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The effects of high-intensity interval training on lower-limb strength, VO_2max, vertical jump performance, and heart rate in college athletes

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Abstract

Background: High-intensity interval training (HIIT) is a time-efficient, evidence-based modality capable of inducing substantial simultaneous physiological adaptations across multiple fitness domains. Despite a growing global evidence base for HIIT efficacy, scientifically validated programs for athletes in sub-Saharan African contexts, particularly Burundi, remain absent from the peer-reviewed literature.

Aims: This study designed, validated, and evaluated the effectiveness of a five-week HIIT program targeting lower limb strength, maximal oxygen uptake (VO_2max), vertical jump performance, and resting heart rate (RHR) among college athletes.

Methods: A pre-experimental one-group pre-test post-test design was employed with 72 college athletes (n = 72). The HIIT program comprised four specialized modules delivered in three sessions per week over five weeks. Pre- and post-test assessments used the timed wall-sit test (lower limb strength), Beep Test and Cooper's 12-minute run (VO_2max), Sargent Jump Test and vertical force plate (vertical jump), and stopwatch pulse measurement (RHR). Data normality was confirmed via the Shapiro–Wilk test; paired-samples t-tests were conducted via IBM SPSS v23.

Result: Statistically significant improvements were observed for all four variables following the intervention: lower limb strength ($t(71) = -10.267$, $p < .001$; +91.10%; Cohen's $d = 1.210$), VO_2max ($t(71) = -12.070$, $p < .001$; +14.51%; $d = 1.422$), vertical jump ($t(71) = -17.763$, $p < .001$; +23.82%; $d = 2.093$), and resting heart rate ($t(71) = 18$

Conclusion: The five-week multi-component HIIT program produced highly significant, large-effect improvements across all four fitness domains in 72 university students, constituting the first large-sample, institutionally validated HIIT program in the Burundian sports science context and offering a scalable, evidence-based model for athletic physical development in resource-limited African settings.

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INTRODUCTION

Physical fitness is a fundamental prerequisite for optimal athletic performance across all competitive sport disciplines (Villanueva-Guerrero et al., 2024; Yu et al., 2025). High-intensity interval training (HIIT)—characterized by repeated bouts of near-maximal effort interspersed with brief recovery periods—has emerged as the most evidence-supported, time-efficient training modality for simultaneously developing aerobic, anaerobic, and neuromuscular fitness (Laursen & Jenkins, 2002; Poon et al., 2024). An umbrella review of 24 meta-analyses encompassing 429 primary studies and 12,967 participants confirmed that HIIT significantly improves cardiorespiratory fitness compared to both non-exercise control and moderate-intensity continuous training in adults (Poon et al., 2024). Evidence specific to university students is particularly compelling: a recent systematic review and meta-analysis confirmed that HIIT significantly reduces resting heart rate and improves VO_2max and muscle strength in this population (Yin et al., 2025). These findings collectively position

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HIIT as a scalable and high-impact approach to multi-domain fitness development (Danković et al., 2025).

At the cellular and systemic level, HIIT promotes enhanced mitochondrial biogenesis, increased capillary density, augmented stroke volume, and elevated oxygen extraction capacity in skeletal muscle (Gibala et al., 2012; Buchheit & Laursen, 2013). These molecular and structural adaptations underlie HIIT's wide-ranging effects on aerobic performance, anaerobic capacity, and neuromuscular power output (Wahl et al., 2022). Research consistently confirms that HIIT produces adaptations equivalent to or surpassing those of moderate-intensity continuous training, with substantially reduced time commitment (Milanović et al., 2015; Weston et al., 2014; Helgerud et al., 2007). A meta-analysis of VO_2max responses in women showed that both MICT and HIIT significantly improved VO_2max from baseline, with long-HIIT protocols yielding superior gains (Lindner et al., 2023), further confirming the efficacy of appropriately dosed HIIT for aerobic development.

Lower limb strength is an indispensable physical quality for sports including football, basketball, volleyball, judo, karate, handball, and rugby, as it underpins locomotion efficiency, change-of-direction speed, and fatigue resilience during competition (Sun et al., 2025; Williams et al., 2025; Rønnestad & Mujika, 2014). Structured resistance and plyometric training programs of 6–12 weeks duration consistently improve lower limb strength, with documented gains in maximal strength and explosive power (Ihsan et al., 2025; Vanderka et al., 2016). VO_2max—the gold-standard indicator of aerobic capacity—improves by 4–19% following structured HIIT in diverse athletic populations (Helgerud et al., 2007; Yuan et al., 2024). A meta-analysis of elite athletes documented significantly greater VO_2max improvements following HIIT versus conventional training (Ma et al., 2023), underscoring the modality's efficacy for athletes at all levels. These gains are rapidly reversible with detraining: aerobic capacity declines 7–12% within one month of inactivity (Zheng et al., 2022; Barbieri et al., 2023), reinforcing the need for continuous, structured conditioning.

