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# Morning sprint interval training produces greater physical performance adaptations than evening training in soccer players

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**While the literature provides evidence supporting the effectiveness of evening sprint interval training (SIT), there remains a limited amount of research investigating the effects of morning SIT among soccer athletes. This study examined the effects of morning versus evening SIT during the preparatory phase on physical and physiological performance in collegiate soccer players. Thirty male players volunteered to participate in the study and were randomly divided into morning, evening, or control groups, each group consisting of 10 subjects. The evaluation of physical (countermovement vertical jump [CMVJ], 20-m sprint, Illinois change of direction, and Yo-Yo intermittent recovery test level 1 [Yo-Yo IR1]) and physiological (graded exercise test and Wingate anaerobic power test) performance took place prior to and following the 7-week SIT, both in the morning and evening testing sessions. Both training groups showed significant improvements in physical and physiological performance from pre- to post-training, regardless of testing session timing ($p < 0.05$). The morning SIT group exhibited greater adaptive changes ($p < 0.05$) compared to the evening SIT group in CMVJ, 20-m sprint, Yo-Yo IR1, peak and mean power outputs at both the morning and evening testing sessions. These findings suggest that male soccer players can benefit from both morning and evening SIT sessions; however, conducting SIT in the morning could result in greater adaptive changes than evening training. To optimize physical performance adaptations, coaches should schedule SIT sessions in the morning. It is recommended to schedule conditioning workouts in the morning and team practices in the afternoon for optimal adaptations.**

**Keywords** Interval training, Team sport, Aerobic power, Athletic performance, Anaerobic power

Soccer is defined as a high-intensity team sport that features intermittent bursts of intense activity, alternating with periods of lower intensity movements[1–3]. The execution of short-distance sprints is crucial in soccer, with the typical duration of these sprints during matches averaging approximately 5 s, highlighting the significant requirement for acceleration speed[4]. An excellent performance in soccer depends on the interaction of well-developed technical, tactical, and physical performance[3]. The aerobic system is the primary energy source utilized during gameplay, with studies demonstrating a positive correlation between aerobic fitness and the rapid recovery of power in successive high-intensity interval exercises[3]. Although aerobic capacity is more significant during lower-intensity activities, it plays a vital role in expediting recovery and sustaining performance throughout matches[4,5]. In contrast, anaerobic metabolism contributes energy for high-intensity movements such as sprinting, changing direction, and jumping[6,7]. Consequently, both aerobic and anaerobic metabolic pathways are essential for optimal soccer performance, making the selection of effective training strategies to enhance these attributes critically important[7].

Various training methods including high-intensity interval training[7], plyometric training[8] and concurrent training[9] have been introduced to improve the physical performance (i.e., jumping and sprinting speed and change of direction ability) in soccer players. However, recent research has shown that the integration of sprint interval training (SIT) lasting less than 10 s for soccer players can yield adaptive responses similar or greater to other training models[4,10]. This form of training not only improves jump and sprint performance but also enhances cardiorespiratory fitness and anaerobic power, all while minimizing perceived exertion and fatigue[4,10].

It is crucial for collegiate soccer players to allocate specific training methods for their preparation. Given the limited time available during the conditioning phase, a well-structured annual training plan can facilitate

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optimal adaptations, thereby enhancing physical performance[11]. Consequently, implementing SIT during the preparation phase may enable players to achieve peak performance in their physical (i.e., jumping and sprinting ability) and physiological components (i.e., cardiorespiratory fitness and anaerobic power), ultimately improving their outcomes in collegiate competitions[2,4]. In fact, to optimize SIT prescription during the preparatory phase of annual training plan, multiple elements are taken into account[12]; however, one alternative variable typically missed in designing SIT is the *time of day*, which significantly affects human performance and should be considered in the athletic conditioning schedule[13]. Despite its importance, the effect of training time on SIT adaptations remains underexplored, particularly in soccer players.

More importantly, the absence of time in conditioning programs for collegiate athletes allows for the implementation of various components of conditioning or soccer training throughout the day, which can be beneficial for the athletes' development[11]. As a result, conditioning program and soccer training should be manipulating through a training day for optimizing adaptations. Regarding the variations in human performance throughout the day[14,15], it appears that individuals exhibit superior performance in short-duration, high-intensity exercises lasting under 6 s, such as jumping and sprinting, as well as in their change of direction ability, during the evening compared to the morning[16,17]. This indicates that scheduling training interventions at particular times of the day may serve as an effective approach to mitigate the effects of daily performance fluctuations on physical capabilities, as proposed by Mirizio et al.[14]. Given the importance of SIT for soccer performance and the potential influence of training timing, this study investigates how morning and evening SIT sessions impact physical performance adaptations during the preparatory phase. Additionally, a large number of previous studies have typically used SIT in the afternoon[2,4,5,7], and the effectiveness of morning SIT during the preparatory phase of annual training cycle remains unknown. Given the factors mentioned earlier, it is imperative to analyze whether engaging in SIT during the morning can lead to comparable or varying improvements in the physical and physiological capabilities of soccer players than evening, as extensively documented in prior research. It is of utmost importance, therefore, for soccer players, coaches, and trainers with an interest in conditioning to determine the impact of participation in SIT during morning or evening hours to optimize training adaptability during preparatory phase of annual training cycle. Therefore, this study aims to compare the effects of 7 weeks of morning and evening SIT on physical and physiological adaptations in collegiate male soccer players during the preparatory phase.

