Short-term training effects on aerobic and anaerobic fitness in varsity soccer players

Efectos del entrenamiento a corto plazo sobre la aptitud aeróbica y anaeróbica en jugadores de fútbol universitario

Authors

Arom Treeraj [1]
Chawannat Choodam [1]
Giancarlo Condello [2]
Chutimon Khemtong [1]

[1] Mahidol University (Thailand)
[2] University of Parma (Italy)

Corresponding author:
Chutimon Khemtong
chutimon.khe@mahidol.ac.th

Received: 18-08-25
Accepted: 25-09-25

How to cite in APA

Treeraj, A., Choodam, C., Condello, G., & Khemtong, C. (2025). Short-term training effects on aerobic and anaerobic fitness in varsity soccer players. *Retos, 73*, 702-714. https://doi.org/10.47197/retos.v73.117428

Abstract

Objective: This study investigates the efficacy of 4-week intermittent sprint (INT) and circuit training (CT) on aerobic and anaerobic performance in varsity soccer players.
Methodology: Participants were randomly equally assigned to one of two training groups (INT or CT). Both groups were required to complete the standard soccer training regimen, supplemented by their respective training programs for the 4-week duration. Maximal oxygen consumption (VO_2max), anaerobic capacity (AC), and anaerobic power were assessed as primary indicators of aerobic and anaerobic performance, respectively. Additionally, blood lactate concentrations were measured at 0 and 3 minutes following a repeated sprint test.
Results: Repeated measures ANOVA revealed significant improvements in VO_2max ($p = 0.004$) and AC ($p = 0.009$) after the 4-week training period, with no significant differences between the two interventions. Notably, a significant increase in minimum anaerobic power (P_{min}) was observed ($p = 0.043$), despite higher lactate accumulation compared to pre-training levels, suggesting an enhanced ability to maintain speed under conditions of muscular fatigue.
Conclusion: These findings indicate that both training methods are effective training programs in enhancing aerobic and anaerobic performance in varsity soccer players. However, the underlying mechanisms driving the physiological responses and adaptations to these training modalities require further investigation.

Keywords

Circuit training; intermittent training; blood lactate; aerobic; anaerobic.

Resumen

Objetivo: Este estudio investiga la eficacia de cuatro semanas de entrenamiento intermitente de sprints (INT) y entrenamiento en circuito (CT) sobre el rendimiento aeróbico y anaeróbico en jugadores de fútbol universitario.
Metodología: Los participantes fueron asignados aleatoriamente y de manera equitativa a uno de los dos grupos de entrenamiento (INT o CT). Ambos grupos completaron el régimen estándar de entrenamiento de fútbol, complementado con sus respectivos programas de entrenamiento durante las cuatro semanas. El consumo máximo de oxígeno (VO_2max), la capacidad anaeróbica (CA) y la potencia anaeróbica se evaluaron como indicadores principales del rendimiento aeróbico y anaeróbico, respectivamente. Además, se midieron las concentraciones de lactato en sangre a los 0 y 3 minutos tras una prueba de sprints repetidos.
Resultados: Un ANOVA de medidas repetidas reveló mejoras significativas en VO_2max ($p = 0.004$) y en la CA ($p = 0.009$) después del periodo de entrenamiento de cuatro semanas, sin diferencias significativas entre las dos intervenciones. Cabe destacar que se observó un aumento significativo en la potencia anaeróbica mínima (P_{min}) ($p = 0.043$), a pesar de una mayor acumulación de lactato en comparación con los niveles previos al entrenamiento, lo que sugiere una mayor capacidad para mantener la velocidad bajo condiciones de fatiga muscular.
Conclusión: Estos hallazgos indican que ambos métodos de entrenamiento son eficaces para mejorar el rendimiento aeróbico y anaeróbico en jugadores de fútbol universitario. Sin embargo, los mecanismos fisiológicos subyacentes que explican las respuestas y adaptaciones a estas modalidades de entrenamiento requieren una investigación más profunda.

Palabras clave

Entrenamiento en circuito; entrenamiento intermitente; lactato en sangre; aeróbico; anaeróbico.

Introduction

Soccer is an intermittent team sport characterized by high-intensity activities interspersed with periods of lower-intensity exertion over a 90-minute match (Orendurff et al., 2010). During a game, players perform multiple explosive bursts of activity, including jumping, kicking, tackling, turning, and sprinting (Stølen et al., 2005). These movements are closely associated with skill-related components of fitness such as rapid changes in direction, speed, agility, and reaction time. In addition, players cover an average distance of approximately 10 kilometers, incorporating both intermittent and continuous running, interspersed with brief recovery periods (Orendurff et al., 2010; Stølen et al., 2005). This underscores the importance of both aerobic and anaerobic energy systems in sustaining stamina and facilitating recovery throughout the game (Siahkouhian et al., 2013). Furthermore, superior performance in covering greater distances at high-speed zones (Fernandes-da-Silva et al., 2016; Rampinini et al., 2007; Rebelo et al., 2014), lower injury risks (Gastin et al., 2015), and maintaining high technical performance throughout the game are all more efficiently achieved by players with enhanced anaerobic and aerobic fitness (Joseph et al., 2020). Therefore, a well-structured training program targeting improvements in both aerobic and anaerobic fitness is essential, especially during the pre-competition phase of periodization.

Training methods approach should ideally mimic the natural movements of the sport while promoting improvements in athletic performance. Previous studies in soccer have explored various training approaches over periods of 8 to 12 weeks, including continuous training (Aguiar et al., 2008), interval training (Dupont et al., 2004; Zarrinkalam et al., 2022), intermittent training (Aguiar et al., 2008; Ortiz et al., 2024), and small-sided games (Karahan, 2020). However, in practical settings, coaches and athletes often face time constraints due to the demands of frequent competitions, which may limit the ability to complete a full training cycle. As a result, time-efficient training programs, such as intermittent sprint training (INT) and circuit training (CT), have gained attention. INT involves repeated sprints with brief rest intervals and has been shown to improve VO2max in a relatively short period (Vollaard et al., 2017). In contrast, CT, which has been recognized for its time efficiency in previous studies (Klika & Jordan, 2013), incorporates multiple stations featuring bodyweight resistance exercises that effectively enhance both strength and endurance. While the benefits of these training methods are well-documented, their specific application to varsity soccer players within a limited time frame remains underexplored.

