rather than to direct biomechanical adaptations.

In the present study, significant improvements were also observed in 20 m shuttle run performance after 8 weeks of moderate-intensity continuous running, with increases of $+9.66\%$ in men, $+8.85\%$ in women, and $+8.27\%$ in the total group. The very large Cohen's *d* values demonstrate that this improvement in aerobic performance produced a strong effect both statistically and practically. Recent literature highlights that increases in shuttle run performance are directly related to aerobic capacity, oxygen consumption rate, and running economy. Burnley and Jones (2018) state that oxygen uptake kinetics are one of the primary determinants of endurance performance and that these responses accelerate with regular aerobic loading. Similarly, Jones and Vanhatalo (2017) reported that moderate-intensity endurance training significantly improves critical power/pace, running economy, and sustainable aerobic capacity. In line with these findings, the significant improvement in shuttle run performance observed in this study is thought to result from the enhancement of oxygen consumption kinetics, aerobic energy production, and running economy induced by moderate-intensity continuous loads, enabling athletes to reach higher $\text{VO}_{2\text{max}}$ levels.

When the analysis results are examined, significant improvements were observed in standing long jump performance after 8 weeks of moderate-intensity continuous running, with increases of $+3.79\%$ in men, $+4.47\%$ in women, and $+4.10\%$ in the total group. The very large Cohen's *d* values indicate that this improvement in lower-limb explosive strength represents a strong enhancement both statistically and practically. According to current literature, horizontal jump performance is closely related to lower-limb elastic properties, rate of force production, and mechanical efficiency. Liu et al. (2022) reported that lower-limb stiffness and running economy are important factors affecting jump performance and mechanical power transfer in endurance runners. In addition, Sole et al. (2018) found that elastic energy return capacity is directly associated with jump distance, while Suchomel et al. (2016) emphasized that the rate of force development is a key determinant of lower-limb performance. In the present study, the significant improvements in standing long jump performance are thought to result from enhanced neuromuscular efficiency and improved utilization of elastic energy in the lower limbs, leading to more effective power transfer during jumping.

After 8 weeks of moderate-intensity continuous running, flexibility performance improved significantly, with increases of $+17.34\%$ in men, $+15.02\%$ in women, and $+16.26\%$ in the total group. The very large Cohen's *d* values indicate that these improvements also represent strong practical effects. The literature suggests that lower-limb posterior chain mobility (e.g., hamstrings and related hip extensors) and muscle–tendon stretch tolerance are primary determinants of flexibility performance. Konrad and Tilp (2014) reported that regular loading increases stretch tolerance in the muscle–tendon complex, thereby improving range of motion. Reid et al. (2007) showed that lower-limb mobility is closely related to functional performance and that regular running-based training can positively influence range of motion. In this study, the increase in flexibility performance is thought to result from training-induced

improvements in stretch tolerance and repeated dynamic exposure to end-range joint positions during running, which may be accompanied by favorable changes in passive resistance (i.e., perceived stiffness) over time, leading to increased range of motion in the lower-limb posterior chain.

Overall, the findings indicate that 8 weeks of moderate-intensity continuous running produced consistent and meaningful improvements in key performance components—anaerobic power, speed, agility, endurance, explosive strength, and flexibility—in national-level cross-country athletes. The very large Cohen's *d* values observed across all parameters demonstrate that the training protocol generated strong adaptations even in high-performance groups. These results support the literature suggesting that moderate-intensity continuous training positively affects running economy, oxygen utilization efficiency, neuromuscular coordination, and muscle–tendon function. The findings also demonstrate that not only high-intensity interval training but also planned and sufficiently voluminous moderate-intensity continuous loading is an effective method for multidimensional performance enhancement in endurance athletes. Therefore, it is considered beneficial to periodically incorporate moderate-intensity continuous running into training plans to achieve sustainable performance improvements.

Additionally, the training program applied in the present study was designed by the researchers based on practical and contextual considerations. Although the protocol was structured in accordance with current training principles, this may represent a potential limitation, as the involvement of the researchers in program design could have influenced training implementation and outcome interpretation. Future studies employing externally standardized or independently designed training protocols may help to further reduce potential design-related bias.

CONCLUSION

In this study, it was determined that 8 weeks of moderate-intensity continuous running training produced significant improvements in key performance indicators—such as speed, agility, endurance, explosive strength, and flexibility—in national-level cross-country athletes. The very large Cohen's *d* values obtained across all parameters indicate that moderate-intensity loads can generate effective physiological and neuromuscular adaptations even in athletes with high performance levels. These findings demonstrate that endurance athletes' performance development should not rely solely on high-intensity intervals but should also include planned moderate-intensity continuous running sessions.

SUGGESTIONS

Based on these results, the following recommendations can be made for practitioners:

- Incorporating moderate-intensity continuous running 3–4 days per week during in-season and preparatory periods.
- Using the 65–75% HRmax range to strengthen the aerobic base without causing excessive fatigue.
- Programming these sessions in balance with fundamental running workouts to support improvements in agility, speed, and explosive strength.

Overall, moderate-intensity continuous running training is recommended as an effective, applicable, and sustainable method for the multidimensional development of performance.

LIMITATIONS

Although this research presents important findings, several limitations should be considered when interpreting the results. First, the study group consisted solely of national-level cross-country athletes, which restricts the generalizability of the findings to different age groups, training backgrounds, or sports disciplines. Since the research was conducted on a homogeneous sample with a specific performance level, it is not fully clear how training responses might differ across various athlete profiles.

Second, although the primary training stimulus of the intervention was based on moderate-intensity continuous running, the applied program also included supplementary training components (e.g., sprint, agility, flexibility, and strength-related exercises) as part of the athletes' regular training routines. These additional training exposures could not be fully controlled, which limits the extent to which performance

changes can be attributed exclusively to the moderate-intensity continuous running component. This represents an unavoidable methodological constraint, particularly common in studies conducted under real-world field conditions.

Third, the performance assessments used in the study were based on field tests. While field tests are practical, applicable, and sport-specific, they offer limited capacity to reveal the underlying mechanisms of training-induced physiological adaptations (e.g., oxygen uptake kinetics, muscle–tendon mechanical properties, neuromuscular activation patterns, metabolic response profiles). The absence of laboratory-based measurements makes it more difficult to examine the biological basis of adaptation in depth.

Finally, individual differences in training responses may be influenced by factors such as genetic structure, previous training experience, recovery capacity, sleep patterns, and nutritional habits. The inability to fully control these factors limits the interpretation of the results in terms of individual variation. Therefore, future studies employing larger and more heterogeneous samples, controlled training designs, laboratory-based measurements, and long-term follow-up periods will enhance the validity and generalizability of the findings.

Ethical Approval and Permission Information

Ethics Committee: Ağrı İbrahim Çeçen University Scientific Research Ethics Committee

Protocol/Number: 176

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