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Pre-to-Post Changes in Selected Field Performance Indicators Following a HIIT-Based Multicomponent Training Program in Junior Middle-Distance Runners: A Pre-Experimental Study in Djelfa, Algeria

Évolution pré-post de certains indicateurs de performance mesurés sur le terrain à la suite d'un programme d'entraînement multicomposant fondé sur le HIIT chez des coureurs de demi-fond juniors : une étude pré-expérimentale menée à Djelfa, en Algérie

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Abstract:

This study examined pre-to-post changes in selected field-based indicators of high-intensity running performance and complementary physical performance following an 8-week structured high-intensity interval training (HIIT)-based multicomponent training program in competitive junior middle-distance runners. Ten male runners (18.30 ± 0.67 years) affiliated with athletics clubs in Djelfa Province, Algeria, completed 24 supervised training sessions over 8 weeks. The program combined individualized maximal aerobic speed (MAS)-based running intervals, event-specific pacing, longer aerobic intervals, hill running, horizontal bounding, recovery running, and supplementary bodyweight conditioning. Field assessments were conducted before and after the intervention and included 300 m running performance, a 1-minute alternating single-leg bounding test, and a 10-second pull-up test. Pre-to-post changes were analyzed using paired-samples t-tests, with exact Wilcoxon signed-rank tests as non-parametric sensitivity analyses. Bonferroni adjustment was applied to the three primary comparisons.

Mean 300 m running time decreased from 48.50 ± 0.71 s to 46.41 ± 0.62 s, representing a 2.09 s (4.31%) improvement ($p < 0.001$). One-minute bounding performance increased from 62.32 ± 1.01 to 65.50 ± 1.31 repetitions, representing a 3.18-repetition (5.10%) improvement ($p < 0.001$). Ten-second pull-up performance increased from 6.70 ± 0.86 to 8.18 ± 0.68 repetitions, representing a 1.48-repetition (22.09%) improvement ($p < 0.001$). All three comparisons remained statistically significant after Bonferroni adjustment.

Overall, participation in the structured multicomponent training program was associated with substantial improvements in the selected field performance indicators over the 8-week period. However, because the study used a single-group pretest-posttest design without a control group, the observed changes cannot be interpreted as causal effects of HIIT or of any individual component of the training program.

Keywords: High-Intensity Interval Training; Middle-Distance Running; Maximal Aerobic Speed; Speed Endurance; Field Performance; Pre-Experimental Design; Junior Athletes.

1. Introduction

Middle-distance running events, particularly the 800 m and 1500 m, require the integrated contribution of aerobic energy production, anaerobic glycolytic capacity, neuromuscular function, running economy, and the ability to maintain effective performance as fatigue develops. Competitive performance therefore depends not only on general aerobic fitness but also on the ability to sustain high running velocities while preserving effective mechanical and neuromuscular function under substantial metabolic stress.

Within applied sports training, specific endurance can be understood broadly as the capacity to sustain performance characteristics relevant to the competitive event despite accumulating fatigue. In middle-distance running, this construct encompasses the ability to maintain high-intensity running, tolerate substantial metabolic demands, and preserve effective movement mechanics as fatigue develops. Because specific endurance is multidimensional, field

investigations frequently use operational performance indicators rather than a single physiological measure.

High-intensity interval training (HIIT) involves repeated bouts of relatively high-intensity exercise interspersed with recovery periods. Training intensity can be individualized according to physiological or performance markers and combined with complementary training modalities according to the demands of the sport[1]. Recent evidence supports the potential value of interval-based training in young athletic populations. A meta-analysis by Matzka et al. (2025) included 28 studies involving 707 youth athletes and reported favorable effects of HIIT compared with several alternative training approaches on selected endurance-related outcomes. These findings align with broader evidence on school-aged and adolescent cohorts demonstrating substantial cardiorespiratory and neuromuscular adaptations to interval conditioning[2]. More recently, Zhang et al. (2026) reported favorable effects of HIIT-based interventions on several physical-fitness outcomes in trained adolescent athletes, including cardiorespiratory fitness and selected performance measures.

Evidence from trained runners also suggests that combining high-intensity running with complementary resistance-oriented training may influence selected physiological and performance outcomes[3] . In a randomized controlled trial involving well-trained runners, examined combined HIIT and resistance training and reported improvements in selected physiological and performance variables. Furthermore, Spilsbury et al. (2021) demonstrated that manipulation of training volume and interval intensity during tapering could influence subsequent 1500 m performance in trained middle-distance runners. Systematic periodization and individualization of these combined loads remain central to maximizing adaptations while managing fatigue.

Nevertheless, previous investigations vary considerably in participant characteristics, intervention duration, intensity prescription, recovery structure, and outcome measures. Field-based evidence remains limited concerning structured programs that simultaneously combine individualized MAS-based running intervals, event-specific pacing, complementary neuromuscular training, and systematic progression among junior middle-distance runners in regional North African settings. This issue is particularly relevant in club environments where

[1] - Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle, Part I: Cardiopulmonary and neuromuscular highlights. *Sports Medicine*, 43(5), p.313–338.

https://link.springer.com/article/10.1007/s40279-013-0029-x

[2] - Bauer, N., Sperlich, B., Holmberg, H.-C., & Engel, F. A. (2022). Effects of high-intensity interval training in school on the physical performance and health of children and adolescents: A systematic review with meta-analysis. *Sports Medicine - Open*, p.8, 50.

https://link.springer.com/article/10.1186/s40798-022-00437-8

[3] - Leonardo Trevisol Possamai, Luiz Guilherme Antonacci Guglielmo, Amadeo Felix Salvador, Benedito Sérgio Denadai, and Paulo Cesar Do Nascimento Salvador, "Effects of High-Intensity Interval Training and Resistance Training on Physiological Parameters and Performance of Well-Trained Runners: A Randomized Controlled Trial," *Journal of Sports Sciences* 42, no. 9 (2024): 785–792, https://doi.org/10.1080/02640414.2024.2364425.

laboratory-based monitoring may be unavailable and training prescriptions must be implemented using practical field measures.