There is currently a lack of evidence regarding the effectiveness of these training methods in team sports during the pre-competition period. Therefore, the aim of this study was to examine the effects of short-term intermittent sprint training and circuit training on both anaerobic and aerobic performance in varsity soccer athletes. We hypothesized that the INT training methods would more effectively enhance aerobic and anaerobic performance, even with only a 4-week training period

Method

A parallel, randomized, counterbalanced study design was employed to compare the effectiveness of two distinct 4-week training programs. A minimum sample size of 16 participants was computed using an a priori power analysis conducted with G*Power (version 3.1.9.6, University of Dusseldorf, Dusseldorf, Germany), based on repeated measures ANOVA with a large effect size of 0.4, a statistics power (1-β) of 0.80, and a significant level of 0.05 (Faul et al., 2007). All participants were randomly and equally assigned to one of two training groups: intermittent sprint training (INT) or circuit training (CT). A familiarization session was conducted prior to the pre-training test to ensure participants understood the exercise interventions and testing procedures. Maximal oxygen consumption (VO_2max) and anaerobic capacity (AC) were assessed before and after the 4-week training to evaluate changes of aerobic and anaerobic performance. Meanwhile, the secondary outcomes (i.e., power, speed, and fatigue index) were measured. Additionally, the blood lactate and heart rate were measured during testing to assess the recovery capacity.

Participants

During the initial phase of the study (Figure 1), 30 soccer players from a single club were assessed. Of these, 8 participants were excluded based on the inclusion criteria. Consequently, 22 participants were recruited, meeting the minimum requirement for study enrollment. Twenty-two youth male soccer players from a single club competing in the Thailand university games were screened for eligibility to participate in this study. Inclusion criteria were as follows: (a) aged between 18-25 years; (b) a minimum of three years of experience in soccer training and competition; (c) no history of musculoskeletal injuries within the past six months; (d) non-smokers and not currently using any medications; (e) absence of known cardiovascular, pulmonary, metabolic, bone, or joint diseases; and (f) an estimated maximal oxygen consumption (VO_2max) range of at least 49.0 ml/kg/min. Participants who satisfied the inclusion criteria and agreed to follow all the instructions provided their written informed consent and were recruited to participate in this study. The general characteristics of participants by intervention groups were summarized in Table 1. Independent t-test revealed no significant different between groups in all variables. This study was conducted according to the Declaration of Helsinki (World Medical Association, 2013) and was approved by the Mahidol University Central Institutional Review Board (No. 2023/118.1508).

Figure 1. CONSORT flowchart representing the progression of participant throughout the study

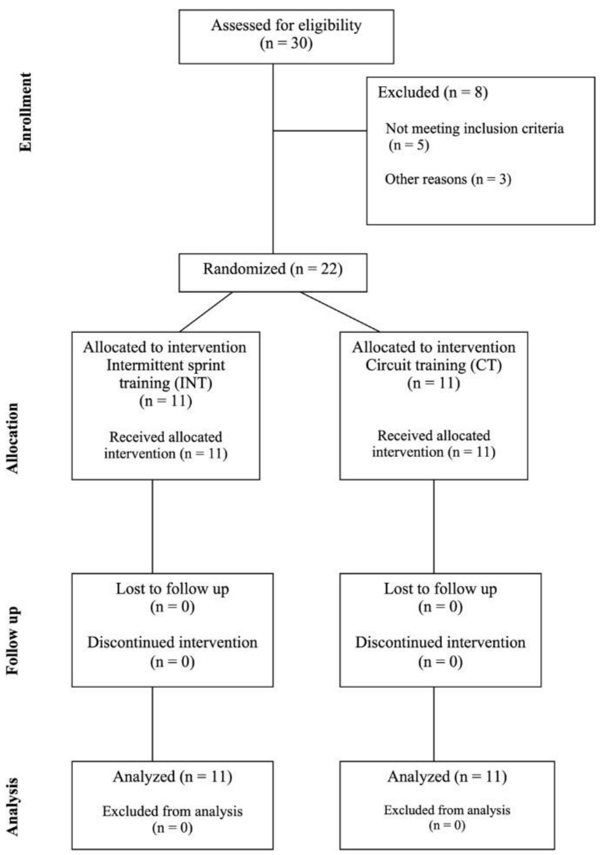


Table 1. Descriptive data of general characteristics of participants (mean ± SD)

Parameters	INT (n = 11)	CT (n = 11)	p-value
Age (year)	20 ± 1	20 ± 1	0.258
Weight (kg)	61.5 ± 5.8	64.9 ± 6.8	0.225
Height (m)	171.8 ± 4.5	175.7 ± 4.6	0.057
BMI (kg/m^2)	20.8 ± 1.4	21.0 ± 1.4	0.808
SBP (mmHg)	127 ± 16	127 ± 14	0.916
DBP (mmHg)	64 ± 10	63 ± 8	0.567
Pulse (bpm)	73 ± 11	71 ± 13	0.530

BMI: Body Mass Index; DBP: Diastolic Blood Pressure; INT: Intermittent training;
SBP: Systolic Blood Pressure; CT = Circuit training.

Procedure

Training protocol

After recruitment process, participants were randomly and equally assigned to one of two training groups: intermittent sprint training (INT, n = 11) or circuit training (CT, n = 11). The INT program was designed with a work-to-rest ratio of 1:2, consisting of 6 sets of 6 repetitions of 35-meter sprints, with a 10-second rest between repetitions and a 2-minute rest between sets. The CT program, which aimed to target the anaerobic energy system, combined bodyweight resistance exercises performed at a fast pace. The CT program consisted of 7 exercises: sit-ups (upright), Oblique sit-ups (left and right), superman, mountain climbers, split jumps, and burpees. Participants performed exercise 1 to 6 for 30 repetitions each, followed by 20 repetitions of the final exercise, in the given order. All exercise were performed consecutively without rest between exercises, with a 2-minute rest between sets. Participants completed a total of 6 sets of the CT program. All participants performed both training programs three times per week (Monday, Wednesday, and Friday) over a 4-week period before soccer tactics training. Details of the overall experiment procedures are provided in Figure 2. During the experiment period, all participants underwent the same soccer skills program, which was implemented during the pre-competition period. The program included a 15-minute general warm-up, 20 minutes of basic skills, 60 minutes of specific soccer skills (20 minutes focused on soccer techniques and 40 minutes on soccer tactics), and a 15-minute cool-down. The total duration of each training session was 110 minutes. Both training sessions were supervised by the sports scientist of the soccer team to ensure the correct sequence of training activities, as well as the appropriate training volume and intensity. The full details of the training program over the 4-week period are provided in Table 2.