## Materials and methods

### Study design

A randomized-controlled design was employed to evaluate the impact of morning vs. evening SIT on physical and physiological performance adaptations in male soccer players during preparatory phase (i.e., preseason) of annual training period. The study lasted ten weeks (1-week familiarization, 1-week pre-test, 7-week training, and 1-week post-test) (Table 1). During the week 1, all players were familiarized with study design and aims as well as explanations of SIT protocols. In addition, they were performed some trials in the exercise tests (i.e., practice of tests) to become familiar with testing procedures. The researchers measured anthropometric parameters during a laboratory familiarization session with all participants. The physical performance tests included countermovement vertical jump (CMVJ), 20-m sprint, Illinois change of direction (CoD) speed, and Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1). The physiological parameters were assessing maximum oxygen uptake ($VO_{2max}$), peak power output (PPO) and average power output (APO). Participants underwent four testing sessions (i.e., 2 days in the morning and 2 days in the evening) prior to (pre) and following six weeks of SIT (post). To address the potential sources of bias, participants were required to complete the identical performance test battery on two different occasions in random order: once at 8:00 A.M. and again at 5:00 P.M both at pre and post-training duration. The order of testing times was randomized for each participant. For example, a player might take the CMVJ test first in the evening and subsequently in the morning. This methodology was consistently applied to each participant during both pre- and post-testing phases.

### Sample size calculation and randomization

The study referred to the research conducted by Arazi et al.[2] in order to determine the appropriate sample size for this particular study. The findings indicated that SIT had a positive impact on the cardiorespiratory performance adaptations of soccer players. G*Power software (Version 3.1.9.2, University of Kiel, Germany) was

| | | Pre test | Training intervention | Post test |
|---|---|---|---|---|
| Week 1 | | Week 2 | Week 3–9 | Week 10 |
| Familiarization | Week days | Time | Intervention | Time |
| Height | Monday | 8AM | Soccer training | 8AM |
| Weight | Tuesday | 5PM | SIT | 5PM |
| | Wednesday | - | Soccer training | - |
| | Thursday | - | SIT | - |
| | Friday | 8AM | Soccer training | 8AM |
| | Saturday | 5PM | SIT | 5PM |
| | Sunday | - | Rest | - |

**Table 1**. Study design.

employed to determine the necessary sample size, utilizing the statistical test of "ANOVA/repeated measures/ within–between interaction." The analysis was based on an anticipated effect size (f) of 0.25, a significance level (α) of 0.05, a desired statistical power of 0.90, and a correlation coefficient of 0.5, which indicated that a total sample size of $n = 24$ (i.e., 8 subjects per group) was required[2]. However, to account for potential participant dropout during data collection, the sample size was subsequently increased to 10 participants per group. The randomization sequence was generated electronically using the website (https://www.randomizer.org) and remained undisclosed until the interventions were assigned. Furthermore, the assignments within the group were determined by chance, leading to unpredictability for both the authors and the participants.

## Participants

Thirty male soccer players (twelve defenders, twelve midfielders, and six attackers), who were members of a College Division II Soccer Team, volunteered to participate in the study and were randomly divided into three groups consisting of morning SIT (MSIT, $n = 10$, age = 22.6 ± 2.3 y, height = 1.78 ± 0.09 m, weight = 76.8 ± 3.5 kg, soccer training age = 5.3 ± 2.2 y), evening SIT (ESIT, $n = 10$, age = 23.2 ± 3.1 y, height = 1.79 ± 0.1 m, weight = 78.2 ± 2.8 kg, soccer training age = 5.5 ± 3.1 y), or control group (CON, $n = 10$, age = 23.5 ± 2.8 y, height = 1.75 ± 0.8 m, weight = 78.8 ± 3.3 kg, soccer training age = 5.8 ± 3.2 y). The athletes were engaged in the yearly preparatory stage, particularly focusing on a specific phase of the training regimen prior to their participation in the competition. They were familiar with different forms of interval training but not engaged in all-out SIT during the three months preceding this study. The subjects were excluded if they had (1) lower body injuries sustained within the past three months and (2) any medical or orthopedic conditions that could hinder participation or performance, which a physician confirmed. All participants provided informed consent, and the study received approval from the Ethics Committee of the Wuhan Sports University. The study was conducted according to the ethical guidelines outlined in the Declaration of Helsinki.

## Players' chronotype

The Morningness-Eveningness Questionnaire by Horne and Östberg[18] was employed to assess the chronotype of athletes using a self-reported questionnaire with 19 items. This tool determines whether an individual lean towards being a morning person or an evening person based on their sleep habits, wake patterns, and preferred times for physical and mental activities. Scores on the questionnaire range from 16 to 96, with lower scores indicating a preference for evening activities and higher scores indicating a preference for morning activities. According to Horne and Östberg's classification system, scores between 16 and 41 indicate evening types, scores between 42 and 58 indicate intermediate types, and scores between 59 and 86 indicate morning types. Consequently, 16 players were classified as intermediate types, 7 players as evening types, and 7 players as morning types.