The present study therefore examined an 8-week structured HIIT-based multicomponent training program in a field setting in Djelfa Province, Algeria. HIIT-based running intervals constituted the principal high-intensity component, while event-specific pacing, longer aerobic intervals, hill running, horizontal bounding, recovery running, and supplementary bodyweight conditioning were integrated within the same training program. The study did not attempt to isolate the effect of HIIT from the other components. Instead, it evaluated whether participation in the complete structured program was accompanied by measurable pre-to-post changes in selected field performance indicators.

1.1. Research Problem

In applied club settings, middle-distance training may rely on generalized running loads and repeated track work without systematic individualization according to maximal aerobic speed, event-specific pacing, and predefined work-to-recovery relationships. Such practices may produce different relative training stimuli among athletes with different physiological and performance characteristics.

A structured program based on individualized MAS prescriptions and event-specific pacing may provide a more systematic approach to high-intensity running preparation. However, field-based evidence describing pre-to-post changes associated with such a multicomponent approach among junior middle-distance runners in Djelfa remains limited.

The primary research question was therefore:

Is participation in an 8-week structured HIIT-based multicomponent training program associated with significant pre-to-post changes in selected field indicators of high-intensity running performance and complementary physical performance among junior middle-distance runners in Djelfa Province, Algeria?

1.2. Sub-Questions

1. Is participation in the program accompanied by a statistically significant reduction in 300 m running time, used as an operational indicator of high-intensity running performance and speed endurance?
2. Is participation in the program accompanied by a statistically significant increase in performance on a 1-minute alternating single-leg bounding test, used as a study-specific indicator of repeated lower-limb performance capacity?
3. Is participation in the program accompanied by a statistically significant increase in performance on a supplementary 10-second pull-up protocol?

1.3. Hypotheses

- ***Main Hypothesis:*** Participation in the 8-week structured HIIT-based multicomponent training program will be associated with statistically significant pre-to-post improvements in selected field indicators of high-intensity running performance and complementary physical performance.
- ***Sub-Hypothesis 1:*** 300 m running completion time will significantly decrease from pre-test to post-test.
- ***Sub-Hypothesis 2:*** The number of technically valid repetitions completed during the 1-minute alternating single-leg bounding test will significantly increase from pre-test to post-test.
- ***Sub-Hypothesis 3:*** The number of technically valid repetitions completed during the supplementary 10-second pull-up protocol will significantly increase from pre-test to post-test.

2. Methods

2.1. Study Design

The study employed a pre-experimental one-group pretest-posttest design:

$$\mathbf{O_1 \rightarrow X \rightarrow O_2}$$

where O_1 represented the pre-intervention assessment, X represented the 8-week structured training program, and O_2 represented the post-intervention assessment.

The design was adopted within the practical constraints of the participating club environment, where the accessible pool of competitive junior middle-distance runners was small and implementation of a parallel untreated group was not feasible within the existing seasonal training structure. This practical constraint does not eliminate the methodological limitations inherent to the design.

The study therefore evaluated longitudinal within-participant changes rather than between-group treatment effects. Because no control group was included, observed changes may also have been influenced by normal athletic development, seasonal progression, previous training, external physical activity, testing familiarization, competitive participation, and other time-related factors. Consequently, the findings are interpreted as pre-to-post associations rather than definitive causal effects.

2.2. Participants and Participant Flow

The accessible population consisted of 14 junior middle-distance runners registered with athletics clubs affiliated with the Athletics League of Djelfa Province during the 2025/2026 competitive season. The participants were male middle-distance runners aged 17–19 years competing in the junior category during the 2025/2026 season.

The final study cohort consisted of 10 male athletes aged 17–19 years who met all predefined inclusion criteria and completed all study procedures.

Four athletes from the accessible population were not enrolled. Two did not meet the minimum training-experience criterion, one was undergoing hamstring rehabilitation, and one could not participate because of an academic scheduling conflict.

- ***Inclusion Criteria:*** The inclusion criteria were:

  - primary competitive specialization in the 800 m and/or 1500 m events;
  - at least three consecutive years of structured middle-distance training;
  - a valid athletics federation license; and
  - no acute or chronic musculoskeletal condition preventing participation in the training and testing procedures.

All 10 enrolled athletes completed pre-intervention testing, the intervention period, and post-intervention testing and were retained for the final analysis.

- ***Participant Flow***

Accessible club population (N = 14) → Not enrolled (n = 4) → Enrolled cohort (n = 10) → Pre-intervention testing (n = 10) → 8-week training intervention (n = 10) → post-intervention testing (n = 10) → Final analytical cohort (n = 10)

Reasons for non-enrollment (n = 4): Training experience <3 years (n = 2); hamstring rehabilitation (n = 1); academic scheduling conflict (n = 1).

Table 1. Baseline Characteristics of the Participants (N = 10)

Parameter	**Mean ± SD**	**Observed Range**
Age (years)	18.30 ± 0.67	17.00–19.00
Body mass (kg)	61.40 ± 3.24	56.50–66.00
Stature (cm)	174.50 ± 4.12	168.00–181.00
Training history (years)	3.80 ± 0.79	3.00–5.00
Baseline MAS (km/h)	17.85 ± 0.58	17.00–18.75

2.3. Ethical Considerations

The study procedures were conducted in accordance with the principles of the Declaration of Helsinki. Formal administrative authorization was obtained from the Athletics League of Djelfa Province and the technical authorities of the participating athletics clubs[4].