Figure 2. A schematic illustrating an overview of the experimental procedures of the present study

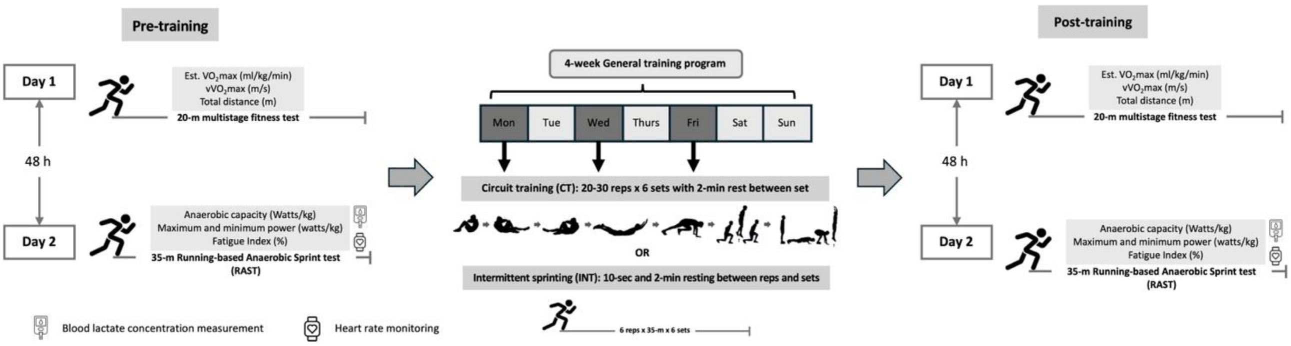


Table 2. Overall details of 4-week football training program.

Day/ Training session	Session 1 - Morning	Session 2 - Evening
Monday	General weight training	Soccer tactics
Tuesday	Rest	Soccer techniques small-sided games
Wednesday	General weight training	Soccer tactics
Thursday	Rest	Soccer techniques Small-sided games
Friday	General weight training	Soccer tactics
Saturday	Rest	Non-competitive match
Sunday	Fully resting day	

Testing protocol

Both anaerobic and aerobic performance were assessed pre- and post-training. Testing was conducted on two separate days: aerobic performance was evaluated on Day 1 using the multistage fitness test (Beep test), and anaerobic performance was assessed on Day 2 using the running-based anaerobic sprint test (RAST). Prior to each test, participants performed the same warm-up and dynamic stretching routine, which included 5 minutes of slow, linear jogging followed by hip rotations (outward and inward), front lunges, and leg swings. The warm-up and stretching protocols were administered by the same sports scientist to ensure consistency and readiness of the athletes before testing.

Outcome measures and instruments

Aerobic performance testing

The Multistage Fitness Test, also known as the Beep Test (Cavar et al., 2019; Léger et al., 1988), was selected to assess aerobic performance parameters, including estimated maximal oxygen consumption (est. VO_2max) and maximum speed at VO_2max (vVO_2max) and total distance pre- and post-training. Prior to the test, participants stood behind one of the lines, facing the opposite line 20 meters apart, and began running when instructed by the recorded beeps. The running speed increased gradually with each testing stage and level. If a participant failed to reach the line before the beep sounded, they were given a warning and instructed to continue running to the line. If the participant was unable to reach the line within 2 meters of the beep, the test was terminated. The final stage and level reached during the test were recorded and used for statistical analysis

Anaerobic performance testing

The Running-Based Anaerobic Sprint Test (RAST) consisted of 6 repetitions of 35-meter sprints, with 10 seconds of rest between each sprint. This test was conducted pre- and post-training to assess changes in anaerobic performance. The RAST has been validated as an effective protocol for measuring anaerobic power (Andrade et al., 2015) and short-distance performance (Andrade et al., 2015; Zagatto et al., 2009). Prior to each test, participants were positioned 1 meter behind the timing sensor at the starting line. The tester provided a verbal cue to begin the test and counted down the time for each sprint. Participants were instructed to sprint as quickly as possible and pass through the timing sensor without decelerating. To ensure maximal effort, strong verbal encouragement and real-time feedback on times were provided throughout the 6 sprints. Speed and time for each repetition were recorded by a timing gate system (TestYou, Mobile PRO Timing System, Krakow, Poland) to the nearest 0.01 seconds. Anaerobic performance parameters, including anaerobic capacity (AC), anaerobic power (P_{max}), minimum power (P_{min}), best speed, and fatigue index, were derived from the timing gate data. Additionally, heart rate (HR) was recorded during the test using a Polar H10 sensor (Finland), and blood lactate concentration ([La^-]) was measured from fingertip blood samples using a Lactate Scout (EKF Diagnostics, Barleben, Germany) at 0- and 3-minutes post-test to assess recovery rates in the athletes

Data analysis

Statistical analyses were performed using IBM SPSS statistics (version 29.0, Armonk, NY: IBM Corp). All data was expressed as mean ± SD and were normal distributed as evaluated using the Shapiro-Wilk test. The two-way repeated measures ANOVA (group x time) was performed on dependent variables to ascertain the effect of training programs. Moreover, the two-way repeated measures ANOVA (sprint x time) was applied to ascertain the changes of sprinting speed and heart rate over 6 trials (sprint: T1-to-T6) between two time-point (time: PRE-POST). If the significant interactions emerged, pairwise (post-hoc) comparison with Bonferroni adjustments was applied. Effect size for the main effects were calculated as the partial eta squared (η^2_ρ) and interpreted as a small (0.01-0.06), medium ($0.06 < \eta^2_\rho < 0.14$), and large (> 0.14) effect. While the effect size of each comparison was calculated using Cohen's d and was interpreted as a trivial (< 0.19), small (0.20 – 0.59), moderate (0.60 – 1.19), large (1.20 – 1.99), very large (2.0 – 4.0), and extremely large (> 4.0) [21]. The significant difference of dependent variables was set at $p < 0.05$. Lastly, Pearson correlation was used to evaluated the association among the anaerobic derived-variables at last trial of test (T6). The strength of associations was quantified and interpreted according to the following categories: ≤ 0.1 (trivial), 0.11–0.30 (small), 0.31–0.50 (moderate), 0.51–0.70 (large), 0.71–0.90 (very large), and ≥0.9 (nearly perfect) (Sammoud et al., 2021).

Results

Aerobic performance

A main effect of time without interaction emerged for estimated maximal oxygen consumption (est. VO_2max) ($F = 14.32$, $p = 0.004$, $\eta^2_\rho = 0.59$) and maximum speed at VO_2max (vVO_2max) ($F = 7.86$, $p = 0.019$, $\eta^2_\rho = 0.44$), and total distance ($F = 13.60$, $p = 0.004$, $\eta^2_\rho = 0.576$). The est. VO_2max was significantly greater at POST (55.6 ± 2.6 ml/min/kg) compared to PRE (53.5 ± 3.1 ml/min/kg, p = 0.001, d = 0.80). Besides, the vVO_2max significantly increased at POST (14.1 ± 0.3 m/s) compared to PRE (13.9 ± 0.4 m/s, p = 0.005, d = 0.68). Moreover, the total distance was significantly improved at POST (2267 ± 178 m) compared to PRE (2120 ± 212 m, p = 0.001, d = 0.78).

