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Combined Effects of Aerobic Interval Training and Nutrient-Fortified Fermented Rice Porridge on Endurance Performance, Cardiopulmonary Fitness, and Recovery Kinetics in Collegiate Distance Runners: A Four-Arm Randomised Controlled Trial

Soundharya Periyapandi[1], Saravana Prabha Rajendran[1], Karthikeyan Nagaraj[2], Satheeshkumar Palanivel[3], Pavithra Selvaraj[4], Erianti[5], Josyula Tejaswi[6]

AFFILIATIONS

[1]Avinashilingam Institute for Home Science and Higher Education for Women, Department of Physical Education, Coimbatore, Tamil Nadu, India
[2]Ramakrishna Mission Vivekananda Educational and Research Institute, Faculty of General & Adapted Physical Education and Yoga, Coimbatore, Tamil Nadu, India
[3]Takshashila University, Department of Physical Education, Tindivanam, Villupuram District, Tamil Nadu, India
[4]REVA University, Sports and Exercise Science, Bengaluru, Karnataka, India
[5]Universitas Negeri Padang, Faculty of Sports Sciences, Sumatera Barat, Indonesia
[6]Symbiosis International (Deemed University), Symbiosis School of Sports Sciences, Maharashtra, India

CORRESPONDENCE

Erianti, Universitas Negeri Padang, Faculty of Sports Sciences, Jl. Prof. Dr. Hamka Kec. Padang Utara, Kota Padang, Sumatera Barat 25173, Indonesia, *erianti@fik.unp.ac.id*

Abstract

To examine the combined effects of aerobic interval training (AIT) and nutrient-fortified fermented rice porridge (NFFRP) on endurance performance, cardiopulmonary fitness, and recovery kinetics in collegiate distance runners. A 12-week, single-centre, four-arm parallel-group randomised controlled trial enrolled 90 collegiate runners (18–25 years) allocated equally to: (1) AIT + NFFRP, (2) AIT + placebo, (3) conventional training (CT) + NFFRP, or (4) CT + placebo. AIT comprised three weekly sessions of 4×4-min intervals at 90–95% HRmax. NFFRP (300 mL twice daily on training days) provided carbohydrate, protein, iron, and probiotics; the placebo contained approximately 120 kcal versus 295 kcal in NFFRP. The primary outcome was half-marathon completion time. Secondary outcomes included VO_2max, peripheral oxygen saturation (SpO_2), one-minute recovery heart rate, blood lactate, heart rate variability (RMSSD), rating of perceived exertion, haemoglobin, and running economy. All 90 participants completed the trial. The AIT + NFFRP group showed the greatest improvement in half-marathon time (−14.6%; mean −16.8 min; 95% CI −19.3 to −14.3; $p<0.001$), VO_2max (+15.8%), blood lactate reduction (−31.7%), and RMSSD improvement (+34.9%). Significant group-by-time interactions were observed across all outcomes ($p<0.001$; $\eta^2p = 0.34–0.46$). Combining AIT with NFFRP was associated with greater improvements in endurance performance and recovery than either intervention alone. However, NFFRP's caloric and nutritional composition differed substantially from the placebo, and the specific contributions of fermentation, probiotics, or iron cannot be isolated from the current design.

Keywords: *faerobic interval training, fermented rice, endurance running, VO_2max, recovery kinetics, half marathon, collegiate athletes, sports nutrition, probiotics*

Introduction

Endurance running performance is governed by three interconnected physiological determinants: maximal oxygen uptake (VO_2max), lactate threshold, and running economy (Bassett, 2000a). In collegiate athletes near a physiological plateau, multifactorial interventions that target these determinants simultaneously have clear practical relevance (Seiler, 2010a). The half marathon demands sustained aerobic output across 90–120 minutes, requiring not only a high VO_2max but also the capacity to resist progressive lactate accumulation alongside efficient inter-session recovery (Barnett, 2006; Faude et al., 2009).

Aerobic interval training (AIT) characterised by repeated work bouts at or near VO_2max intensity is among the most evidence-based strategies for improving cardiorespiratory fitness. Protocols of 4×4 min at ~90–95% HRmax produce substantial VO_2max gains in trained individuals (Helgerud et al., 2007), and meta-analyses confirm superiority over moderate-intensity continuous training across multiple populations, though outcomes vary by training status and protocol design (Milanović et al., 2015). Mechanistically, high-intensity intervals drive central adaptations (left ventricular remodelling, plasma volume expansion) alongside peripheral adaptations (mitochondrial enzyme activity, capillarisation), thereby enhancing oxygen delivery and utilisation (Buchheit & Laursen, 2013a).