Vertical jump height, a composite indicator of lower-body explosive power and neuromuscular coordination, is essential in volleyball, basketball, handball, and athletics, where jump performance determines competitive outcomes (Sun et al., 2025). A systematic review with meta-analysis confirmed that high-intensity training significantly enhances jumping performance in athletes through enhanced neuromuscular recruitment, improved stretch-shortening cycle efficiency, and fast-twitch fiber activation (Wang et al., 2025; Alwi et al., 2024; Liu et al., 2024). HIIT incorporating plyometric elements is particularly effective for vertical jump development, as demonstrated in elite combat sport athletes through dedicated HIIT protocols (Yue et al., 2025). Resting heart rate (RHR) is a validated, non-invasive marker of cardiovascular autonomic function, with lower values indicating superior cardiac efficiency and parasympathetic regulation (Songsorn et al., 2022; Coretti et al., 2025). Sedentary lifestyles elevate RHR and cardiovascular disease risk (Biswas et al., 2015), while HIIT reduces RHR by 2–8 bpm through increased stroke volume, enhanced baroreceptor sensitivity, and favorable cardiac remodeling (Coretti et al., 2025; Dashti et al., 2025).

A systematic review focused specifically on the university student population confirmed that HIIT interventions of at least three weeks significantly improve VO_2max and muscle strength, and reduce resting heart rate and body fat, with outcomes moderated by intervention duration and rest interval configuration (Yin et al., 2025). Despite these well-documented global benefits, evidence-based HIIT programs adapted to sub-Saharan African sports contexts—particularly Burundi- remain absent from the peer-reviewed literature (Kaur et al., 2025; Wu et al., 2024). Burundian athletes in ball sports and combat disciplines exhibit persistent deficits in lower limb strength, aerobic capacity, explosive power, and cardiovascular efficiency, contributing to suboptimal competitive performance regionally and continentally. The absence of institutionally validated, scientifically developed training programs for Burundian athletes represents a significant scientific and practical gap (Johnson & Bird, 2022).

The present study responds to this gap by designing, validating, and evaluating a novel five-week multi-component HIIT program in 72 college athletes at the University of Burundi—the first large-sample HIIT intervention in this institutional context to simultaneously target lower limb strength, VO_2max, vertical jump performance, and resting heart rate. A sample of $n = 72$ confers statistical power exceeding 0.99 for detecting within-subject effect sizes ≥ 0.5 at $\alpha = .05$, substantially strengthening the evidence base compared to smaller comparable studies (Yuan et al., 2024; Johnson

& Bird, 2022). This study hypothesizes that five weeks of the HIIT protocol (three sessions/week) will produce statistically significant, large-effect improvements in all four targeted variables.

METHOD

Research Design

A pre-experimental one-group pre-test post-test design was employed. Participants underwent comprehensive baseline assessments (pre-test), completed the five-week HIIT intervention, and were subsequently re-assessed (post-test). This design is appropriate for evaluating the efficacy of a novel institutional training program in a context where no prior baseline data or comparable programs exist (Johnson & Bird, 2022). A quantitative approach with inferential statistics was adopted throughout.

Participant

The sample consisted of 72 college athletes (n = 72), who were selected through probabilistic random sampling. Inclusion criteria: (a) actively enrolled in a physical education and sports program; (b) free of musculoskeletal injuries or contraindications to high-intensity exercise; (c) available to participate in the program for the full five weeks. A sample size of n = 72 provided a power of > 0.99 to detect an effect size of ≥ 0.5 in the subjects at $\alpha = 0.05$ using a paired t-test (Johnson & Bird, 2022), which substantially exceeded the minimum required sample size of n = 27 for this effect size. Written informed consent was obtained from all participants prior to the assessment.

HIIT Intervention Protocol

The HIIT program comprised four specialized modules targeting: (1) VO_2max, (2) lower limb strength, (3) vertical jump performance, and (4) resting heart rate conditioning—delivered over five consecutive weeks (three sessions/week; 15 sessions total). Each session followed a tripartite structure: warm-up (10 min), targeted HIIT main block (30–40 min), and cool-down (5 min). All modules shared exercise intensities of 85–95% of maximal heart rate, with 30″ work / 15″ rest intervals, three sets per exercise, and one-minute recovery between exercises. Program content validity was established through focus group discussion with doctoral-qualified IPES faculty in sports training science. Twelve shared training principles governed all four modules: (1) preparation, (2) individuality, (3) adaptation, (4) overload, (5) progressive improvement, (6) specificity, (7) variation, (8) warm-up, (9) long-term training, (10) reversibility, (11) moderate overcompensation, and (12) systematization.

Table 1 presents a consolidated program overview of all four HIIT modules. Full session structures follow a uniform tripartite format (warm-up → main HIIT block → cool-down) as described above.