Anaerobic performance

The changes of anaerobic performance between training groups at PRE and POST was shown in **Table 3**. A main effect of time without interaction emerged for anaerobic capacity (AC) ($F = 10.25$, $p = 0.009$, $\eta^2_\rho = 0.51$), minimum power (P_{min}) ($F = 5.37$, $p = 0.043$, $\eta^2_\rho = 0.35$), and blood lactate concentration at 3-min ($[La^-]_{3\text{-}min}$) ($F = 8.23$, $p = 0.017$, $\eta^2_\rho = 0.45$). AC was significantly higher at POST as well as the P_{min} compared to PRE (AC: p = 0.003, d = 0.70; P_{min}: p = 0.026, d = 0.51). In addition, $[La^-]_{3\text{-}min}$ was significantly increased at POST compared to PRE (p = 0.046, d = 0.45). However, there was no significant difference in anaerobic power (P_{max}), best speed, fatigue index, and blood lactate concentration at 0-min ($[La^-]_{0\text{-}min}$). Additionally, a significant main effect of sprint was observed without interaction in the sprinting speed of the INT group ($F = 30.033$, $p < 0.001$, $\eta^2_\rho = 0.91$), as well as in heart rate for both the INT ($F = 165.54$, $p < 0.001$, $\eta^2_\rho = 0.943$) and CT ($F = 138.57$, $p < 0.001$, $\eta^2_\rho = 0.93$) groups (**Figure 3**). In the CT group, both the main effects of sprint ($F = 7.65$, $p = 0.020$, $\eta^2_\rho = 0.43$) and time ($F = 30.335$, $p < 0.001$, $\eta^2_\rho = 0.75$) without interaction were found. Overall, sprinting speed significantly improved following CT (p = 0.020, d = 0.81), while in the INT group, an upward trend was observed, but the improvement was not statistically significant compared to the PRE condition. Consider the effect of sprint, both INT and CT demonstrated significantly slower of speed at T3 (INT: 6.76 ± 0.27 m/s, d = 0.38; CT: 6.71 ± 0.31 m/s, d = 1.10), T4 (INT: 6.52 ± 0.27 m/s, d = 2.38; CT: 6.48 ± 0.28 m/s, d = 2.03), T5 (INT: 6.33 ± 0.23 m/s, d = 3.37; CT: 6.34 ± 0.32 m/s, d = 2.37), and T6 (INT: 6.25 ± 0.23 m/s, d = 3.70; CT: 6.28 ± 0.34 m/s, d = 2.48) compared to T1 (INT: 7.14 ± 0.25 m/s; CT: 7.02 ± 0.25 m/s, p < 0.001). Oppositely, heart rate was significantly increased at T2 (INT: 157 ± 8 bpm, d = 2.94; CT: 159 ± 10 bpm, d = 2.47), T3 (INT: 164 ± 8 bpm, d = 3.63; CT: 163 ± 10 bpm, d = 2.77), T4 (INT: 170 ± 7 bpm, d = 4.38; CT: 168 ± 10 bpm, d = 3.15), T5 (INT: 172 ± 8 bpm, d = 4.41; CT: 171 ± 10 bpm, d = 3.37), and T6 (INT: 175 ± 8 bpm, d = 4.71; CT: 173 ± 9 bpm, d = 3.62) compared to T1 (INT: 127 ± 12 bpm; CT: 126 ± 16 bpm, p < 0.001).

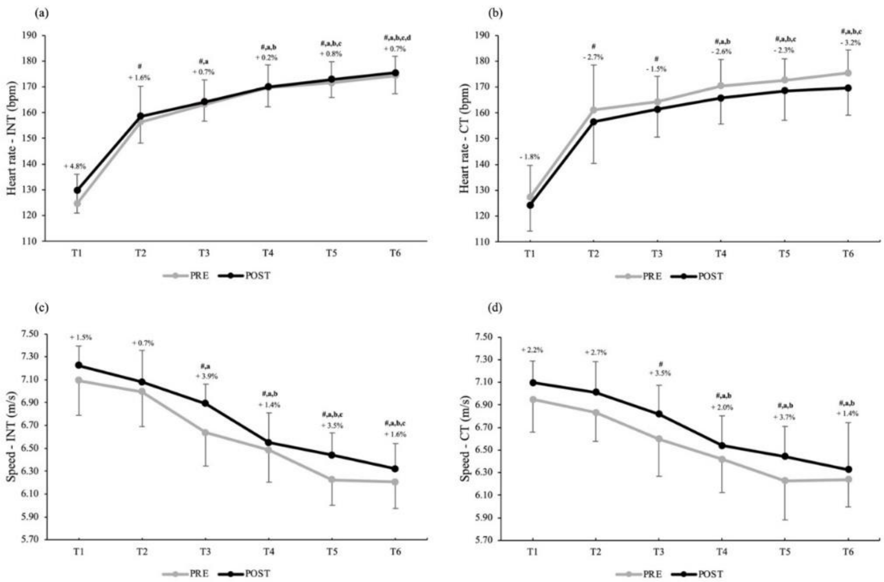
Table 3. Changes of anaerobic performance derived parameters for INT and CT groups

Measures	INT (n = 11)			CT (n = 11)			Group	Time	Group x Time
	PRE	POST	d	PRE	POST	d	p (ES)	P (ES)	p (ES)
AC (watts/kg)	8.34 ± 0.82	8.82 ± 0.69	0.63	8.09 ± 0.80	8.71 ± 0.75	0.80	0.505 (0.04)	0.009* (0.51)	0.687 (0.02)
P_{max} (watts/kg)	10.46 ± 1.45	10.65 ± 0.76	0.16	9.86 ± 1.03	10.49 ± 0.88	0.66	0.270 (0.12)	0.114 (0.23)	0.400 (0.07)
P_{min} (watts/kg)	6.66 ± 0.63	7.08 ± 0.75	0.61	6.46 ± 0.85	7.04 ± 1.14	0.58	0.773 (0.01)	0.043* (0.35)	0.721 (0.01)
Best speed (m/s)	7.14 ± 0.34	7.19 ± 0.17	0.19	7.00 ± 0.25	7.16 ± 0.20	0.71	0.284 (0.11)	0.101 (0.25)	0.443 (0.06)
Fatigue index (%)	7.27 ± 2.56	6.92 ± 1.08	0.18	6.91 ± 2.61	7.29 ± 3.71	0.12	0.997 (0.00)	0.968 (0.00)	0.605 (0.03)
$[La^-]_{0\text{-}min}$ (mmol/L)	11.12 ±3.09	12.91 ± 1.83	0.70	11.44 ± 3.12	11.99 ± 1.63	0.22	0.747 (0.01)	0.088 (0.26)	0.337 (0.09)
$[La^-]_{3\text{-}min}$ (mmol/L)	12.14 ± 2.15	13.67 ± 2.02	0.73	12.34 ± 3.03	13.04 ± 1.82	0.28	0.771 (0.01)	0.017* (0.45)	0.527 (0.04)

*Bold number denotes the main effect of time emerged (p < 0.05).

INT: Intermittent sprint training; ES: main effect size calculated as the partial eta squared (η^2_ρ); d: Cohen's d effect size; $[La^-]_{0\text{-}min}$: Blood lactate concentration at 0-min; $[La^-]_{3\text{-}min}$: Blood lactate concentration at 3-min; CT: Circuit training.