Nutrition is a complementary component of training adaptation. Fermented cereal substrates reduce phytic acid, improving non-haem iron bioavailability (Hotz & Gibson, 2007a), and emerging evidence links gut microbiota modulation to endurance performance through metabolic and immunological pathways (Mohr et al., 2020). However, isolating fermentation-specific effects from concurrent effects of carbohydrate, protein, and micronutrient delivery is methodologically challenging and has rarely been achieved in controlled trials.

No study to date has examined the combined effects of structured AIT and a culturally relevant, food-based nutritional intervention such as NFFRP on endurance performance in collegiate runners. NFFRP is low-cost and ecologically valid within South Asian dietary contexts, yet its ergogenic potential in a controlled training framework remains unexplored. Accordingly, this four-arm RCT evaluated the independent and combined effects of AIT and NFFRP on half-marathon performance, cardiopulmonary fitness, and recovery kinetics. It was hypothesised that the combined intervention would produce greater improvements than either component alone, with no specific mechanistic assumptions made regarding the source of any additive effect.

Materials and methods

Study Design

This was a 12-week, single-centre, four-arm, parallel-group superiority RCT with a 2 (within: pre/post) × 4 (between: AIT+NFFRP, AIT+Placebo, CT+NFFRP, CT+Placebo) mixed design. Ethical approval was obtained from the Institutional Human Ethics Committee of Avinashilingam Institution (Ref: IHEC/23-24/Phy/Edu-02; approval: AUM/IHEC/23-24/Phy/Edu/FHP-02). All participants provided written informed consent. The study conformed to the Declaration of Helsinki (2013) and reporting follows CONSORT 2010 guidelines (Schulz et al., 2010). No interim analyses were conducted.

Participants

Eligible participants were collegiate distance runners aged 18–25 years with ≥2 years of competitive training and a documented baseline half-marathon time of 100–135 minutes. Inclusion required current university enrolment and GPS-confirmed training load ≥35 km/week. Key exclusion criteria included musculoskeletal injury within 8 weeks, cardiovascular or haematological disorder, concurrent probiotic or iron supplementation within 4 weeks, gastrointestinal disease, and antibiotic use within 6 weeks. Sample size calculation (G*Power 3.1; 80% power, α=0.05, Cohen's d ≈0.94 from pilot data) required 20 participants per group; with 10% dropout allowance, 90 were enrolled.

Randomisation and blinding

The allocation sequence was computer-generated (block size 8, stratified by sex and baseline half-marathon time: <110 min vs. ≥110 min) and concealed in sequentially numbered opaque envelopes managed by an independent coordinator. Given that training group blinding was not feasible, the trial was assessor- and statistician-blinded. NFFRP and placebo were identical in volume (300 mL) and appearance but differed in caloric content (NFFRP ≈295 kcal; placebo ≈120 kcal per serving); participants were informed only that they were receiving a rice-based beverage. This caloric and compositional difference was an unavoidable consequence of maintaining the nutritional integrity of the active intervention. Blinding effectiveness was evaluated post-intervention using a validated blinding index (Bang et al., 2004); the blinding index for outcome assessors was 0.08 (95% CI −0.04 to 0.20), indicating adequate assessor blinding. Participant-level expectancy effects cannot, however, be excluded given the perceptible differences between beverages, and this is acknowledged as a limitation.

Interventions

All four groups maintained their standard university training programme (~42–43 km/week). AIT groups replaced three weekly sessions with structured interval sessions (4×4-min work bouts at 90–95% HRmax, 3-min active recovery at 60–70% HRmax, ~5.8 km per session); a fifth interval was added at weeks 5 and 9. CT groups performed steady-state running at 65–75% HRmax in place of those sessions. Total weekly mileage and average training intensity were recorded via GPS watch (Garmin Forerunner 45S) for all participants; group-level mileage and intensity distributions across the 12 weeks are summarised in Supplementary Table S1. Mean weekly mileage did not differ substantially between AIT and CT groups (difference <3 km/week), confirming that performance differences cannot be attributed to greater total training volume.

NFFRP was prepared from parboiled rice fermented for 16–18 hours at 30°C with Lactobacillus plantarum NCIMB 8826 and L. acidophilus NCFM, fortified with ferrous gluconate. Each 300 mL serving provided 58.4 g carbohydrate (glycaemic index 52±4), 12.6 g protein, 6.2 mg elemental iron, and 1.2×10^9 CFU. The placebo (plain boiled rice water; ~120 kcal) was matched only for volume and appearance. NFFRP was provided twice daily on training days and once daily on rest days. Full specifications are in Table 1.