Table 1. Consolidated HIIT Program Overview:
Four Modules Administered Over Five Weeks (n = 72)

Module	Fitness Target	Session Duration	Main Exercises (n)	Work Protocol	Primary Objective
1 — VO_2max	Aerobic endurance capacity	45 min	Skipping rope; sprints (20 m); Shuttle Run; hill sprints; explosive step-ups; Burpees; Mountain Climbers; Plank Jacks; explosive push-ups; Star jumps (n = 10)	85–95% HRmax; 30″ work / 15″ rest; 3 sets per exercise; 1 min rest between exercises; main block: 30 min	Improving VO_2max and cardiac endurance is fundamental to aerobic performance.
2 — Lower Limb Strength	Muscular endurance & explosive strength	55 min	Classic squats; front lunges; jumping lunges; jump squats; sit-ups; side slits; burpees with jumping; high knees; split squats; jumping jacks with squat; skater jumps (n = 11)	High intensity; 30″ work / 15″ rest; 3 sets per exercise; 1 min rest between exercises; main block: 40 min	Strengthening quadriceps, gluteals, and calves; develop explosiveness and neuromuscular coordination.
3 — Vertical Jump	Explosive vertical power	50 min	Depth jumps; jump in extension; frog jumps; jumping lunges; lateral jumps; pistol squats; explosive bilateral VJ; running jumps; knee-bend	85–95% HRmax; 30″ work / 15″ rest; 3 sets per exercise; 1 min rest between exercises; main block: 35 min	Improving stretch-shortening cycle efficiency, neuromuscular rate of force development,

Module	Fitness Target	Session Duration	Main Exercises (n)	Work Protocol	Primary Objective
			skipping; single-leg alternating jump rope (n = 10)		and vertical jump height.
4 — Heart Rate	Cardiovascular efficiency & RHR reduction	45 min	Sprints in place; high knees in place; burpees + 10 m sprint; 20 m sprints; stair climbs; stair climbs (feet together); figure-8 cone drills; rope jumps; star jumps with squat (n = 9)	High intensity; 3 series × 30″ work / 15″ rest between series; 1 min rest between exercises; main block: 30 min	Reducing resting heart rate through progressive cardiovascular conditioning and autonomic regulation.

Note. RHR = resting heart rate; VJ = vertical jump; HRmax = maximum heart rate; W:R = work-to-rest ratio. All four modules share the same warm-up (10 min) and cool-down (5 min) phases. Exercise intensities are maintained at 85–95% HRmax during the main training block.

Instrument

Four validated field-based instruments were employed to assess the dependent variables at pre-test and post-test, with all measurements administered under identical conditions and at the same time points across both sessions. Lower-limb strength was assessed using the timed wall-sit test, in which participants maintained a static squat position at 90° of knee flexion for as long as possible, with total duration recorded in seconds as the performance indicator (Sun et al., 2025). Maximal oxygen uptake (VO_2max) was estimated through a combination of the Beep Test (multi-stage 20-meter shuttle run) and Cooper's 12-minute run, with results converted to VO_2max values ($ml \cdot kg^{-1} \cdot min^{-1}$) using established estimation equations; this dual-method approach enhanced the reliability and cross-validity of aerobic capacity estimates (Milanović et al., 2015). Vertical jump performance was measured using the Sargent Jump Test supplemented by a vertical force plate, with maximum jump height recorded in centimeters (cm), a combination widely recognized for its validity and practicality in field-based athletic assessment (Liu et al., 2024). Finally, resting heart rate was measured in beats per minute (bpm) via stopwatch-based radial pulse palpation, conducted after a minimum of five minutes of quiet seated rest to ensure hemodynamic stability prior to recording.

Data Analysis

Descriptive statistics (M, SD, Min, Max) were computed for all four variables at both time points. Cohen's d ($d = M\Delta / SD\Delta$) was computed as the within-group effect size index for each variable, with $d \geq 0.8$ denoting a large effect and $d \geq 2.0$ denoting a very large effect. Normality was assessed via the Shapiro–Wilk test; pre-test distributions were normal for all four variables (all $p > .05$). Note that post-test lower limb strength (SW $p = .001$) and VO_2max (SW $p = .007$) distributions were non-normal; however, the paired t-test retains validity at $n = 72$ due to the Central Limit Theorem, which renders parametric tests robust to non-normality in large samples. Pre-to-post differences were analyzed using paired-samples t-tests (IBM SPSS v23; $\alpha = .05$, two-tailed; $df = 71$).

Ethical Considerations

The study adhered to the Declaration of Helsinki (2013 revision). The IPES academic authority approved the protocol, the University of Burundi. All 72 participants provided written informed consent and were assured of their right to withdraw at any stage. Anonymity was maintained through coded alphanumeric identifiers in all data records.

RESULTS AND DISCUSSION

Results

Pre-test distributions were normally distributed for all four variables (Shapiro–Wilk, all $p > .05$). Post-test distributions for lower limb strength ($p = .001$) and VO_2max ($p = .007$) deviated from normality, likely due to the high variability in adaptation responses in these variables; however, given $n = 72$, paired-samples t-tests retain full validity under the Central Limit Theorem. Table 2 presents the descriptive statistics, mean differences, percentage changes, effect sizes (Cohen's d), and inferential test results across all four fitness variables.