[4] - Athletics League of Djelfa Province. (2025). *Administrative and field authorization for sport science research protocol* (Authorization Ref. No. ALDP-CR2025-09). Ligue d'Athlétisme de la Wilaya de Djelfa, Algeria.

Written informed consent was obtained from participants aged 18 years or older. For participants younger than 18 years, written informed consent was obtained from a parent or legal guardian, together with written participant assent.

Before participation, all athletes were informed about the study procedures, expected physical demands, confidentiality of individual data, and their right to withdraw without academic or sporting penalty.

2.4. Study Setting

Training and testing were conducted at the synthetic 400 m athletics track of the 1st November Stadium in Djelfa, Algeria.

Djelfa is located in the Algerian High Plateaus at approximately 1,140 m above sea level and is characterized by a semi-arid climate. Training sessions were generally scheduled between 16:30 and 18:30. Ambient temperature was monitored using a calibrated digital weather station and ranged from approximately 14°C to 18°C during the scheduled training periods.

The altitude and environmental characteristics of the study setting are relevant to external validity because training responses observed under these conditions may not be directly transferable to sea-level environments.

2.5. Field Testing Procedures and Instrumentation

Testing was performed during two assessment periods:

- **Pre-intervention:** October 12–14, 2025
- **Post-intervention:** December 16–18, 2025

MAS was estimated before the intervention using the progressive VAMEVAL track protocolhour -on separate testing days with 48 The physical performance tests were administered[5]. recovery intervals between sessions.

All athletes completed a standardized warm-up before each assessment. Testing instructions, equipment, surface, timing procedures, and assessment sequence were kept as consistent as practicable between pre- and post-intervention testing.

2.5.1. 300 m Running Performance Test

[5] - Cazorla, G. (1990). *Tests de terrain pour évaluer la capacité aérobie et la vitesse maximale aérobie*. Association Recherche et Évaluation en Activités Physiques et Sportives (AREAPS).

The 300 m running test was used as an operational field indicator of high-intensity running performance and speed endurance[6].

The test was performed on the synthetic track from a standing start. Running time was recorded to the nearest 0.01 s using calibrated wireless dual-beam photocells, in accordance with standardized timing procedures for sprint and speed-endurance field evaluations[7].

The test was performed on the synthetic track from a standing start. Running time was recorded to the nearest 0.01 s using calibrated wireless dual-beam photocells.

The 300 m distance requires the athlete to sustain high running velocity while tolerating substantial metabolic and neuromuscular stress. However, performance over this distance is also influenced by acceleration, pacing, anaerobic contribution, neuromuscular coordination, and technical execution. Accordingly, the measure was interpreted as an operational field indicator rather than as a direct laboratory measure of specific endurance.

2.5.2. One-Minute Alternating Single-Leg Bounding Test

The 1-minute alternating single-leg bounding test was used as a study-specific functional field indicator of repeated lower-limb performance capacity.

Following a 5 m rolling start, athletes performed continuous alternating forward bounds along an athletics turf strip for 60 seconds. A technically valid repetition required continuous alternating contacts, a stable forward trajectory, and no prolonged interruption.

Two trained evaluators independently counted technically valid repetitions. The same counting criteria were applied during both assessments.

Because the test was specifically operationalized for the present investigation, its results were interpreted as a functional field indicator of repeated lower-limb performance rather than as a definitive standardized measure of muscular endurance, reactive strength, or running-specific endurance.

2.5.3. Ten-Second Pull-Up Protocol

The 10-second pull-up protocol was included as a supplementary upper-body performance indicator.

Athletes performed as many technically valid pull-ups as possible within 10 seconds using a pronated, approximately shoulder-width grip. A repetition was considered valid when the chin

[6] -Daniels, J. (2016). *Daniels' Running Formula* (3rd ed.). Amphora.

[7] - Haugen, T., & Buchheit, M. (2016). Sprint running performance monitoring: Methodological and practical considerations. *Sports Medicine*, 46(5), p.641–656. https://doi.org/10.1007/s40279-015-0446-8

clearly passed above the bar, no deliberate swinging or lower-body kicking was used, and the elbows returned to full extension before the subsequent repetition.

The protocol was customized for the present study and should not be considered an exact replication of historical youth fitness protocols such as the AAHPER Youth Fitness Test Manual.

Because performance over 10 seconds can be influenced by strength, power, coordination, body mass, and familiarization, this variable was treated as a supplementary upper-body performance outcome rather than as a direct measure of middle-distance running endurance.

2.5.4. Pilot Reliability Assessment

A preliminary test-retest assessment was conducted two weeks before baseline testing in an independent pilot cohort of six junior middle-distance runners.

The pilot cohort completed the same field procedures on two occasions separated by seven days. Preliminary Pearson test-retest correlations were:

- 300 m running: $r = 0.91$
- 1-minute bounding: $r = 0.88$
- 10-second pull-ups: $r = 0.86$

These coefficients indicated satisfactory preliminary measurement consistency. However, because the pilot sample was small and Pearson correlation evaluates association rather than measurement agreement, these estimates should be considered preliminary reliability evidence rather than definitive validation coefficients.

2.6. Training Program

The intervention was implemented over eight weeks during the specific preparation phase from October 18 to December 13, 2025.

The program consisted of three supervised sessions per week (Monday, Wednesday, and Friday), yielding 24 scheduled sessions per athlete and 240 planned session-exposures across the cohort.

Each session lasted approximately 75–90 minutes and generally included:

- approximately 20 minutes of dynamic warm-up and mobility;
- approximately 45–60 minutes of main training content; and
- approximately 10 minutes of low-intensity recovery running or cool-down.