Table 1. Intervention protocol specifications

Parameter	AIT Protocol	NFFRP Composition
Structure	4×4 min at 90–95% HRmax; 3-min active recovery at 60–70% HRmax	Parboiled rice fermented 16–18 h with L. plantarum NCIMB 8826 and L. acidophilus NCFM; fortified with ferrous gluconate
Frequency	3 sessions/week for 12 weeks; RPE progressed 16→18 (Borg 6–20)	Twice daily on training days (pre- and post-training); once daily (morning) on rest days
Volume / Progression	~5.8 km high-intensity per session; volume increased ~10% at weeks 5 and 9 (fifth interval added)	300 mL per serving (600 mL/day on training days)
Carbohydrate	—	58.4 g per serving (maltose + amylose; GI 52±4)
Protein	—	12.6 g per serving
Iron	—	6.2 mg elemental iron per serving (ferrous gluconate; enhanced bioavailability via phytic acid reduction)
Probiotics	—	1.2×10^9 CFU/serving (L. plantarum + L. acidophilus); viability confirmed at manufacture and mid-trial
Energy density	—	~295 kcal per 300 mL serving; placebo (plain boiled rice water) ~120 kcal
Supervision	All sessions supervised by certified exercise physiologist; HR telemetry (Polar H10) verified intensity	Supervised intake for weeks 1–4; thereafter self-administered with daily log and fortnightly container-return count

Note. AIT = aerobic interval training; NFFRP = nutrient-fortified fermented rice porridge; HRmax = maximum heart rate; CFU = colony-forming units; GI = glycaemic index; RPE = rating of perceived exertion (Borg 6–20).

Outcome Measures

The primary outcome was half-marathon completion time, assessed over a standardised 21.1-km outdoor road course at baseline (week 0) and post-intervention (week 12). Both assessments were conducted under comparable environmental conditions (ambient temperature 26–31°C, relative humidity 65–74%, wind <3 m/s) using electronic chip timing (±0.1 s).

Secondary outcomes included: VO_2max (University of Montreal Track Test; COSMED K5 portable analyser), running economy (sub-maximal treadmill stage at 70% VO_2max; Cosmed M10), peripheral oxygen saturation — SpO_2 (Nonin 9600 pulse oximeter), post-effort blood lactate (Lactate Pro 2), heart rate variability — RMSSD from 5-min resting ECG (Kubios HRV v3.5), one-minute recovery heart rate, haemoglobin (Sysmex XN-550 from fasting venous blood draw), and RPE (Borg 6–20 scale). All assessments were performed by the same blinded assessor under standardised conditions at both time-points.

Statistical analysis

Intention-to-treat analyses used two-way repeated-measures ANOVA (group × time). Normality was confirmed by Shapiro–Wilk test and Q–Q plots; homogeneity of variance by Levene's test. Post-hoc pairwise comparisons applied Bonferroni correction. Effect sizes are reported as partial eta-squared (η^2p). Analyses were performed in SPSS v27.0 and R v4.3.1.

Results

Participant flow and baseline characteristics

Ninety collegiate distance runners were randomised (n=23, 23, 22, 22 per group). All 90 completed the 12-week intervention (0% attrition). AIT session compliance averaged 96.4%; NFFRP/placebo compliance was 94.8%. No serious adverse events were recorded. Baseline characteristics were well matched across groups (Table 2; all p>0.05).

Table 2. Baseline participant characteristics by randomised group

Variable	AIT+NFFRP (n=23)	AIT+Placebo (n=23)	CT+NFFRP (n=22)	Control (n=22)
Age (years)	21.4±1.8	21.6±1.7	21.3±1.9	21.5±1.8
Male / Female (n)	16/7	15/8	14/8	15/7
Body mass (kg)	62.4±6.1	62.8±5.9	62.2±6.3	62.6±6.0
Height (cm)	171.2±6.4	170.8±6.1	171.5±6.6	171.0±6.3
BMI (kg/m²)	21.3±1.6	21.5±1.5	21.2±1.7	21.4±1.6
Training age (years)	3.8±1.2	3.6±1.3	3.9±1.1	3.7±1.2
Weekly mileage (km)	42.6±7.3	43.1±7.1	42.8±7.4	42.4±7.2
Resting HR (bpm)	58.4±5.2	58.8±5.0	58.2±5.4	58.6 ±5.1
Haemoglobin (g/dL)	13.8±1.1	13.9±1.0	13.7±1.1	13.8±1.0

Note. Data are mean ± SD unless otherwise stated. AIT = aerobic interval training; NFFRP = nutrient-fortified fermented rice porridge; CT = conventional training; BMI = body mass index; HR = heart rate.

Primary outcome: half-marathon performance

A significant group-by-time interaction was observed for half-marathon completion time ($F_{3,86}$=24.7; p<0.001; $\eta^2 p$=0.46). The AIT+NFFRP group reduced mean completion time from 115.4±8.2 to 98.6±6.1 minutes (−14.6%; mean change −16.8 min; 95% CI −19.3 to −14.3; p<0.001). AIT+Placebo improved by 9.3% (−10.8 min; 95% CI −12.4 to −9.2; p<0.001), CT+NFFRP by 6.1% (−7.1 min; 95% CI −8.6 to −5.6; p<0.001), and the control group by a non-significant 1.8% (p=0.062). Post-hoc comparisons confirmed the combined group outperformed all other arms at week 12 (all p<0.01). Results are illustrated in Figure 1.