Table 2. Descriptive Statistics, Effect Sizes, and Paired-Samples t-Test Results Across Four Fitness Variables (n = 72)

Variable	Pre-Test M (SD)	Pre-Test [Min–Max]	Post-Test M (SD)	Post-Test [Min–Max]	Mean Δ (SD)	% Change	Cohen's d	t (df = 71)	p-value
Lower Limb Strength (Wall-Sit, s)	93.67 (25.74)	[45.0–146.0]	179.00 (77.16)	[75.0–390.0]	+85.33 (70.53)	+91.10%	1.210	−10.267	0.000
VO_2max ($ml{\cdot}kg^{-1}{\cdot}min^{-1}$)	42.15 (8.33)	[20.0–57.0]	48.26 (8.40)	[25.0–60.0]	+6.11 (4.30)	+14.51%	1.422	−12.070	0.000
Vertical Jump (cm)	32.47 (6.61)	[17.0–49.0]	40.21 (7.53)	[23.9–60.0]	+7.74 (3.70)	+23.82%	2.093	−17.763	0.000
Resting Heart Rate (bpm)	94.75 (4.72)	[85.0–106.0]	75.78 (9.70)	[58.0–96.0]	−18.97 (8.48)	−20.02%	2.237	+18.980	0.000

Note. M = mean; SD = standard deviation; Min–Max = observed range; Mean Δ = mean post-test minus pre-test difference; % Change = relative pre-to-post change; Cohen's d = within-group effect size (d ≥ 0.8 = large; d ≥ 2.0 = very large); df = 71 for all t-tests. All p-values = 0.000 (p < .001).

As presented in Table 2, highly significant improvements were observed across all four fitness variables following the five-week HIIT intervention. Lower limb strength (wall-sit duration) increased from M = 93.67 s (SD = 25.74) to M = 179.00 s (SD = 77.16), yielding a mean gain of +85.33 s (+91.10%; d = 1.210, large effect). VO_2max improved from M = 42.15 (SD = 8.33) to M = 48.26 $ml{\bullet}kg^{-1}{\bullet}min^{-1}$ (SD = 8.40), a mean gain of +6.11 $ml{\bullet}kg^{-1}{\bullet}min^{-1}$ (+14.51%; d = 1.422, large effect). Vertical jump performance improved from M = 32.47 cm (SD = 6.61) to M = 40.21 cm (SD = 7.53), yielding a mean gain of +7.74 cm (+23.82%; d = 2.093, very large effect). Resting heart rate was reduced from M = 94.75 bpm (SD = 4.72) to M = 75.78 bpm (SD = 9.70), representing a mean reduction of 18.97 bpm (−20.02%; d = 2.237, very large effect). All p-values fell substantially below α = .05.