Figure 3. Changes in anaerobic performance throughout 6 trials of sprinting test in INT and CT groups. (a) changes of heart rate in INT group (HR-INT); (b) changes of heart rate in CT group (HR-CT); (c) changes of speed in INT group (Speed-INT); (d) changes of speed in CT group (Speed-CT).



The number indicated the percentage changes between PRE and POST.
* denotes significant different from T1 (p < 0.05); [a] denotes significant different from T2 (p < 0.05); [b] denotes significant different from T3 (p < 0.05); [c] denotes significant different from T4 (p < 0.05); [d] denotes significant different from T5 (p < 0.05).

Analysis of associations

A potential explanation for the improvement in anaerobic performance observed in INT and CT groups during the sixth sprint of the repeated shuttle running test (RAST) was explored by examining the associations among heart rate, blood lactate, anaerobic power, sprinting speed, and sprint time (**Table 4**). For INT group, there was a positive large correlation between anaerobic power (r = 0.673, p = 0.023) and speed (r = 0.659, p = 0.027) with blood lactate. Moreover, the sprinting time also showed large negative correlation with blood lactate (r = -0.647, p = 0.031). While CT group showed large positive correlation between anaerobic power (r = 0.692, p = 0.018) and speed (r = 0.702, p = 0.016) with heart rate. Additionally, Pearson correlation revealed a negative large correlation between anaerobic power (r = -0.603, p = 0.049) and sprinting time (r = -0.706, p = 0.015) with blood lactate.

Table 4. Correlation coefficient between parameters derived from last trial (6th sprint) of anaerobic performance testing of INT and CT groups

INT	Anaerobic power	Speed	Sprinting time
Heart rate	-0.001 (p = 0.999)	-0.006 (p = 0.986)	0.006 (p = 0.986)
Blood lactate	0.673* (p = 0.023)	0.659* (p = 0.027)	-0.647* (p = 0.031)
CT	**Anaerobic power**	**Speed**	**Sprinting time**
Heart rate	0.692* (p = 0.018)	0.702* (p = 0.016)	-0.706* (p = 0.015)
Blood lactate	-0.603* (p = 0.049)	-0.592 (p = 0.055)	0.584 (p = 0.059)

INT: Intermittent sprint training; CT: Circuit training
* Bold text denotes significant correlation (p < 0.05)

Discussion

The present study investigated the effectiveness of two distinct training programs, intermittent sprint training and specific circuit training, over a 4-week period on anaerobic and aerobic performance in varsity soccer players. The results demonstrate that both training programs yield similar beneficial effects on anaerobic performance, including improvements in anaerobic power, anaerobic capacity, and minimum power, as assessed by the repeated sprint test. Furthermore, aerobic performance, measured by maximal oxygen consumption and maximal velocity at VO_2max, also showed significant improvements despite the short duration of the 4-week training period. This study highlights that both training programs are effective in enhancing both anaerobic and aerobic fitness, which are crucial for soccer performance.

Anaerobic fitness is defined as the ability to perform high-intensity activities without sufficient oxygen availability (American College of Sports Medicine, 2013). Our results revealed that athletes exhibited enhanced ability to maintain velocity and power during the repeated sprint test after 4 weeks of training with both additional programs. The intermittent sprint training (INT) program was designed to reflect the demands of soccer matches, where players perform high-speed sprints interspersed with brief rest periods. This training method closely resembles short sprint interval training (sSIT), which consists of repeated sprints followed by short recovery periods, a method that has been shown to offer benefits in previous meta-analyses (Boullosa et al., 2022; Vollaard et al., 2017). Our findings align with those of a previous study (Benítez-Flores et al., 2018), which compared the effects of short sprints (5 seconds) and long sprints (20 seconds) performed with 16 and 4 repetitions, respectively. The study demonstrated that only short sprints (5 seconds) improved anaerobic capacity and minimum power, likely due to enhanced phosphocreatine (PCr) availability and ATP resynthesis (Gaitanos et al., 1993), critical factors for sustaining power output and facilitating recovery (Bogdanis et al., 1996; Forbes et al., 2008). Furthermore, the circuit training program, which utilized bodyweight exercises, also improved anaerobic performance, consistent with previous studies (Myers et al., 2015; Sonchan, 2017). Myers and colleagues (2015) compared the effects of circuit training and combined training, finding that minimum power increased only in the circuit training group, while anaerobic capacity improved in both groups (Myers et al., 2015). Additionally, Sonchan (2017) confirmed that circuit training led to improvements in anaerobic capacity compared to a control group after 8 weeks of training (Sonchan, 2017). In the current study, the circuit training program was designed to mimic the various explosive movements in soccer, incorporating fast-paced exercises without rest intervals. This approach, similar to intermittent sprint training, effectively stimulated the development of anaerobic performance (Mathur, 2022).

Additionally, physiological changes during exercise, as indicated by heart rate and blood lactate levels, are considered internal markers of high-intensity exercise (Karahan, 2020). Our results demonstrated that blood lactate concentration increased at the 3-minute post-rest interval following anaerobic testing, while no significant changes were observed immediately post-test (0 minutes). Notably, running speed and minimum power improved without changes in the fatigue index, despite elevated blood lactate levels and heart rate. During intense exercise, the rate of anaerobic glycolysis increases to provide energy for excitation-contraction coupling mechanisms (Bangsbo, 2014). This anaerobic energy production results in lactate production, the release of hydrogen ions, and subsequent acidosis (Nasuka et al., 2018), which are directly associated with muscle fatigue (McKenna et al., 2008), leading to impaired athletic performance. Oppositely, our study found that athletes demonstrated improved repeated sprint performance during the accumulation of blood lactate. This finding is consistent with previous research, which showed that training methods such as high-intensity exercise (HIE) (Sahlin, 2014) and speed endurance training (SET) (Hostrup & Bangsbo, 2017) can enhance cellular energy production and reduce acidosis by improving the muscle's buffering capacity. Furthermore, a study by Iaia and colleagues (Iaia et al., 2008) investigated the effects of 4 weeks of low-volume, high-intensity sprint training. They observed that glycogen and phosphocreatine utilization during a second bout of intense exercise were reduced, despite higher blood lactate accumulation and longer time to exhaustion. Our findings support these results, demonstrating that short-term sprint training promotes muscle oxidative adaptation and mechanical efficiency, enhancing metabolic stability and delaying impairments in excitation-contraction coupling during intense exercise. Additionally, previous research has shown that sprint training can induce neural adaptations, improving muscle activation sequencing, enhancing fast-twitch motor unit recruitment, and increasing muscle power and anaerobic capacity (Ross et al., 2001). To evaluate the effectiveness of different training programs in practical settings, anaerobic performance is often assessed by an individual's ability to maintain speed and power, particularly during the final sprint of RAST, where minimum anaerobic power is typically observed. Accordingly, examining the relationships between derived physiological variables and performance outcomes can provide valuable insights into the efficacy of each training program. Our analysis revealed a strong correlation between heart rate and measures of anaerobic power, speed, and sprinting time in the CT group, a pattern not observed in the INT group. Interestingly, blood lactate concentration showed a positive correlation with anaerobic power in the INT group, whereas a strong negative correlation was observed in the CT group. These findings align with previous work indicating that buffering of H^+ ions is particularly important during sprint-type exercise, where rapid accumulation of H^+ results from the high rate of non-mitochondrial ATP resynthesis required to sustain power output (Bishop et al., 2004; Edge et al., 2006). Our study also observed a trend of lower lactate accumulation at post-training (0-min) in the CT compared to INT (10.3% vs. 22.4%). This may be explained by the structured combination of resistance and endurance elements in the CT program, which likely enhanced muscle strength and elevated the anaerobic threshold. In contrast, the INT program appeared to influence neuromuscular adaptations more strongly, potentially improving motor unit activation timing and increasing the recruitment and firing rate of fast-twitch fibers [Ross 2001], ultimately contributing to greater improvements in minimum power output (Gaitanos et al., 1993). Therefore, both intermittent sprint training (INT) and circuit training (CT) effectively improve anaerobic performance by enhancing intramuscular buffering capacity and facilitating neural adaptations, leading to improved speed and power maintenance, as observed in this study.