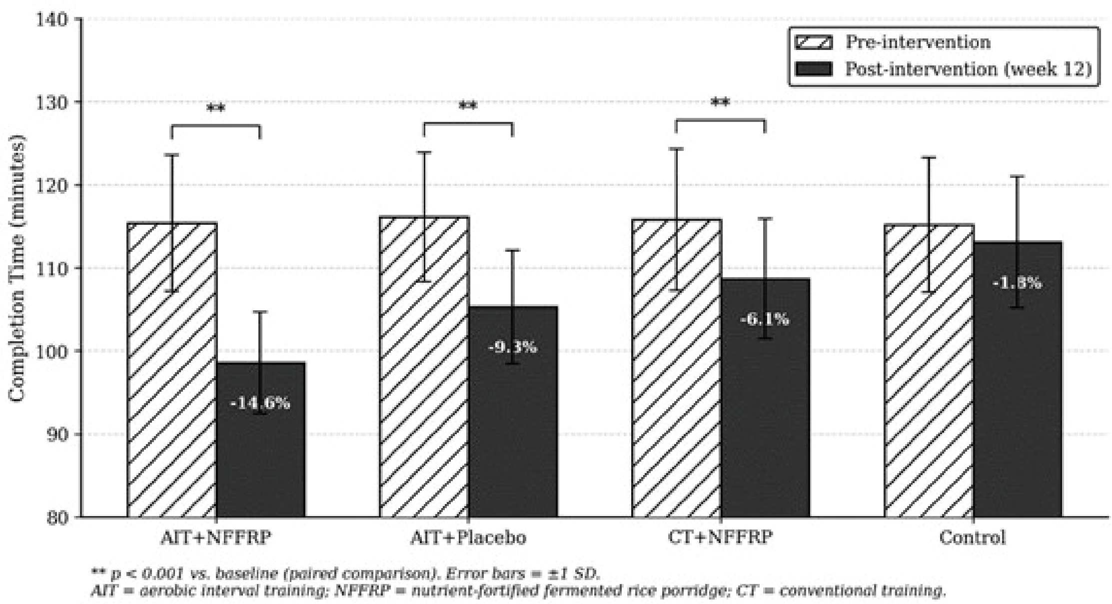

Figure 1. Half-marathon completion time (minutes) at baseline and week 12 for all four groups

Note. Error bars represent 95% confidence intervals. †p<0.001 vs. pre (within-group); ‡p<0.01 vs. control; §p<0.01 vs. AIT+Placebo and CT+NFFRP (Bonferroni post-hoc). AIT = aerobic interval training; CT = conventional training; NFFRP = nutrient-fortified fermented rice porridge.

VO_2max

VO_2max increased most in the AIT+NFFRP group (+7.6 mL/kg/min; 95% CI 5.9–9.3; $p<0.001$) and AIT+Placebo (+5.2 mL/kg/min; 95% CI 3.8–6.6; $p<0.001$). CT+NFFRP showed a smaller but significant gain (+2.8 mL/kg/min; 95% CI 1.2–4.4; $p=0.001$). No meaningful change was observed in the control group (+0.5 mL/kg/min; $p=0.32$). The group-by-time interaction was significant ($F_{3,86}=18.4$; $p<0.001$; $\eta^2p=0.39$). Percentage changes are shown in Figure 2.