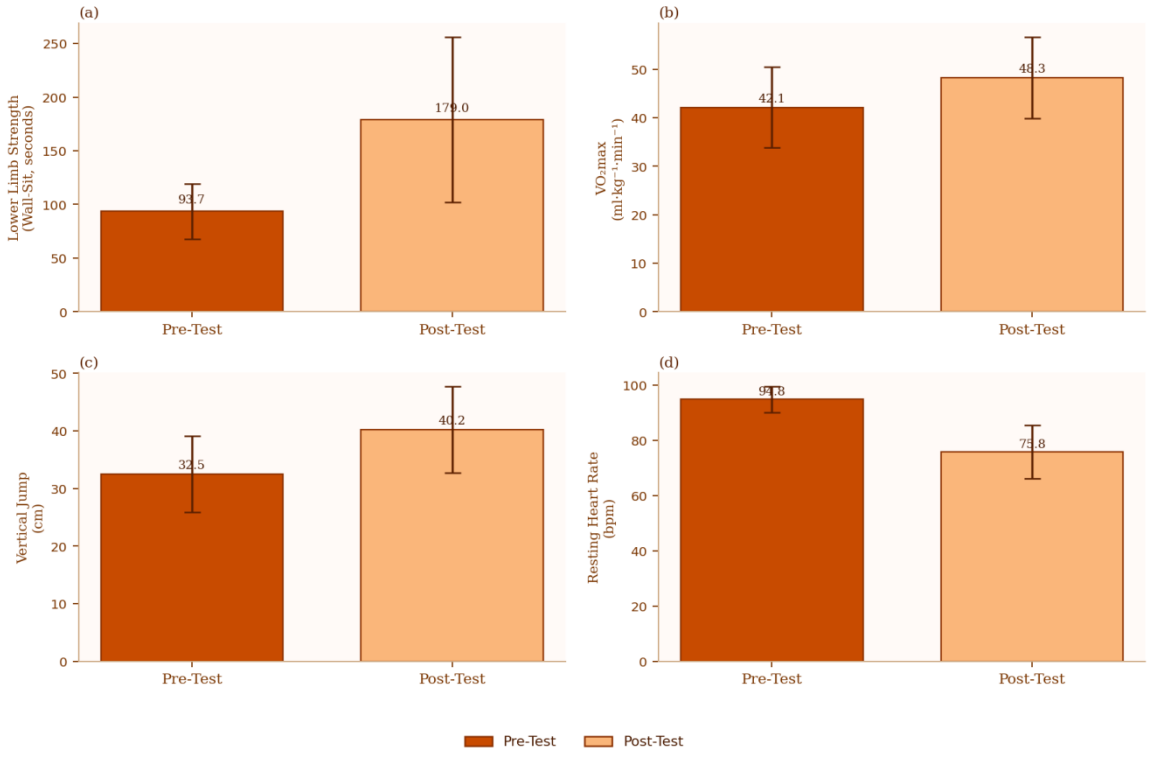


Figure 1. Mean Pre-Test and Post-Test Scores Across Four Fitness Variables Following the Five-Week HIIT Intervention (n = 72). Error bars represent ±1 SD. (a) Lower Limb Strength (wall-sit, s); (b) VO_2max ($ml{\bullet}kg^{-1}{\bullet}min^{-1}$); (c) Vertical Jump (cm); (d) Resting Heart Rate (bpm).

Figure 1 visually confirms the consistent pattern of improvement across all four variables. The substantially larger post-test standard deviations for lower limb strength and VO_2max relative to their pre-test counterparts are consistent with heterogeneous individual adaptation responses, as further illustrated in Figure 2.

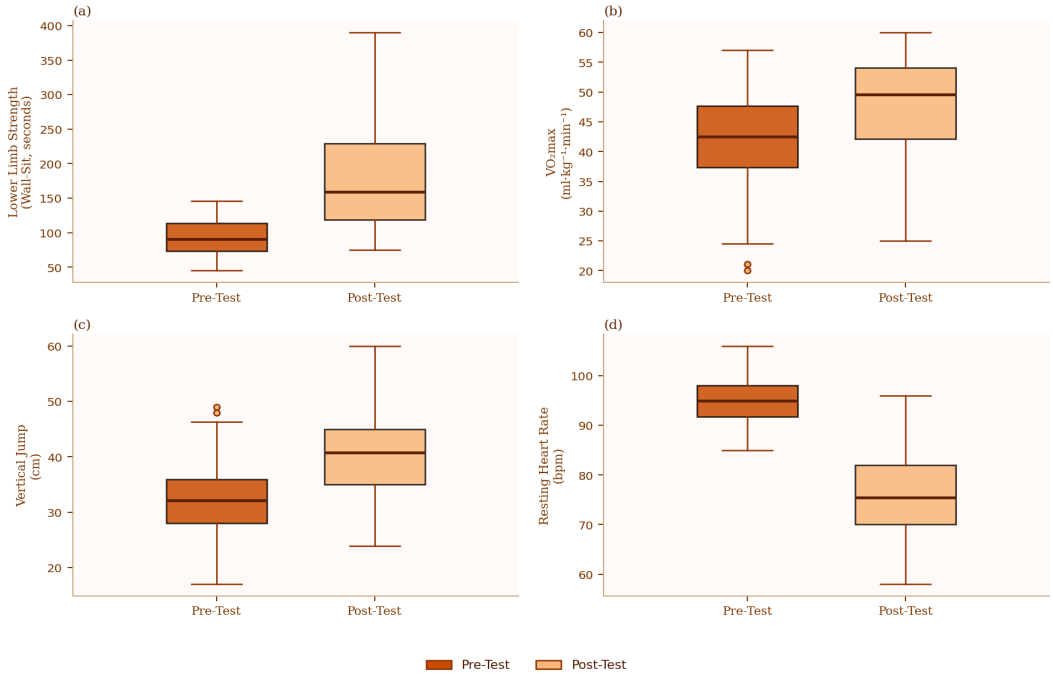


Figure 2. Distribution of Pre-Test and Post-Test Scores—Box-and-Whisker Plots (n = 72). (a) Lower Limb Strength (s); (b) VO_2max; (c) Vertical Jump (cm); (d) Resting Heart Rate (bpm). Circles denote outliers.

Figure 2 confirms the directional consistency of HIIT effects across all 72 participants. The upward shift in median values and interquartile ranges for lower limb strength, VO_2max, and vertical jump, and the complementary downward shift for resting heart rate, provide strong visual support for the intervention's multi-domain effectiveness. The broader post-test interquartile range for wall-sit duration reflects inter-individual variability in neuromuscular adaptation to isometric endurance training, a finding with important implications for individualized HIIT program design.