Aerobic performance is a crucial requirement for soccer players, with maximal oxygen uptake (VO_2max) serving as the primary indicator of cardiorespiratory endurance and aerobic fitness (Carey & Richardson, 2003). The present study demonstrated a significant improvement in VO_2max after 4 weeks of intermittent sprint training (INT) and circuit training (CT), with no differences observed between the two training groups. This finding is consistent with previous studies on short-sprint interval training (sSIT) (Ijichi et al., 2015; Parra et al., 2000) and circuit training (Myers et al., 2015; Sonchan, 2017). A recent meta-analysis on sSIT [14] reported that improvements in aerobic performance ranged from 7.4% to 13.9%, depending on the number and duration of sprints, even when the training duration was fixed at 4 weeks (Bayati et al., 2011; Harris et al., 2014; Ijichi et al., 2015; Zelt et al., 2014). Few studies have investigated the effects of sprint training with a sprint duration similar to that used in the present study (<10 seconds). For example, Hellsten-Westing et al. (1993) reported that 6 weeks of sprint training, involving 10-second sprints for 15 repetitions with 50 seconds of rest, resulted in a 2.4% improvement in VO_2max (Hellsten-Westing et al., 1993). In contrast, Hazell et al. (2010) demonstrated that 2 weeks of sprint training, consisting of 6 repetitions interspersed with 120 seconds and 240 seconds of rest, led to VO_2max improvements of 3.9% and 8.5%, respectively (Hazell et al., 2010). However, another study by Skleryk et al. (2013) found a 1.7% decrease in VO_2max after 2 weeks of sprint training with 8-12 repetitions and 80 seconds of rest between sprints (Skleryk et al., 2013). In terms of circuit training, previous studies have shown that it can improve VO_2max after 5 weeks [28] and 8 weeks (Sonchan, 2017). The similarity between these studies and the current study lies in the design of the circuit training program, which involved minimal to no rest between exercises. Thus, the rest duration appears to be a key factor in VO_2max improvements. An inappropriate rest-to-work ratio may hinder improvements in cardiorespiratory fitness. Furthermore, improvements in anaerobic performance may also contribute to enhanced aerobic performance, as they support phosphocreatine (PCr) regeneration and stimulate mitochondrial biogenesis (Little et al., 2010; Scalzo et al., 2014), reducing fatigue and increasing the ability to sustain prolonged exercise (Benítez-Flores et al., 2018; Islam et al., 2017). Therefore, an appropriately designed anaerobic training program can enhance both anaerobic and aerobic fitness in athletes.

This study possesses several strengths that support the validity of the findings. First, a substantial sample size of 22 varsity soccer players who were fully familiarized with both field tests was employed. Second, a parallel, randomized, counterbalanced design was implemented to enhance the reliability of the results. Third, the quality and consistency of both the training and testing protocols were rigorously controlled by a sports scientist. However, the current study also has limitations that should be considered when designing future research. These include 1) the limited measurement of blood lactate concentration at only two time points post-testing, which may not be sufficient to adequately track recovery changes; 2) the absence of subjective measures (e.g., perceived exertion using the Rating of Perceived Exertion [RPE]) during training to assess training intensity; and 3) the lack of a control group performing only the standard training protocols in the team's schedule. Therefore, future research should aim to include a control group and assess training effects over multiple time points, incorporating both objective and subjective measures to better evaluate the internal and external training load associated with each training program for varsity soccer players.

Conclusions

Our findings highlight the beneficial effects of two practical training programs (intermittent sprint training and circuit training) on enhancing both aerobic and anaerobic performance in varsity soccer players over a 4-week period. This study is the first to compare the effectiveness of these training programs within such a short timeframe. However, the underlying mechanisms driving these improvements remain limited and warrant further investigation. Considering the favorable safety profile and demonstrated performance enhancements, coaches and sport scientists are encouraged to incorporate these training programs to improve critical performance attributes in soccer players, particularly in time-constrained training environments.

Acknowledgements

The authors would like to thank all the participants from the soccer club who took part to the study along with all the students who cooperated during the data collection.

Financing

The author acknowledges the financial support by the College of Sports Science and Technology, Mahidol University.

References

Aguiar, M., Abrantes, C., Vitor, M., Leite, N., Sampaio, J., & Ibáñez, S. (2008). Effects of intermittent or continuous training on speed, jump and repeated-sprint ability in semi-professional soccer players. *Open Sports Sci J*, *1*, 15-19. https://doi.org/10.2174/1875399X00801010015

American College of Sports Medicine. (2013). *ACSM's guidelines for exercise testing and prescription*. Lippincott williams & wilkins.

Andrade, V., Zagatto, A., Kalva-Filho, C., Mendes, O., Gobatto, C., Campos, E., & Papoti, M. (2015). Running-based anaerobic sprint test as a procedure to evaluate anaerobic power. *Int J Sports Med*, *36*(14), 1156-1162. https://doi.org/10.1055/s-0035-1555935

Bangsbo, J. (2014). *Physiological demands of football*. Gatorade Sports Science Institute (GSSI). https://www.gssiweb.org/sports-science-exchange/article/sse-125-physiological-demands-of-football

Bayati, M., Farzad, B., Gharakhanlou, R., & Agha-Alinejad, H. (2011). A practical model of low-volume high-intensity interval training induces performance and metabolic adaptations that resemble 'all-out' sprint interval training. *J Sports Sci Med*, *10*(3), 571-576.