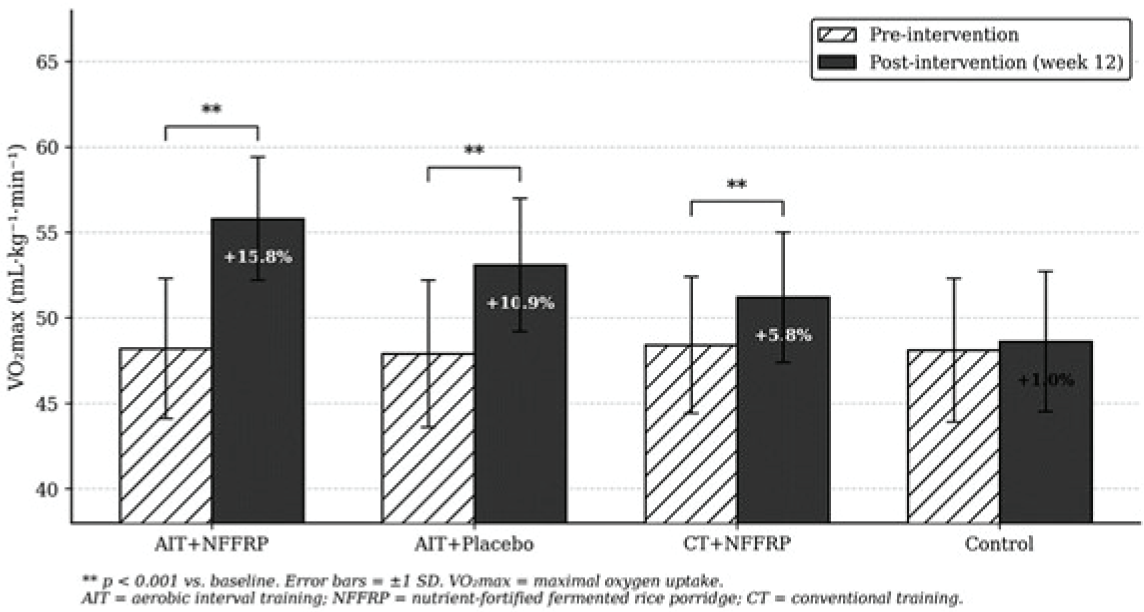

Figure 2. Percentage change in VO_2max (mL/kg/min) from baseline to week 12 by group

Note. Error bars represent 95% CIs. Group symbols as in Figure 1.

Recovery kinetics

The combined group produced the largest gains across all recovery metrics (Table 3). Post-effort blood lactate fell by 31.7% (8.2 to 5.6 mmol/L), RMSSD rose by 34.9% (42.1 to 56.8 ms; $\eta^2p=0.38$), and one-minute recovery heart rate declined by 24 bpm (16.9%). Haemoglobin rose by 7.2% (13.8 to 14.8 g/dL), the largest between-group gain. Running economy improved by 11.9% (218 to 192 mL/kg/km). Figure 3 summarises percentage changes in three key recovery metrics across all groups.

Table 3. Primary and secondary outcomes at baseline and week 12 by randomised group

Outcome	Time	AIT+NFFRP (n=23)	AIT+Placebo (n=23)	CT+NFFRP (n=22)	Control (n=22)
Half-marathon time (min)	Pre	115.4±8.2	116.1±7.8	115.8±8.5	115.2±8.1
	Post	98.6±6.1†‡§	105.3±6.8†	108.7±7.2†	113.1±7.9
	Δ%	−14.6%	−9.3%	−6.1%	−1.8%
VO_2max (mL/kg/min)	Pre	48.2±4.1	47.9±4.3	48.4±4.0	48.1±4.2
	Post	55.8±3.6†‡§	53.1±3.9†	51.2±3.8†	48.6±4.1
	Δ%	+15.8%	+10.9%	+5.8%	+1.0%
SpO_2 (%)	Pre	97.2±0.8	97.4±0.7	97.3±0.9	97.1±0.8
	Post	98.6±0.6†‡	98.1±0.7†	97.8±0.8†	97.2±0.9
	Δ%	+1.4%	+0.7%	+0.5%	+0.1%
Recovery HR 1-min (bpm)	Pre	142.0±12.0	144.0±11.0	143.0±12.0	141.0±12.0
	Post	118.0±9.0†‡§	128.0±10.0†	132.0±11.0†	139.0±12.0
	Δ%	−16.9%	−11.1%	−7.7%	−1.4%

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Table 3. Primary and secondary outcomes at baseline and week 12 by randomised group

Outcome	Time	AIT+NFFRP (n=23)	AIT+Placebo (n=23)	CT+NFFRP (n=22)	Control (n=22)
Blood lactate (mmol/L)	Pre	8.2±1.2	8.4±1.3	8.1±1.2	8.3±1.2
	Post	5.6±0.9†‡§	6.8±1.1†	7.1±1.0†	8.1±1.2
	Δ%	−31.7%	−19.0%	−12.3%	−2.4%
HRV – RMSSD (ms)	Pre	42.1±8.4	41.8±8.1	42.4±8.6	42.0±8.3
	Post	56.8±7.2†‡§	50.4±7.8†	47.2±8.0†	42.9±8.4
	Δ%	+34.9%	+20.6%	+11.3%	+2.1%
RPE (Borg 6–20)	Pre	16.8±1.2	16.9±1.1	16.7±1.3	16.8±1.2
	Post	13.6±1.1†‡§	14.8±1.2†	15.2±1.2†	16.5±1.3
	Δ%	−19.0%	−12.4%	−9.0%	−1.8%
Haemoglobin (g/dL)	Pre	13.8±1.1	13.9±1.0	13.7±1.1	13.8±1.0
	Post	14.8±1.0†‡§	14.4±0.9†	14.2±1.0†	13.9±1.0
	Δ%	+7.2%	+3.6%	+3.6%	+0.7%
Running economy (mL/kg/km)	Pre	218.0±18.0	220.0±17.0	217.0±19.0	219.0±18.0
	Post	192.0±14.0†‡§	204.0±15.0†	207.0±16.0†	216.0±18.0
	Δ%	−11.9%	−7.3%	−4.6%	−1.4%