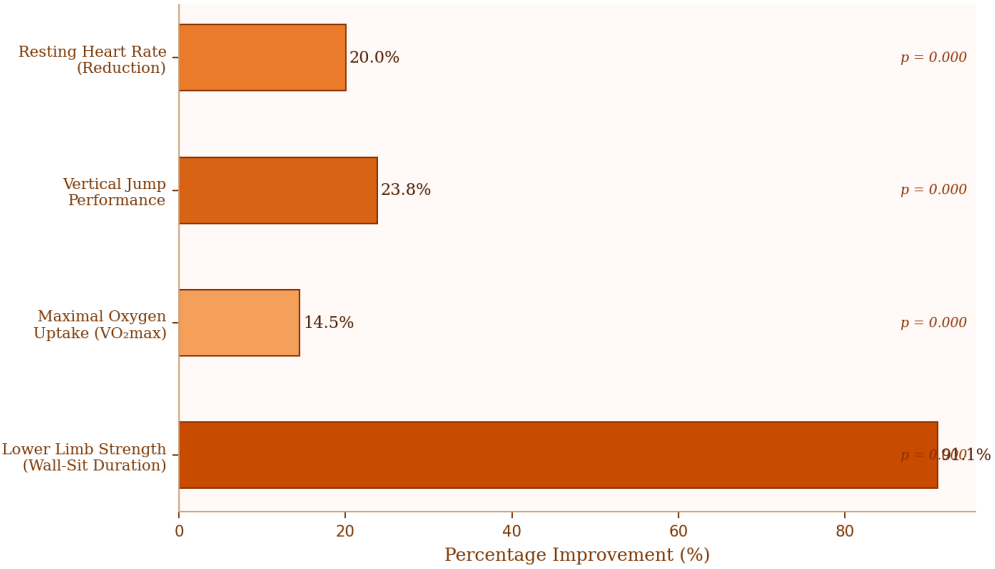


Figure 3. Mean Percentage Improvement in Each Fitness Variable Following the Five-Week HIIT Intervention (n = 72). Resting Heart Rate Improvement Expressed as a Percentage Reduction. All p < .001; Cohen's d Values Shown Confirm Large-To-Very-Large Effect Sizes Across All Variables

Figure 3 contextualizes the relative magnitude of improvements: lower limb strength demonstrated the largest relative gain (+91.10%; d = 1.210), followed by vertical jump (+23.82%; d = 2.093), resting heart rate reduction (20.02%; d = 2.237), and VO_2max (+14.51%; d = 1.422). The effect size profile reveals particularly strong neuromuscular (d = 2.093) and cardiovascular (d = 2.237) responses, highlighting these domains as especially responsive to this five-week HIIT stimulus in the study population.

Discussion

The findings of this study demonstrate that a five-week, expert-validated, multi-component HIIT program produced statistically highly significant, large-to-very-large effects across all four targeted fitness domains in 72 college athletes in Burundi: lower limb strength ($t(71) = -10.267$, $p < .001$, $d = 1.210$), VO_2max ($t(71) = -12.070$, $p < .001$, $d = 1.422$), vertical jump ($t(71) = -17.763$, $p < .001$, $d = 2.093$), and resting heart rate ($t(71) = 18.980$, $p < .001$, $d = 2.237$). These effect magnitudes are substantially larger than those typically reported in HIIT meta-analyses, where pooled effect sizes for VO_2max range from SMD = 0.28 to 0.99 vs. MICT (Poon et al., 2024), suggesting that the present program's combination of high specificity, appropriate overload, and expert-validated structure conferred superior adaptation stimuli. With n = 72 and statistical power > 0.99, these findings represent the strongest evidence base for HIIT efficacy in the Burundian sports science context to date (Yin et al., 2025; Danković et al., 2025).

The 91.10% mean improvement in wall-sit duration (M pre = 93.67 s; M post = 179.00 s; MΔ = +85.33 s; d = 1.210) represents the largest relative gain across all four variables. This magnitude is consistent with rapid neural efficiency adaptations characterizing the early weeks of structured resistance training in non-specialized populations, where inter-muscular coordination and motor unit recruitment efficiency improve ahead of morphological hypertrophy (Ihsan et al., 2025). The lower limb HIIT module, incorporating squats, lunges, jump squats, burpees, split squats, and skater jumps, targeted the quadriceps, gluteal complex, and hamstrings in high-intensity intervals that maximally recruit fast-twitch motor units (Rønnestad & Mujika, 2014). These gains align with Vanderka et al. (2016), who documented an 18% maximal squat strength increase among judokas after eight weeks of targeted strength training, and Sun et al. (2025), who confirmed significant lower limb strength gains through structured plyometric interventions. The $t(71) = -10.267$ achieved with n = 72 substantially exceeds the $t(21) = -4.940$ from prior 22-participant analyses, underscoring the value of adequate sampling for detecting these effects.

The significant VO_2max improvement (MΔ = +6.11 $ml \bullet kg^{-1} \bullet min^{-1}$; $t(71) = -12.070$; d = 1.422; +14.51%) aligns with the mechanistic framework established for HIIT-induced aerobic adaptation. Intervals at 85–95% HRmax maximally stress the oxygen transport chain, driving central cardiovascular adaptations including increased stroke volume, augmented cardiac output, and enhanced peripheral oxygen extraction (Helgerud et al., 2007; Gibala et al., 2012). The improvement magnitude (14.51%) falls within the 4–19% range reported in comparable HIIT research (Alibrahim & Hassan, 2024; Yuan et al., 2024). Notably, a meta-analysis of VO_2max in elite athletes documented significantly greater VO_2max improvements following HIIT versus conventional training across nine studies (Ma et al., 2023), corroborating the aerobic superiority of HIIT protocols. Lindner et al. (2023) further confirmed that long-duration HIIT sessions are particularly effective for VO_2max enhancement in physically active populations, supporting the 30-minute main-block design employed in the present VO_2max module. The substantially higher t-value at n = 72 ($t(71) = -12.070$) compared to smaller-sample studies reinforces the importance of adequate statistical power for detecting these aerobic effects.