The intervention was classified as a HIIT-based multicomponent program rather than a pure HIIT protocol.[8] High-intensity running intervals constituted the principal high-intensity stimulus, while event-specific pacing, longer aerobic intervals, hill running, horizontal bounding, recovery running, and supplementary bodyweight conditioning were integrated according to the intended training objectives.

The program was organized into two four-week blocks. Weeks 1–3 and Weeks 5–7 emphasized progressive loading, Week 4 incorporated reduced loading, and Week 8 incorporated a tapering structure before post-intervention testing[9].

2.6.1. Individualized MAS Prescription

Running intensities were prescribed individually according to each athlete's baseline MAS obtained from the VAMEVAL test[10]. For example, an athlete with a baseline MAS of 17.85 km/h (4.96 m/s) would perform a 100 m repetition at approximately:

- 105% MAS = 5.21 m/s, corresponding to approximately 19.2 s per 100 m;
- 110% MAS = 5.45 m/s, corresponding to approximately 18.3 s per 100 m.

These calculations were used to individualize interval velocity rather than prescribing identical running times to all athletes[11].

2.6.2. Short MAS-Based Intervals

Short running intervals were generally performed at 105–110% of baseline MAS.

A work-to-recovery ratio of approximately 1:1 was used for the principal short intervals, with approximately 20 seconds of walking recovery for 100 m repetitions and 2–3 minutes between sets.

2.6.3. Event-Specific Pacing Intervals

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[8] - Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle, Op Cit, p.313–338.

[9] - Spilsbury, K. L., Fudge, B. W., Nimmo, M. A., & Faulkner, S. H. (2021). Lower volume throughout the taper and higher intensity in the last interval session prior to a 1500 m time trial improves performance. *Applied Physiology, Nutrition, and Metabolism*, 46(11), 1345–1353. https://cdnsciencepub.com/doi/10.1139/apnm-2021-0103

[10] - Cazorla, G.Op Cit.

[11] - Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle, Op Cit, p.313–338.

The target 300 m training split was calculated from each athlete's seasonal best performance using the following linear-equivalent formula:

Target 300 m Split=(300Event Distance)×Seasonal Best TimeTarget\ 300\,m\ Split = \left(\frac{300}{Event\ Distance}\right) \times Seasonal\ Best\ Time

This calculation represented **a** linear-equivalent 300 m split rather than an assumption that running performance scales linearly across all middle-distance events. The resulting value was therefore used as a practical pacing reference within the training program and was not interpreted as a direct physiological equivalence.

Athletes competing primarily in the 800 m or 1500 m event used the distance corresponding to their principal competitive specialization.

Recovery between 300 m repetitions ranged from approximately 3 to 4 minutes of passive walking depending on the training week.

2.6.4. Longer Aerobic Intervals

Longer intervals of 800–1000 m were prescribed at approximately 90–95% of MAS.

This intensity was selected as a submaximal aerobic training prescription intended to provide sustained aerobic running exposure while remaining below MAS. Because no laboratory-derived physiological threshold was measured, the prescription was not interpreted as equivalent to an individualized lactate or ventilatory threshold.

2.6.5. Recovery Running

During reduced-load periods, continuous running at approximately 70–75% MAS was used to provide lower-intensity aerobic work within the overall training structure.

2.6.6. Hill Running and Bounding

Hill repetitions and horizontal bounding were incorporated as complementary neuromuscular and lower-limb loading modalities.

Bounding consisted primarily of 3–4 sets of 20–30 m horizontal bounds during selected sessions.

Hill repetitions were generally performed over approximately 60 m with walk-back recovery.

These modalities were considered complementary components of the multicomponent program and were not treated as isolated experimental interventions.

2.6.7. Supplementary Bodyweight Conditioning

Pull-ups were included approximately twice per week according to the following progression:

- Weeks 1–3: 3 × 4–5 repetitions
- Week 4: 2 × 3 repetitions
- Weeks 5–7: 3 × 6–7 repetitions
- Week 8: 2 × 4 repetitions

The inclusion of pull-ups was intended to provide supplementary general physical conditioning rather than directly target running-specific endurance.

Table 2. Operational 8-Week Training Program

Week	**Day**	**Primary Modality**	**Work Protocol**	**Prescribed Intensity**	**Recovery**
W1	Mon	Short MAS intervals	2 × 6 × 100 m	105% MAS	~1:1 work; 2 min between sets
W1	Wed	Speed endurance	4 × 300 m	Linear-equivalent event pace	4 min passive walking
W1	Fri	Long aerobic + hills	3 × 800 m + 4 × 60 m hills	90% MAS / high effort	2.5 min after 800 m; walk-back on hills
W2	Mon	Short MAS intervals	2 × 7 × 100 m	105% MAS	~1:1 work; 2 min between sets
W2	Wed	Speed endurance	5 × 300 m	Linear-equivalent event pace	3.5–4 min passive recovery
W2	Fri	Long aerobic + hills	3 × 1000 m + 5 × 60 m hills	90% MAS / high effort	3 min after 1000 m; walk-back on hills
W3	Mon	Short MAS intervals	2 × 8 × 100 m	105–110% MAS	~1:1 work; 2–3 min between sets
W3	Wed	Speed endurance	5 × 300 m	Linear-equivalent event pace	3.5 min recovery
W3	Fri	Long aerobic + hills	3 × 1000 m + 6 × 60 m hills	90–95% MAS / high effort	3 min after 1000 m; walk-back on hills
W4	Mon	Reduced-load intervals	1 × 6 × 100 m	100% MAS	1:1.5 work; ~30 s
W4	Wed	Technical pacing	3 × 300 m	85–90% of linear-equivalent pace	5 min light active recovery
W4	Fri	Aerobic continuity	25 min continuous running	70–75% MAS	Continuous
W5	Mon	Short MAS intervals	2 × 7 × 100 m	110% MAS	~1:1 work; 2 min between sets