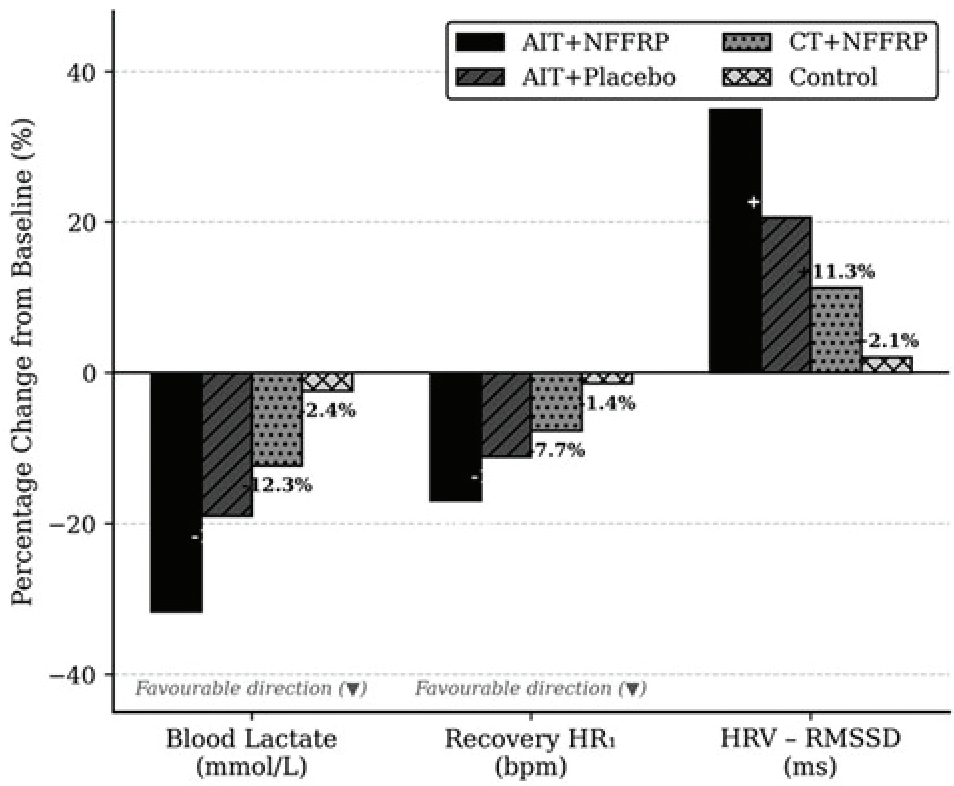

Figure 3. Percentage changes in three key recovery kinetics metrics (blood lactate, RMSSD, and one-minute recovery heart rate) at week 12 by group

Note. RMSSD = root mean square of successive differences; HR = heart rate. Group symbols as in Figure 1. For blood lactate and one-minute recovery HR, negative values indicate improvement.

Discussion

This four-arm RCT provides evidence that combining structured AIT with twice-daily NFFRP is associated with greater improvements in half-marathon performance, cardiopulmonary fitness, and recovery kinetics than either intervention alone over 12 weeks. The 14.6% reduction in completion time in the combined group (mean 16.8 min) is clinically meaningful in collegiate competition. However, several important interpretive caveats accompany these findings.

Non-isoenergetic control and attribution of effects. A critical limitation that requires direct acknowledgment is that NFFRP (~295 kcal/serving, consumed twice daily on training days) was not isoenergetically or isoproteically matched to the placebo (~120 kcal). On training days, participants in the NFFRP arms consumed approximately 350 additional kilocalories and 25.2 g additional protein per day from the intervention beverage alone. This energy and protein differential could independently explain a portion of the observed performance and recovery advantage irrespective of the fermentation process, probiotic organisms, or iron content. Accordingly, the effects attributed to NFFRP in this trial should be understood as the aggregate effect of additional energy, protein, iron, and probiotic intake within a fermented matrix, and cannot be attributed to fermentation or probiotics specifically. Future trials comparing NFFRP against a nutritionally matched, non-fermented comparator are needed to isolate fermentation-specific contributions.

Blinding and expectancy. Assessor blinding was adequate (blinding index 0.08; 95% CI −0.04 to 0.20). However, participants could plausibly detect which beverage they received, given the perceptible differences in taste, viscosity, and satiety stemming from the unavoidable caloric disparity. Expectancy effects may have influenced subjective outcomes such as RPE and potentially pacing behaviour during half-marathon testing. This limitation is most consequential for the subjective endpoints and warrants consideration when interpreting the RPE differences between groups.