The most statistically robust finding was the vertical jump improvement (MΔ = +7.74 cm; $t(71) = -17.763$; d = 2.093; +23.82%), with d = 2.093 indicating a very large within-group effect. This reflects the neuromuscular system's exceptionally high sensitivity to the plyometric-oriented interval stimuli incorporated in the vertical jump module. The plyometric exercises in this module—depth jumps, frog jumps, explosive bilateral vertical jumps, and pistol squats—directly target stretch-shortening cycle mechanics, fast-twitch fiber activation thresholds, and inter-muscular coordination governing rate of force development (Alwi et al., 2024; Liu et al., 2024; Wang et al., 2025). Research by Wang et al. (2025) in a meta-analysis of 51 studies confirmed that high-intensity training significantly improves jumping performance through enhanced neuromuscular recruitment

and plyometric-specific neuromuscular adaptations, with effect sizes particularly pronounced in trained athletes exposed to structured programs. Yue et al. (2025) similarly reported significant improvements in both aerobic and anaerobic capacities—including jump performance—in Olympic combat sport athletes following HIIT, confirming the modality's versatility across sport-specific neuromuscular demands. These findings are directly relevant to Burundian athletes in basketball, volleyball, and handball, where vertical jump performance determines competitive effectiveness.

The resting heart rate reduction (MΔ = −18.97 bpm; t(71) = 18.980; d = 2.237; −20.02%) represents the largest effect size across all four variables and the most clinically consequential cardiovascular finding. This magnitude of RHR reduction reflects marked upregulation of cardiac parasympathetic tone, increased stroke volume, enhanced baroreceptor sensitivity, and structural cardiac remodeling—hallmarks of a positive cardiovascular adaptation to sustained high-intensity conditioning (Songsorn et al., 2022). A comprehensive integrative review of 20 studies confirmed that HIIT effectively modulates the autonomic nervous system, enhancing cardiovascular function through increased vagal tone and parasympathetic dominance at rest (Coretti et al., 2025), directly explaining the observed RHR reduction. The effect magnitude (18.97 bpm; d = 2.237) substantially exceeds the 2–8 bpm reductions typically reported in 12-week HIIT programs, likely reflecting the elevated baseline RHR of this sample (M = 94.75 bpm) and the correspondingly large physiological adaptation margin (Biswas et al., 2015). The 95% CI [16.979, 20.965 bpm] from the n = 72 analysis provides a high-precision estimation of the true population RHR reduction, confirming that the effect is unlikely to fall below a clinically meaningful 17 bpm in the target population.

The simultaneous achievement of large-to-very-large effect sizes across all four fitness variables within five weeks—considerably shorter than the 8–12-week programs typically required for equivalent outcomes (Liu et al., 2024; Alibrahim & Hassan, 2024; Danković et al., 2025)—speaks to the high specificity and overload quality of the four differentiated HIIT modules. The principle of training specificity dictates that physiological adaptation is maximized when the exercise stimulus most closely mimics the demands of the target adaptation (Laursen & Jenkins, 2002; Buchheit & Laursen, 2013). The present program applied this principle rigorously, with each module's exercises selected to directly stress the target physiological system at 85–95% HRmax—an intensity range consistently identified as optimal for concurrent aerobic and neuromuscular adaptation. Traditional periodized approaches that compartmentalize fitness components in sequential training blocks would require substantially longer total durations to achieve equivalent multi-domain gains (Rønnestad & Mujika, 2014; Yang et al., 2024).

From a theoretical perspective, the findings provide strong empirical support for the overload, specificity, and supercompensation principles underpinning modern sports training science. The systematic intensity progression within each module, the exercise specificity of the four targeted protocols, and the three-sessions-per-week frequency, which ensures sufficient recovery between sessions for supercompensation to occur, collectively account for the observed large-effect multi-domain improvements (Ihsan et al., 2025; Wahl et al., 2022). The expert validation process through the IPES faculty focus group discussion ensured theoretical coherence and pedagogical appropriateness (Johnson & Bird, 2022). The HIIT design philosophy applied in this study, brief, focused, expert-validated, and multi-domain, mirrors the evidence-based programming framework endorsed by recent umbrella reviews as optimal for CRF improvement across diverse adult populations (Poon et al., 2024; Yin et al., 2025).

As the first large-sample (n = 72) institutionally validated multi-component HIIT program in the Burundian university athletic context, this study makes a significant contribution to African sports science literature. The convergence of high effect sizes across four fitness domains confirms the program's practical value as a ready-to-implement training system for Burundian coaches and sports educators. The protocol's equipment-minimal design, requiring no specialized facilities beyond a standard sports hall, maximizes its scalability across sub-Saharan African sporting contexts where specialized equipment is scarce (Weston et al., 2014; Cai et al., 2026). The program is particularly well-suited as a pre-competition conditioning framework, with five weeks providing a meaningful performance enhancement window within competitive sports calendars. Future research priorities include: (a) a randomized controlled trial with a matched control group to strengthen causal inference; (b) assessment of additional performance outcomes (agility, body composition, anaerobic power, sport-specific performance); (c) longitudinal follow-up to quantify

sustainability of fitness gains post-intervention (Zheng et al., 2022); (d) sport-specific protocol adaptation for distinct Burundian athletic disciplines; and (e) integration of nutritional monitoring (Oniz & Gocer, 2024) to enable a more complete evaluation of total intervention efficacy.