W5	Wed	Speed endurance	5 × 300 m	Linear-equivalent event pace	3.5 min recovery
W5	Fri	Mixed intervals	3 sets of variable short bouts	100–110% MAS	2 min between sets
W6	Mon	Short MAS intervals	2 × 8 × 100 m	110% MAS	~1:1 work; 2 min between sets
W6	Wed	Speed endurance	6 × 300 m	Linear-equivalent event pace	3 min recovery
W6	Fri	Mixed intervals	3 sets of variable short bouts	100–110% MAS	2 min between sets
W7	Mon	Peak MAS intervals	2 × 8 × 100 m	110% MAS	~1:1 work; 2 min between sets
W7	Wed	Speed endurance	6 × 300 m	Linear-equivalent event pace	3 min recovery
W7	Fri	Power / bounding	5 × 100 m hills + bounding	High / explosive effort	Full walk-back recovery
W8	Mon	Taper	1 × 6 × 100 m	100–105% MAS	1:1.5 work; ~30 s
W8	Wed	Race-pace tune-up	3 × 300 m	Linear-equivalent event pace	4 min full recovery
W8	Fri	Neuromuscular preparation	4 × 60 m accelerations	Near-maximal	3 min walking recovery

2.6.8. Training Adherence

Across the cohort, 234 of 240 originally scheduled session-exposures were completed as scheduled, corresponding to an initial on-schedule completion rate of 97.5%.

Six originally scheduled session-exposures were missed during the intervention. All six missed exposures were subsequently completed through protocol-approved make-up sessions that replicated the corresponding training stimulus within the same training week or the nearest feasible recovery window.

Thus, all 240 planned training exposures were ultimately completed before post-intervention testing.

No musculoskeletal injuries were reported during the intervention period.

2.7. Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics, Version 26.0.

The primary analysis evaluated paired pre-to-post differences for each outcome. Difference scores were calculated as:

Di=Xpost,i−Xpre,iD_i = X_{post,i} - X_{pre,i}

Normality was assessed using the Shapiro-Wilk test applied to the paired difference scores. No statistically significant departure from normality was detected ($p > 0.05$).

Because three primary outcome comparisons were evaluated, two-tailed paired-samples t-tests were conducted using a Bonferroni-adjusted family-wise significance threshold:

αadjusted=0.053=0.0167\alpha_{adjusted}=\frac{0.05}{3}=0.0167

Given the small sample size, exact Wilcoxon signed-rank tests were additionally performed as non-parametric sensitivity analyses. Because all 10 participants demonstrated non-zero changes in the same direction for each outcome, exact two-sided Wilcoxon probabilities were reported.

Relative percentage change was calculated as:

Δ%=Post−PrePre×100\Delta\%=\frac{Post-Pre}{Pre}\times100

For each outcome, the standardized paired effect size was calculated as Cohen's dzd_z:

dz=D¯SDDd_z=\frac{\bar D}{SD_D}

where D¯\bar D represents the mean paired difference and SDDSD_D represents the standard deviation of the paired difference scores.

The standard deviation of the paired differences was calculated as:

SDD=∑i=1n(Di−D¯)2n−1SD_D= \sqrt{ \frac{ \sum_{i=1}^{n}(D_i-\bar D)^2 }{ n-1 }}

Ninety-five percent confidence intervals for the mean paired differences were calculated as:

95% CI=D¯±t0.975,9(SDDn)95\%\,CI= \bar D\pm t_{0.975,9} \left(\frac{SD_D}{\sqrt n}\right)

with t0.975,9=2.262t_{0.975,9}=2.262.

The statistical analysis was designed to determine whether systematic pre-to-post changes occurred within the cohort. It was not intended to establish causal efficacy relative to an untreated control group.

3. Results

3.1. Individual Participant Data

All 10 participants demonstrated improvement in each of the three assessed performance outcomes.

Table 3. Individual Pre-Test, Post-Test, and Difference Scores (N = 10)

Athlete	300 m Pre (s)	300 m Post (s)	Δ300 m (s)	Bounding Pre	Bounding Post	ΔBounding	Pull-up Pre	Pull-up Post	ΔPull-up
A01	48.20	46.10	−2.10	63.00	66.00	+3.00	6.00	8.00	+2.00
A02	49.60	47.40	−2.20	61.00	64.00	+3.00	7.00	8.00	+1.00
A03	48.90	46.80	−2.10	62.00	65.00	+3.00	6.00	7.00	+1.00
A04	47.80	45.90	−1.90	64.00	68.00	+4.00	8.00	9.00	+1.00
A05	48.40	46.30	−2.10	62.00	65.00	+3.00	7.00	9.00	+2.00
A06	47.50	45.60	−1.90	63.00	67.00	+4.00	8.00	9.00	+1.00
A07	49.10	47.00	−2.10	61.50	64.50	+3.00	5.50	7.50	+2.00
A08	49.40	47.10	−2.30	62.00	64.50	+2.50	6.50	8.00	+1.50
A09	48.00	45.80	−2.20	63.50	66.50	+3.00	7.00	8.50	+1.50
A10	48.10	46.10	−2.00	61.20	64.50	+3.30	6.00	7.80	+1.80
Mean	**48.50**	**46.41**	**−2.09**	**62.32**	**65.50**	**+3.18**	**6.70**	**8.18**	**+1.48**

The individual data demonstrated a consistent direction of change. All 10 athletes reduced their 300 m running time, while all 10 increased their bounding and pull-up performance.