Benítez-Flores, S., de Sousa, A. F. M., da Cunha Totó, E. C., Santos Rosa, T., Del Rosso, S., Foster, C., & Boullosa, D. (2018). Shorter sprints elicit greater cardiorespiratory and mechanical responses with less fatigue during time-matched sprint interval training (SIT) sessions. *Kinesiology*, *50*(2), 137-148. https://doi.org/10.26582/k.50.2.13

Bishop, D., Edge, J., & Goodman, C. (2004). Muscle buffer capacity and aerobic fitness are associated with repeated-sprint ability in women. *Eur J Appl Physiol*, *92*(4-5), 540-547. https://doi.org/10.1007/s00421-004-1150-1

Bogdanis, G. C., Nevill, M. E., Boobis, L. H., & Lakomy, H. K. (1996). Contribution of phosphocreatine and aerobic metabolism to energy supply during repeated sprint exercise. *J Appl Physiol (1985)*, *80*(3), 876-884. https://doi.org/10.1152/jappl.1996.80.3.876

Boullosa, D., Dragutinovic, B., Feuerbacher, J. F., Benítez-Flores, S., Coyle, E. F., & Schumann, M. (2022). Effects of short sprint interval training on aerobic and anaerobic indices: A systematic review and meta-analysis. *Scand J Med Sci Sports 32*(5), 810-820. https://doi.org/10.1111/sms.14133

Carey, D. G., & Richardson, M. T. (2003). Can aerobic and anaerobic power be measured in a 60-second maximal test? *J Sports Sci Med*, *2*(4), 151-157.

Cavar, M., Marsic, T., Corluka, M., Culjak, Z., Cerkez Zovko, I., Müller, A., Tschakert, G., & Hofmann, P. (2019). Effects of 6 weeks of different high-intensity interval and moderate continuous training on aerobic and anaerobic performance. *J Strength Cond Res*, *33*(1), 44-56. https://doi.org/10.1519/jsc.0000000000002798

Dupont, G., Akakpo, K., & Berthoin, S. (2004). The effect of in-season, high-intensity interval training in soccer players. *J Strength Cond Res*, *18*(3), 584-589. https://doi.org/10.1519/1533-4287(2004)18<584:Teoihi>2.0.Co;2

Edge, J., Hill-Haas, S., Goodman, C., & Bishop, D. (2006). Effects of resistance training on H+ regulation, buffer capacity, and repeated sprints. *Med Sci Sports Exerc*, *38*(11), 2004-2011. https://doi.org/10.1249/01.mss.0000233793.31659.a3

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*, *39*(2), 175-191. https://doi.org/10.3758/bf03193146

Fernandes-da-Silva, J., Castagna, C., Teixeira, A. S., Carminatti, L. J., & Guglielmo, L. G. (2016). The peak velocity derived from the Carminatti Test is related to physical match performance in young soccer players. *J Sports Sci*, *34*(24), 2238-2245. https://doi.org/10.1080/02640414.2016.1209307

Forbes, S. C., Slade, J. M., & Meyer, R. A. (2008). Short-term high-intensity interval training improves phosphocreatine recovery kinetics following moderate-intensity exercise in humans. *Appl Physiol Nutr Metab*, *33*(6), 1124-1131. https://doi.org/10.1139/h08-099

Gaitanos, G. C., Williams, C., Boobis, L. H., & Brooks, S. (1993). Human muscle metabolism during intermittent maximal exercise. *J Appl Physiol (1985)*, *75*(2), 712-719. https://doi.org/10.1152/jappl.1993.75.2.712

Gastin, P. B., Meyer, D., Huntsman, E., & Cook, J. (2015). Increase in injury risk with low body mass and aerobic-running fitness in elite Australian football. *Int J Sports Physiol Perform*, *10*(4), 458-463. https://doi.org/10.1123/ijspp.2014-0257

Harris, E., Rakobowchuk, M., & Birch, K. M. (2014). Sprint interval and sprint continuous training increases circulating CD34+ cells and cardio-respiratory fitness in young healthy women. *PLoS One*, *9*(9), e108720. https://doi.org/10.1371/journal.pone.0108720

Hazell, T. J., Macpherson, R. E., Gravelle, B. M., & Lemon, P. W. (2010). 10 or 30-s sprint interval training bouts enhance both aerobic and anaerobic performance. *Eur J Appl Physiol*, *110*(1), 153-160. https://doi.org/10.1007/s00421-010-1474-y

Hellsten-Westing, Y., Balsom, P. D., Norman, B., & Sjödin, B. (1993). The effect of high-intensity training on purine metabolism in man. *Acta Physiol Scand*, *149*(4), 405-412. https://doi.org/10.1111/j.1748-1716.1993.tb09636.x

Hostrup, M., & Bangsbo, J. (2017). Limitations in intense exercise performance of athletes - effect of speed endurance training on ion handling and fatigue development. *J Physiol*, *595*(9), 2897-2913. https://doi.org/10.1113/JP273218

Iaia, F. M., Thomassen, M., Kolding, H., Gunnarsson, T., Wendell, J., Rostgaard, T., Nordsborg, N., Krustrup, P., Nybo, L., Hellsten, Y., & Bangsbo, J. (2008). Reduced volume but increased training intensity elevates muscle Na+-K+ pump alpha1-subunit and NHE1 expression as well as short-term work capacity in humans. *Am J Physiol Regul Integr Comp Physiol*, *294*(3), R966-974. https://doi.org/10.1152/ajpregu.00666.2007

Ijichi, T., Hasegawa, Y., Morishima, T., Kurihara, T., Hamaoka, T., & Goto, K. (2015). Effect of sprint training: training once daily versus twice every second day. *Eur J Sport Sci*, *15*(2), 143-150. https://doi.org/10.1080/17461391.2014.932849

Islam, H., Townsend, L. K., Dunn, E., Eys, M., Robertson-Wilson, J., & Hazell, T. J. (2017). Modified sprint interval training protocols. Part II. Psychological responses. *Appl Physiol Nutr Metab*, *42*(4), 347-353. https://doi.org/10.1139/apnm-2016-0479

Joseph, J., Woods, C., & Joyce, C. (2020). Relationship between repeated kicking performance and maximal aerobic capacity in elite junior Australian football. *J Strength Cond Res*, *34*(8), 2294-2301. https://doi.org/10.1519/jsc.0000000000002220

Karahan, M. (2020). Effect of skill-based training vs. small-sided games on physical performance improvement in young soccer players. *Biol Sport*, *37*(3), 305-312. https://doi.org/10.5114/biolsport.2020.96319

Klika, B., & Jordan, C. (2013). High-intensity circuit training using body weight: Maximum results with minimal investment. *ACSMs Health Fit J*, *17*(3), 8-13. https://doi.org/10.1249/FIT.0b013e31828cb1e8

Léger, L. A., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *J Sports Sci*, *6*(2), 93-101. https://doi.org/10.1080/02640418808729800

Little, J. P., Safdar, A., Wilkin, G. P., Tarnopolsky, M. A., & Gibala, M. J. (2010). A practical model of low-volume high-intensity interval training induces mitochondrial biogenesis in human skeletal muscle: potential mechanisms. *J Physiol*, *588*(6), 1011-1022. https://doi.org/10.1113/jphysiol.2009.181743

Mathur, C. (2022). Effect of circuit training on agility and anaerobic power among college-level football players. *Bull Env Pharmacol Life Sci*, *11*(6), 132-137.