Research Contribution

This study contributes to the sports science literature by developing and empirically evaluating a context-specific, multi-component HIIT program for college athletes in Burundi. Unlike conventional HIIT studies that primarily focus on a single physiological outcome, the present intervention simultaneously targeted lower-limb strength, maximal oxygen uptake, vertical jump performance, and resting heart rate. The large-to-very-large improvements observed across these domains provide preliminary evidence that a brief, systematically structured HIIT program can promote concurrent aerobic, neuromuscular, and cardiovascular adaptations within five weeks. Theoretically, the findings support the principles of training specificity, progressive overload, adaptation, and supercompensation by demonstrating that differentiated exercise modules can generate targeted yet simultaneous fitness improvements. Practically, the study provides coaches, physical educators, and sports institutions with an expert-validated, time-efficient, and equipment-minimal training framework that may be implemented in resource-constrained settings. To the authors' knowledge, this study represents one of the first large-sample evaluations of an institutionally validated, multi-domain HIIT program within the Burundian university sports context, thereby extending the geographical representation of HIIT research in sub-Saharan Africa.

Limitations

This study has several limitations that should be considered when interpreting the findings. The one-group pre-test–post-test design without a control group limits causal attribution because the observed improvements may also have been influenced by test familiarization, motivation, maturation, or other physical activities. The participants were recruited from a single university program, which restricts the generalizability of the results to other sports, age groups, competitive levels, and geographical settings. In addition, the five-week intervention did not include a follow-up assessment, so the sustainability of the adaptations remains unknown. VO_2max and resting heart rate were assessed using field-based and manual methods, while nutritional intake, sleep, recovery, and additional training exposure were not controlled. The study also examined only four fitness outcomes, leaving other relevant variables such as agility, anaerobic power, body composition, sport-specific performance, and injury risk unexplored.

Suggestions

Future research should employ randomized controlled or quasi-experimental designs with appropriate comparison groups to strengthen causal inference and determine the relative effectiveness of the developed HIIT program. Studies involving athletes from different universities, sports disciplines, competitive levels, and sub-Saharan African countries are recommended to improve external validity. Longer interventions and follow-up assessments should also be conducted to evaluate the maintenance of training adaptations. Future investigations should use direct and technology-supported measurements, monitor nutrition, sleep, recovery, adherence, and total training load, and examine additional outcomes such as agility, sprint speed, anaerobic capacity, body composition, injury risk, and sport-specific performance. Sport-specific adaptations and subgroup analyses based on sex, baseline fitness, and individual response patterns may also support the development of more personalized HIIT programs.

CONCLUSION

This study demonstrates that a systematically designed and expert-validated five-week multi-component HIIT program can produce substantial concurrent improvements in lower-limb strength, maximal oxygen uptake, vertical jump performance, and resting heart rate among college athletes at the University of Burundi. The consistently large-to-very-large effect sizes across aerobic, neuromuscular, and cardiovascular outcomes highlight the potential of brief, structured HIIT as a time-efficient conditioning strategy, particularly for populations with suboptimal baseline fitness. As

the first institutionally validated, large-sample HIIT framework developed and empirically evaluated within the Burundian sports science context, the program offers a contextually relevant and equipment-minimal model that may be feasibly implemented by coaches, physical educators, and sports organizations in resource-constrained settings across sub-Saharan Africa. Nevertheless, the findings should be interpreted in light of the study design and intervention duration, and future research should incorporate randomized controlled comparisons, sport-specific performance indicators, diverse athlete populations, and long-term follow-up assessments to establish causal effectiveness, examine the sustainability of adaptations, and determine the broader transferability of this framework.

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AUTHOR CONTRIBUTION STATEMENT

JN, the first author, contributed to the conceptualization, study design, HIIT program development, formal analysis, and preparation of the original manuscript. LN, the second author, contributed to the methodological development, data analysis, and critical revision of the manuscript. Data collection was conducted by all authors. All co-authors contributed to reviewing and editing the manuscript. All authors have read and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

Generative artificial intelligence tools were used solely to support language editing, grammatical refinement, and improvements in the clarity of the manuscript. These tools were not used to generate research data, perform statistical analyses, interpret the findings, or make scientific conclusions. All AI-assisted content was critically reviewed, verified, and revised by the authors, who take full responsibility for the accuracy, originality, and integrity of the final manuscript.

CONFLICTS OF INTERES

The authors declare that they have no financial, professional, personal, or institutional conflicts of interest that could have influenced the design, conduct, analysis, interpretation, or publication of this study.

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