The difference-score standard deviations calculated directly from the individual participant data were approximately 0.129 s for the 300 m test, 0.470 repetitions for bounding, and 0.452 repetitions for pull-ups. These values were used for the paired-samples calculations.

3.2. Inferential Analysis

Table 4. Pre-to-Post Inferential Statistical Comparisons (N = 10)

Performance Indicator	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Difference	SD of Mean Difference	Relative Change	*t*(9)	*p*	Exact Wilcoxon *p*†	Cohen's *dz*	95% CI of Difference
300 m running (s)	48.50 ± 0.71	46.41 ± 0.62	−2.09 s	0.129 s	−4.31 %	−51.37	<0.001	0.00195	−16.24	−2.18 to −2.00

1-min bounding (reps)	62.32 ± 1.01	65.50 ± 1.31	+3.18 reps	0.473 reps	+5.10%	21.42	<0.001	0.00195	6.77	2.84 to 3.52
10-s pull-up (reps)	6.70 ± 0.86	8.18 ± 0.68	+1.48 reps	0.452 reps	+22.09%	10.36	<0.001	0.00195	3.28	1.16 to 1.80

† *Exact two-sided Wilcoxon signed-rank probability. All 10 paired differences were non-zero and had the same direction.*

3.2.1. 300 m Running Performance

Mean 300 m running time decreased from 48.50 ± 0.71 s at pre-test to 46.41 ± 0.62 s at post-test.

The mean paired reduction was 2.09 s, corresponding to a relative improvement of 4.31%. The 95% CI for the mean difference ranged from −2.18 to −2.00 s.

The paired-samples t-test demonstrated a statistically significant pre-to-post difference:

$t(9) = -51.37$, $p < 0.001$.

The result remained statistically significant under the Bonferroni-adjusted threshold of $\alpha = 0.0167$.

The exact two-sided Wilcoxon signed-rank test was also statistically significant:

$p = 0.00195$.

The standardized paired effect size was **$d_z = -16.24$**.

This extremely large standardized value reflects the very small variability of the individual changes rather than providing evidence that a similarly large population-level effect would necessarily occur in a broader sample.

3.2.2. One-Minute Alternating Bounding

Mean bounding performance increased from 62.32 ± 1.01 repetitions to 65.50 ± 1.31 repetitions.

The mean gain was 3.18 repetitions, corresponding to a relative increase of 5.10%. The 95% CI ranged from 2.84 to 3.52 repetitions.

The paired-samples t-test demonstrated a statistically significant increase:

$t(9) = 21.42$, $p < 0.001$.

The difference remained significant under the Bonferroni-adjusted threshold.

The exact two-sided Wilcoxon signed-rank test was also statistically significant:

p = 0.00195.

The standardized paired effect size was **d_z = 6.77**.

As with the other outcomes, the magnitude of this standardized effect should be interpreted in the context of the small sample and low dispersion of individual change scores.

3.2.3. Ten-Second Pull-Up Performance

Mean pull-up performance increased from 6.70 ± 0.86 repetitions to 8.18 ± 0.68 repetitions.

The mean gain was 1.48 repetitions, corresponding to a relative increase of 22.09%. The 95% CI ranged from 1.16 to 1.80 repetitions.

The paired-samples t-test demonstrated a statistically significant increase:

t(9) = 10.36, p < 0.001.

The result remained significant under the Bonferroni-adjusted threshold.

The exact two-sided Wilcoxon signed-rank test was also statistically significant:

p = 0.00195.

The standardized paired effect size was **d_z = 3.28**.

Because pull-ups were incorporated directly into the training program, the observed improvement may reflect both physical adaptation and exercise-specific familiarization or practice.

4. Discussion

The present study examined pre-to-post changes in three field-based performance outcomes following an 8-week structured HIIT-based multicomponent training program in 10 junior middle-distance runners. Significant improvements were observed across all three outcomes. However, because the study used a single-group pretest-posttest design without an independent control group, the findings should be interpreted as changes observed during the intervention period rather than as definitive evidence that the training program, or HIIT specifically, caused the improvements.

4.1. High-Intensity Running Performance and Speed Endurance

The 300 m running time decreased by 2.09 s, corresponding to a 4.31% improvement.The 300 m test was selected as an operational indicator because it requires the athlete to sustain high running velocity while tolerating substantial metabolic and neuromuscular stress. Performance over this distance nevertheless reflects multiple interacting capacities, including acceleration, pacing, anaerobic contribution, neuromuscular coordination, and fatigue resistance.[12]

The training program included repeated 100 m intervals at 105–110% MAS, event-specific 300 m repetitions, longer aerobic intervals, and hill running. Exposure to these combined stimuli may plausibly have supported improved high-intensity running performance. Potential explanations include improved neuromuscular coordination, running economy, tolerance of high-intensity exercise, pacing familiarity, and the ability to maintain effective movement under fatigue[13]. These mechanisms, however, were not directly measured. They should therefore be regarded as plausible interpretations rather than demonstrated physiological adaptations.

The findings are broadly compatible with previous literature indicating that interval-based training can improve selected endurance and physical-performance outcomes in young and trained athletes. Matzka et al. (2025) reported favorable effects of HIIT on selected endurance-related outcomes among youth athletes, while Zhang et al. (2026) reported favorable effects of HIIT-based interventions on several physical-fitness outcomes in trained adolescent athletes. However, the populations and interventions in these studies were heterogeneous, and direct equivalence with the present field-based program cannot be assumed.

4.2. Lower-Limb Repeated Performance

The 1-minute alternating single-leg bounding test improved by 3.18 repetitions, corresponding to a 5.10% increase. The program incorporated horizontal bounding and hill running in addition to high-intensity running. These activities exposed the lower limbs to repeated force-production and coordination demands and may plausibly have contributed to improved repeated movement performance.