The VO_2max response in the AIT+NFFRP group (+7.6 mL/kg/min, +15.8%) lies at the upper boundary of gains reported in meta-analyses of HIIT in athletic populations (Ma et al., 2023). The additional increment over AIT alone (+2.4 mL/kg/min) is consistent with a nutritional contribution to training adaptation possibly through improved inter-session recovery enabled by higher carbohydrate and protein availability (Burke et al., 2011; Jeukendrup, 2014b) but cannot be attributed to any specific NFFRP component without mechanistic measurement.

The 31.7% reduction in post-effort blood lactate in the combined group likely reflects AIT-driven upregulation of monocarboxylate transporter expression (Brooks, 2018), though nutritionally enabled recovery may have amplified this adaptation. Similarly, the 34.9% RMSSD rise exceeds values typically seen with HIIT alone (Plews et al., 2013), suggesting a synergistic effect whose mechanism cannot be determined without continuous HRV monitoring and microbiota analysis. The 7.2% haemoglobin gain in the combined group is consistent with NFFRP's iron content and the known effect of fermentation on non-haem iron bioavailability via phytic acid reduction (Hotz & Gibson, 2007b), though serum ferritin was not measured, so iron-mediated erythropoietic adaptation cannot be confirmed.

The observed running economy improvement of 11.9% in the combined group likely reflects enhanced neuromuscular efficiency and mitochondrial substrate utilisation driven by AIT (Barnes & Kilding, 2015b; Rosenblat et al., 2022), with possible amplification through improved recovery quality.

Limitations include the single-centre design, non-isoenergetic placebo (preventing attribution to specific NFFRP components), reliance on 24-hour dietary recall (subject to recall bias), absence of mechanistic measurements (gut microbiota, serum ferritin, MCT protein quantification, muscle biopsy), limited 12-week duration, and underpowered sex-disaggregated analyses. Future trials should use a nutritionally matched non-fermented control, incorporate direct mechanistic endpoints (including gut microbiota profiling and iron status biomarkers), ensure sex-stratified recruitment with adequate power, and adopt multicentre designs.

Conclusion

In this 12-week, four-arm RCT, the combination of AIT and NFFRP was associated with greater improvements in half-marathon performance, VO_2max, and recovery kinetics than either intervention alone, with complete retention and no adverse events. These findings suggest a potential performance benefit of combining structured interval training with this fermented, nutrient-dense food-based supplement. The NFFRP's caloric and nutritional composition differed substantially from the placebo; the specific contributions of fermentation, probiotics, or iron therefore require confirmation through trials incorporating isoenergetic controls, mechanistic endpoints, and multicentre replication.

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Conflict of Interest
The authors declare no conflicts of interest.

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References

Bang, H., Ni, L., & Davis, C. E. (2004). Assessment of blinding in clinical trials. *Controlled Clinical Trials, 25*(2), 143–156. https://doi.org/10.1016/j.cct.2003.10.016

Barnes, K. R., & Kilding, A. E. (2015a). Running economy: Measurement, norms, and determining factors. *Sports Medicine – Open, 1*(1), 8. https://doi.org/10.1186/s40798-015-0007-y

Barnes, K. R., & Kilding, A. E. (2015b). Strategies to improve running economy. *Sports Medicine, 45*(1), 37–56. https://doi.org/10.1007/s40279-014-0246-y

Barnett, A. (2006). Using recovery modalities between training sessions in elite athletes. *Sports Medicine, 36*(9), 781–796. https://doi.org/10.2165/00007256-200636090-00005

Barton, W., Penney, N. C., Cronin, O., Garcia-Perez, I., Molloy, M. G., Holmes, E., … O'Sullivan, O. (2018). The microbiome of professional athletes differs from that of more sedentary subjects in composition and particularly at the functional metabolic level. *Gut, 67*(4), 625–633. https://doi.org/10.1136/gutjnl-2016-313627

Bassett, D. R. (2000a). Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Medicine & Science in Sports & Exercise, 32*(1), 70–84. https://doi.org/10.1097/00005768-200001000-00012

Brooks, G. A. (2018). The science and translation of lactate shuttle theory. *Cell Metabolism, 27*(4), 757–785. https://doi.org/10.1016/j.cmet.2018.03.008

Buchheit, M., & Laursen, P. B. (2013a). High-intensity interval training, solutions to the programming puzzle: Part I. *Sports Medicine, 43*(5), 313–338. https://doi.org/10.1007/s40279-013-0029-x

Burke, L. M., Hawley, J. A., Wong, S. H. S., & Jeukendrup, A. E. (2011). Carbohydrates for training and competition. *Journal of Sports Sciences, 29*(Suppl. 1), S17–S27. https://doi.org/10.1080/02640414.2011.585473

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

Faude, O., Kindermann, W., & Meyer, T. (2009). Lactate threshold concepts: How valid are they? *Sports Medicine, 39*(6), 469–490. https://doi.org/10.2165/00007256-200939060-00003