McKenna, M. J., Bangsbo, J., & Renaud, J. M. (2008). Muscle K+, Na+, and Cl disturbances and Na+-K+ pump inactivation: implications for fatigue. *J Appl Physiol (1985)*, *104*(1), 288-295. https://doi.org/10.1152/japplphysiol.01037.2007

Myers, T. R., Schneider, M. G., Schmale, M. S., & Hazell, T. J. (2015). Whole-body aerobic resistance training circuit improves aerobic fitness and muscle strength in sedentary young females. *J Strength Cond Res*, *29*(6), 1592-1600. https://doi.org/10.1519/jsc.0000000000000790

Nasuka, N., Santosa, I., Setiowati, A., & Indrawati, F. (2018). Anaerobic capacity and blood lactate level of former elite athletes. *IOP Conf Ser Mater Sci Eng*, *434*(1), 012157. https://doi.org/10.1088/1757-899X/434/1/012157

Orendurff, M. S., Walker, J. D., Jovanovic, M., Tulchin, K. L., Levy, M., & Hoffmann, D. K. (2010). Intensity and duration of intermittent exercise and recovery during a soccer match. *J Strength Cond Res*, *24*(10), 2683-2692. https://doi.org/10.1519/JSC.0b013e3181bac463

Ortiz, J. G., de Lucas, R. D., Teixeira, A. S., Mohr, P. A., & Guglielmo, L. G. A. (2024). The effects of a supramaximal intermittent training program on aerobic and anaerobic running measures in junior male soccer players. *J Hum Kinet*, *90*, 253-267. https://doi.org/10.5114/jhk/170755

Parra, J., Cadefau, J. A., Rodas, G., Amigó, N., & Cussó, R. (2000). The distribution of rest periods affects performance and adaptations of energy metabolism induced by high-intensity training in human muscle. *Acta Physiol Scand*, *169*(2), 157-165. https://doi.org/10.1046/j.1365-201x.2000.00730.x

Rampinini, E., Bishop, D., Marcora, S. M., Ferrari Bravo, D., Sassi, R., & Impellizzeri, F. M. (2007). Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *Int J Sports Med*, *28*(3), 228-235. https://doi.org/10.1055/s-2006-924340

Rebelo, A., Brito, J., Seabra, A., Oliveira, J., & Krustrup, P. (2014). Physical match performance of youth football players in relation to physical capacity. *Eur J Sport Sci*, *14 Suppl 1*, S148-156. https://doi.org/10.1080/17461391.2012.664171

Ross, A., Leveritt, M., & Riek, S. (2001). Neural influences on sprint running: training adaptations and acute responses. *Sports Med*, *31*(6), 409-425. https://doi.org/10.2165/00007256-200131060-00002

Sahlin, K. (2014). Muscle energetics during explosive activities and potential effects of nutrition and training. *Sports Med*, *44 Suppl 2*(Suppl 2), S167-173. https://doi.org/10.1007/s40279-014-0256-9

Sammoud, S., Bouguezzi, R., Negra, Y., & Chaabene, H. (2021). The Reliability and Sensitivity of Change of Direction Deficit and Its Association with Linear Sprint Speed in Prepubertal Male Soccer Players. *J Funct Morphol Kinesiol*, *6*(2). https://doi.org/10.3390/jfmk6020041

Scalzo, R. L., Peltonen, G. L., Binns, S. E., Shankaran, M., Giordano, G. R., Hartley, D. A., Klochak, A. L., Lonac, M. C., Paris, H. L., Szallar, S. E., Wood, L. M., Peelor, F. F., 3rd, Holmes, W. E., Hellerstein, M. K., Bell, C., Hamilton, K. L., & Miller, B. F. (2014). Greater muscle protein synthesis and mitochondrial biogenesis in males compared with females during sprint interval training. *FASEB J*, *28*(6), 2705-2714. https://doi.org/10.1096/fj.13-246595

Siahkouhian, M., Khodadadi, D., & Shahmoradi, K. (2013). Effects of high-intensity interval training on aerobic and anaerobic indices: Comparison of physically active and inactive men. *Sci Sports*, *28*(5), e119-e125. https://doi.org/10.1016/j.scispo.2012.11.006

Skleryk, J. R., Karagounis, L. G., Hawley, J. A., Sharman, M. J., Laursen, P. B., & Watson, G. (2013). Two weeks of reduced-volume sprint interval or traditional exercise training does not improve metabolic functioning in sedentary obese men. *Diabetes Obes Metab*, *15*(12), 1146-1153. https://doi.org/10.1111/dom.12150

Sonchan, W. (2017). The effects of a circuit training program on muscle strength agility anaerobic performance and cardiovascular endurance. *Int J Sports Health Sci 11*(4).

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: an update. *Sports Med*, *35*(6), 501-536. https://doi.org/10.2165/00007256-200535060-00004

Vollaard, N. B. J., Metcalfe, R. S., & Williams, S. (2017). Effect of number of sprints in an SIT session on change in V O2max: A meta-analysis. *Med Sci Sports Exerc*, *49*(6), 1147-1156. https://doi.org/10.1249/MSS.0000000000001204

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

Zagatto, A. M., Beck, W. R., & Gobatto, C. A. (2009). Validity of the running anaerobic sprint test for assessing anaerobic power and predicting short-distance performances. *J Strength Cond Res*, *23*(6), 1820-1827. https://doi.org/10.1519/JSC.0b013e3181b3df32

Zarrinkalam, E., ranjbar, k., & Davoudi, M. (2022). Comparing the effects of eight weeks of low-volume and high-volume High Intensity interval training on lactate response and some performance indicators of soccer players. *New approaches Exerc Physiol (Online)*, *4*(8), 128-141. https://doi.org/10.22054/nass.2023.72704.1127

Zelt, J. G., Hankinson, P. B., Foster, W. S., Williams, C. B., Reynolds, J., Garneys, E., Tschakovsky, M. E., & Gurd, B. J. (2014). Reducing the volume of sprint interval training does not diminish maximal and submaximal performance gains in healthy men. *Eur J Appl Physiol*, *114*(11), 2427-2436. https://doi.org/10.1007/s00421-014-2960-4

Authors' and translators' details:

Arom Treeraj	arom.tre@mahidol.ac.th	Author
Chawannat Choodam	chawannat.cho@mahidol.ac.th	Author
Giancarlo Condello	giancarlo.condello@gmail.com	Author
Chutimon Khemtong	chutimon.khe@mahidol.ac.th	Author