However, the present design cannot determine which training component contributed to the observed improvement. The change may reflect the combined influence of running intervals, hill work, bounding, general conditioning, and repeated exposure to the testing movement. Because the bounding test was study-specific, the result should be interpreted as a functional field indicator rather than as a definitive standardized measure of muscular endurance, reactive strength, or running-specific endurance.

4.3. Supplementary Upper-Body Performance

Pull-up performance increased from 6.70 to 8.18 repetitions, representing a 22.09% relative increase. This was the largest relative change among the three outcomes. However, interpretation

[12] - Al-Ashmali, A. A. N. (2021). A proposed training program using a combination of specific exercises and high-intensity interval training and their effects on developing speed endurance and performance among elite middle-distance runners in Dhamar Governorate. *Al-Bayda University Journal*, 3(3), p.1–18.

[13] - Leonardo Trevisol Possamai et al., 2024.Op Cit, p .785–792.

of this finding differs substantially from that of the 300 m test because pull-ups were directly included in the training program. The improvement may therefore partly reflect exercise-specific practice, motor learning, coordination, and local muscular adaptation. Familiarization with the testing procedure may also have contributed. Accordingly, the pull-up outcome should be interpreted as a supplementary physical-performance measure and not as direct evidence of improved middle-distance running-specific endurance.

4.4. Training Individualization and MAS-Based Prescription

An important characteristic of the intervention was individualization of running intensity using baseline MAS. Rather than assigning identical running velocities to all athletes, MAS-based prescriptions allowed the principal high-intensity interval loads to be adjusted according to individual aerobic running capacity[14].

Event-specific pacing provided an additional practical layer of individualization. The 300 m repetitions were prescribed using a linear-equivalent split derived from each athlete's seasonal best in the primary event. This approach may improve the consistency of relative training exposure within a small training group. Nevertheless, the present study did not compare MAS-based individualization with a non-individualized program. Consequently, the superiority of individualized prescription cannot be established from the current data.

4.5. Statistical Interpretation and Effect Sizes

All three outcomes produced statistically significant pre-to-post differences, and all remained significant after Bonferroni adjustment. The exact two-sided Wilcoxon signed-rank tests also yielded statistically significant results ($p = 0.00195$ for each outcome). The standardized paired effect sizes were very large:

- 300 m: $d_z = -16.24$
- Bounding: $d_z = 6.77$
- Pull-ups: $d_z = 3.28$

These values require careful interpretation. Cohen's dzd_z is calculated using the standard deviation of the paired difference scores. In the present dataset, individual changes were highly homogeneous. For the 300 m test, individual changes ranged from −1.90 to −2.30 s, producing a difference-score SD of approximately 0.129 s. The resulting very large standardized value therefore primarily reflects the consistency of change within this small cohort rather than providing a population-level estimate of the causal effect of the intervention. The effect sizes should consequently be interpreted alongside the raw mean differences and confidence intervals and should not be presented as evidence that comparable effects would necessarily occur in larger or independent samples.

4.6. Relationship to Previous Research

[14] - Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle, Op Cit, p.313–338.

The overall direction of the findings is compatible with previous evidence indicating that interval-based training can improve selected physical-performance outcomes among young and trained athletes. Engel et al. (2018), in a systematic review and meta-analysis of 24 studies, demonstrated that HIIT promotes substantial gains in aerobic endurance and sprint capacity among youth athletes while remaining a time-efficient modality[15]. Matzka et al. (2025), in a meta-analysis of 28 studies involving 707 youth athletes, similarly reported favorable effects of HIIT on selected endurance-related outcomes[16]. Zhang et al. (2026) further corroborated these findings by demonstrating favorable effects of HIIT-based interventions on several physical-fitness components in trained adolescent athletes.

Possamai et al. (2024) provide additional evidence from a randomized controlled trial involving well-trained runners, in which HIIT and resistance-oriented training were examined in relation to physiological and performance outcomes[17]. Spilsbury et al. (2021) also reported that manipulation of training volume and interval intensity during tapering influenced subsequent 1500 m performance in highly trained middle-distance runners[18].

Nevertheless, the present study differs from these investigations in sample characteristics, intervention structure, field setting, outcome measures, and, most importantly, study design. Some of the cited studies used controlled experimental designs, whereas the present investigation used a pre-experimental single-group design. The previous literature should therefore be considered contextual support for the plausibility of the observed changes rather than direct evidence establishing the efficacy of the specific program implemented in Djelfa.

5. Limitations

Several limitations should be considered when interpreting the findings.

5.1. Absence of a Control Group

The principal limitation is the absence of an independent control group. Without a comparator group, the observed changes cannot be separated confidently from maturation, seasonal progression, previous training, external physical activity, testing familiarization, competitive participation, or other time-related influences.

5.2. Small and Homogeneous Sample

[15] - Florian Azad Engel, Alexander Ackermann, Hamdi Chtourou, and Billy Sperlich, "High-Intensity Interval Training Performed by Young Athletes: A Systematic Review and Meta-Analysis," *Frontiers in Physiology* 9 (2018): 1012, https://doi.org/10.3389/fphys.2018.01012.

[16] - Manuel Matzka, Mascha Lenk, Benedikt Meixner, and Billy Sperlich, "Meta-analysis of High-Intensity Interval Training and Alternative Modalities for Enhancing Aerobic and Anaerobic Endurance in Young Athletes," *Physiological Reports* 13, no. 19 (2025): e70598, https://doi.org/10.14814/phy2.70598.