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1. *Behavior Research Methods, 41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Helgerud, J., Høydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., … Hoff, J. (2007). Aerobic high-intensity intervals improve $\dot{V}O_2$max more than moderate training. *Medicine & Science in Sports & Exercise, 39*(4), 665–671. https://doi.org/10.1249/mss.0b013e3180304570

Hotz, C., & Gibson, R. S. (2007a). Traditional food-processing and preparation practices to enhance the bioavailability of micronutrients in plant-based diets. *The Journal of Nutrition, 137*(4), 1097–1100. https://doi.org/10.1093/jn/137.4.1097

Jeukendrup, A. (2014b). A step towards personalized sports nutrition. *Sports Medicine, 44*(Suppl. 1), 25–33. https://doi.org/10.1007/s40279-014-0148-z

Joyner, M. J., & Coyle, E. F. (2008). Endurance exercise performance: The physiology of champions. *The Journal of Physiology, 586*(1), 35–44. https://doi.org/10.1113/jphysiol.2007.143834

Ma, J., Nguyen, A., Siu, G., Lam, E., Cheung, K., & Tsang, H. (2023). Effects of high-intensity interval training on VO_2max in healthy adults: A meta-analysis. *Journal of Exercise Science & Fitness, 21*(2), 125–134.

Midgley, A. W., McNaughton, L. R., & Jones, A. M. (2007). Training to enhance the physiological determinants of long-distance running performance. *Sports Medicine, 37*(10), 857–880. https://doi.org/10.2165/00007256-200737100-00003

Milanović, Z., Sporiš, G., & Weston, M. (2015). Effectiveness of high-intensity interval training (HIT) and continuous endurance training for VO_2max improvements. *Sports Medicine, 45*(10), 1469–1481. https://doi.org/10.1007/s40279-015-0365-0

Mohr, A. E., Jäger, R., Carpenter, K. C., Kerksick, C. M., Purpura, M., Townsend, J. R., … Antonio, J. (2020). The athletic gut microbiota. *Journal of the International Society of Sports Nutrition, 17*(1), 24. https://doi.org/10.1186/s12970-020-00353-w

Plews, D. J., Laursen, P. B., Stanley, J., Buchheit, M., & Kilding, A. E. (2013). Training adaptation and heart rate variability in elite endurance athletes. *Sports Medicine, 43*(9), 773–791. https://doi.org/10.1007/s40279-013-0071-8

Rosenblat, M. A., Perrotta, A. S., & Vicenzino, B. (2022). Interval training programming and performance: A systematic review. *Journal of Strength and Conditioning Research, 36*(6), 1702–1715.

Schulz, K. F., Altman, D. G., Moher, D., & CONSORT Group. (2010). CONSORT 2010 statement: Updated guidelines for reporting parallel group randomised trials. *BMJ, 340*, c332. https://doi.org/10.1136/bmj.c332

Seiler, S. (2010a). What is best practice for training intensity and duration distribution in endurance athletes? *International Journal of Sports Physiology and Performance, 5*(3), 276–291. https://doi.org/10.1123/ijspp.5.3.276

Shibaguchi, T., Koma, R., Riskawati, Y. K., Kawai, Y., Yoneda, T., Aizaki, H., … Masuda, K. (2022). Effect of daily intake of a rice fermented beverage on endurance exercise performance in male college student athletes. *Journal of Physical Fitness and Sports Medicine, 11*(5), 279–294. https://doi.org/10.7600/jpfsm.11.279

Tarvainen, M. P., Niskanen, J.-P., Lipponen, J. A., Ranta-aho, P. O., & Karjalainen, P. A. (2014). Kubios HRV – Heart rate variability analysis software. *Computer Methods and Programs in Biomedicine, 113*(1), 210–220. https://doi.org/10.1016/j.cmpb.2013.07.024

Thron, M., Woll, A., Klos, L., Härtel, S., Ruf, L., Kloss, C., & Altmann, S. (2022). Overestimation of maximal aerobic speed by the Université de Montréal track test in soccer. *Frontiers in Physiology, 13*, 1023257. https://doi.org/10.3389/fphys.2022.1023257

Wang, Z., & Wang, J. (2024). The effects of high-intensity interval training versus moderate-intensity continuous training on athletes' aerobic endurance parameters. *European Journal of Applied Physiology, 124*(8), 2235–2249. https://doi.org/10.1007/s00421-024-05532-0

Weston, M., Taylor, K. L., Batterham, A. M., & Hopkins, W. G. (2014). Effects of low-volume high-intensity interval training (HIT) on fitness in adults. *Sports Medicine, 44*(7), 1005–1017. https://doi.org/10.1007/s40279-014-0180-z

World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA, 310*(20), 2191–2194. https://doi.org/10.1001/jama.2013.281053