

Both groups trained three times per week under supervision by certified strength and conditioning coaches. Testing occurred one week before (baseline) and one week after the intervention.

2.2 Participants

Forty adolescent athletes (22 males, 18 females) aged 14-17 years were recruited from local sports academies (soccer, basketball, athletics, and rugby). Inclusion criteria were:

Minimum 2 years of organized sports participation.

Currently training at least 3 times per week.

Medical clearance for high-intensity exercise.

Exclusion criteria included: history of cardiovascular or respiratory disease, musculoskeletal injuries within the past 6 months, or participation in structured HIIT programs in the previous 3 months.

Parental consent and athlete assent were obtained in compliance with ethical guidelines for research involving minors.

2.3 Training interventions

2.3.1 HIIT training program

The HIIT protocol was designed to progressively increase intensity and volume over 8 weeks as shown in Table 1. Training sessions lasted 25-30 minutes, excluding warm-up and cool-down.

Table 1 Training Regime for 8 weeks

Week	Frequency	Work Interval	Reps	Recovery	Mode
1-2	3×/week	15 sec @ 90% HRmax	10	45 sec jog	Running-based sprints
3-4	3×/week	20 sec @ 90-92% HRmax	12	40 sec jog	Running-based sprints
5-6	3×/week	25 sec @ 92-94% HRmax	14	35 sec jog	Shuttle sprints+hill sprints
7-8	3×/week	30 sec @ 94-95% HRmax	16	30 sec jog	Sprint repeats+resisted runs

Warm-Up (10 minutes): Dynamic stretches, mobility drills, and light jogging.

Main Set: Short, maximal or near-maximal efforts (85-95% HRmax) interspersed with active recovery periods.

Cool-Down (5 minutes): Static stretching and light jogging.

Intensity monitored using heart rate monitors and rate of perceived exertion (RPE≥8/10).

Progressive overload (more resistance, shorter rest periods, and longer work) increased the weekly load.

Average session duration: ~25-30 minutes (excluding warm-up/cool-down).

2.3.2 Control training program

The control group performed traditional training consisting of moderate-intensity continuous running (65-75% HRmax) and short sprint efforts (6-8×60 m), reflecting commonly used conditioning practices in adolescent athletes (Seiler, 2010; Buchheit and Laursen, 2013). Although the total session duration was longer than that of the HIIT group, this difference reflects the time-efficient nature of HIIT protocols (Tomlin and Wenger, 2001; Gibala et al., 2012). Sessions lasted (40-50 minutes) This discrepancy in training volume should be considered when interpreting the results.

Warm-Up (10 minutes): Drills for dynamic mobility.

Main Set: Endurance: Continuous running at 65-75% HRmax for 20-25 minutes.

Speed: 6-8×60-meter sprints with full 2-3 min passive recovery.

Cool-Down (5 minutes): Light jogging and static stretching.