[17] - Leonardo Trevisol Possamai et al., 2024.Op Cit, p785.–792.

[18] - K. L. Spilsbury, B. W. Fudge, M. A. Nimmo, and S. H. Faulkner, Op Cit, p.1345–1353.

The final sample consisted of only 10 male athletes from a single regional setting. Generalization to female athletes, other age groups, recreational runners, or athletes from other training environments is therefore limited.

5.3. Multicomponent Intervention

The intervention incorporated several training modalities. Consequently, the independent contribution of HIIT, event-specific pacing, hill running, bounding, aerobic running, or bodyweight conditioning cannot be isolated.

The study therefore evaluates the response associated with a structured HIIT-based multicomponent program rather than the isolated effect of HIIT.

5.4. Field-Based Outcomes

The study relied on field-based performance measures rather than direct laboratory assessments. VO_2max, blood lactate kinetics, running economy, respiratory thresholds, muscle oxygenation, and neuromuscular activation were not measured.

5.5. Study-Specific Bounding and Pull-Up Protocols

The bounding and 10-second pull-up protocols were operational field measures. Although preliminary test-retest correlations were satisfactory, the study did not establish comprehensive criterion or construct validity against laboratory or established reference measures.

5.6. Environmental and Altitude Considerations

The study was conducted at approximately 1,140 m above sea level under semi-arid environmental conditions. These characteristics may influence training responses and limit direct extrapolation to athletes training under substantially different environmental conditions.

5.7. Seasonal and External Influences

The athletes remained competitive club athletes throughout the study period and may have experienced additional sporting, academic, nutritional, recovery, or lifestyle influences that could not be completely standardized.

6. Conclusion

An 8-week structured HIIT-based multicomponent training program was associated with significant pre-to-post improvements in selected field indicators of physical performance among 10 competitive junior middle-distance runners in Djelfa Province, Algeria. Following the training period, mean 300 m running time decreased by 2.09 s (4.31%), while 1-minute alternating bounding performance increased by 3.18 repetitions (5.10%) and supplementary 10-second pull-up performance increased by 1.48 repetitions (22.09%). All three outcomes demonstrated statistically significant pre-to-post changes, and the findings remained significant after Bonferroni

adjustment. Exact two-sided Wilcoxon signed-rank analyses provided consistent non-parametric evidence.

The findings indicate that participation in the structured program was associated with substantial improvements in selected field performance indicators during the 8-week study period. However, the results should not be interpreted as evidence that HIIT alone caused the observed changes. The single-group pretest-posttest design, small sample, multicomponent intervention, and absence of a control group prevent definitive causal inference. The unusually large standardized paired effect sizes should also be interpreted cautiously because they were strongly influenced by the low variability of individual change scores. Future research should employ larger randomized controlled samples, include female athletes and different competitive levels, and incorporate direct physiological measurements and actual 800 m and 1500 m race performance.

6.1. General findings

The findings of the study can be summarized in the following key points:

1. L'étude a mis en évidence une amélioration générale et cohérente des indicateurs de performance mesurés sur le terrain chez les coureurs après leur participation au programme d'entraînement.
2. Les résultats montrent que le programme d'entraînement multicomposant fondé sur le HIIT est applicable sur le terrain chez les coureurs juniors de demi-fond dans un contexte de clubs sportifs.
3. Les résultats soulignent l'importance d'intégrer le travail à haute intensité, l'allure spécifique à la course, le travail aérobie, la course en côte ainsi que les exercices neuromusculaires et physiques dans la préparation de cette catégorie de coureurs.
4. Compte tenu de l'absence de groupe témoin, de la faible taille de l'échantillon et de la nature multicomposante du programme, les résultats soutiennent l'existence d'une association entre la participation au programme et les améliorations observées, sans permettre d'établir une relation causale directe ni de généraliser les résultats à une population plus large.

6.2. Practical Implications for Coaches

The findings provide several practical considerations for coaches working with junior middle-distance runners:

1. Running intensity can be individualized according to an objective field estimate of MAS rather than assigning identical workloads to all athletes.
2. Training sessions can distinguish between short high-intensity MAS intervals, event-specific pacing repetitions, longer aerobic intervals, and lower-intensity recovery work.
3. Hill running and horizontal bounding can be integrated as complementary neuromuscular components within a broader middle-distance preparation program.
4. Supplementary bodyweight exercises such as pull-ups can be used to develop general physical performance, but improvements in such exercises should not be interpreted as direct evidence of improved running-specific endurance.

5. Progressive loading followed by a reduced-load phase and tapering period provides a practical framework for organizing an 8-week preparation cycle.

6.2. Recommendations

Based on the findings of the present study, the following recommendations are proposed for coaches and practitioners working with junior middle-distance runners:

1. Prescribe interval running velocities relative to individual maximal aerobic speed (MAS) rather than assigning uniform split times across the squad.
2. Systematically integrate short MAS intervals, event-specific race-pace work, hill sprints, and planned recovery/tapering phases.
3. Implement plyometric bounding exercises as a supplementary neuromuscular component within middle-distance training, while monitoring individual tolerance and training load.
4. Treat upper-body calisthenic exercises as supplementary general conditioning that does not directly indicate running-specific endurance.

6.3. Future Research Directions

Based on the findings and limitations of the present study, several directions for future research are suggested:

1. Compare the multicomponent program against a control group to isolate intervention effects from biological maturation and seasonal trends.
2. Include female athletes, different age divisions, and varied competitive performance levels.
3. Combine field tests with direct physiological profiling (VO_2max, blood lactate kinetics, running economy) and official 800 m / 1500 m race times.
4. Contrast isolated training modalities (MAS-based HIIT vs. race-pace running vs. bounding) to determine their relative contributions to athletic preparation.

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