## Procedures

All participants were directed to maintain their regular daily activities and dietary intake throughout the study to ensure consistency. In addition, the players were from the same soccer team that have similar training schedule to control consistency of training load in between the individuals. A personal interview was conducted to verify that the participants complied with the study protocol through the use of dietary logs and training diaries. Before the tests, they underwent a standard warm-up routine lasting 15 min, including 10 min of low-intensity running, followed by 5 min of active stretching, and then three submaximal trials for each test. The performance tests were conducted on a natural grass pitch used for soccer, with the temperature ranging from 27 to 29° and relative humidity ranging from 65 to 70%. To maintain consistency in the tests, participants were instructed to wear the same footwear for both the pre- and post-test.

## Anthropometric measurements

Standing body height and weight were measured while wearing light clothing and without shoes. Height was assessed with a fixed stadiometer (Bodymeter, Germany) to the nearest 0.1 cm, while body mass was measured using a digital scale (Tanita, Tokyo, Japan) with a precision of 0.1 kg.

## Countermovement vertical jump measurement

A wall-mounted vertical jump tester (VERTEC Power System, USA) positioned on the soccer grass pitch was utilized evaluated the CMVJ. After completing the warm-up, each participant executed three maximal jumps, with a 30-second rest period between each attempt, adhering to established protocols. This involved initiating a countermovement knee flexion until reaching parallel of land without utilizing their arms. It was emphasized that all participants should land upright and flex their knees upon landing. The highest score attained in each test was selected for further analysis[19].

## Linear sprint measurement

To evaluate soccer players' sprint performance, 20-m linear sprint test was conducted using two photocell gates (Brower Timing Systems, Draper, UT, USA) placed at the 0-m, and 20-m marks. The players were instructed to initiate the sprint test standing with their preferred foot forward positioned 0.5 m behind the starting line. The sprint test began as the subject passed the first gate at the 0-m mark and continued until they passed the 20-m gates. The photocell gates were positioned at hip level, approximately 0.7 m above the floor. The subjects performed three maximal trials, with a one-minute rest period between each trial, and the best score was recorded for further analysis[20].

## Illinois CoD speed measurement

The Illinois test was employed to assess the CoD capability of soccer players. This test evaluated their capacity to accelerate, decelerate, change directions, and run at various angles. The participants initiated the run from a stationary position upon receiving the command "Go," sprinted for a distance of 10 m, executed a turn, and returned to the starting line. Upon reaching the starting line, they maneuvered through a zig-zag pattern formed by four markers and completed two additional 10-meter sprints. The final CoD time was determined by recording the fastest time achieved in the two trials using photocells (Brower Timing Systems, Draper, UT, USA), which provided an accuracy of 0.001 s[21].

## Yo-Yo intermittent recovery test level 1 measurement

The Yo-Yo IR1 is commonly utilized as a standardized fitness assessment to measure the aerobic capacity of soccer players[22]. The participants completed two trials of a 20-m sprint test as part of a specific warm-up, followed by shuttle runs on a 20-m track with 10 s of rest. Until the participant reached voluntary exhaustion, these trials were repeated and the total distance covered was recorded for subsequent statistical analysis.

## $\dot{V}$O2max measurement

To assess the $VO_{2max}$ of the participants, a graded exercise test was performed on a treadmill (SportsArt, USA) which involved the use of a breath-by-breath gas collection system (Hans Rudolph Inc. Shawnee, KS, USA), as previously described. In brief, the test initiated at a speed of 8 km/hour and incremented by 1 km/hour every 3 min until participants reached a point of volitional exhaustion. There were various criteria to determine the athlete to achieve the $VO_{2max}$, including (a) stabilization of VO2 despite an increase in workload, (b) a respiratory exchange ratio exceeding 1.1, (c) a blood lactate concentration of 8 mmol/L or higher, and (d) a maximum heart rate equal to or greater than 95% of the age-predicted maximum (220 - age)[23].

## Lower body power measurement

A 30-second maximal Wingate anaerobic test was conducted to assess the PPO and APO of the lower body using a mechanically braked cycle ergometer (model 894E, Monark, Sweden). With the resistance adjusted to 0.075 kg.kg−1 of the participants' body mass, the players initiated the test by pedaling at maximum speed against the device's inertial resistance, and then a personalized load was added. To ensure participants maintained their maximum effort, verbal encouragement was provided throughout the 30-second duration. PPO was determined as the highest power achieved at the 5-second mark, while APO represented the average power output throughout the entire test[4].

## Training program

All players in different groups including MSIT, ESIT and CON groups engaged in soccer practices, specifically technical and tactical practice, on Mondays, Wednesdays, and Fridays in the afternoon. The MSIT and ESIT groups followed a training schedule, completing their program on Tuesdays, Thursdays, and Saturday, while the CON group did not perform SIT program and continued their soccer training plans through the study duration. These sessions took place either at 8AM or 5PM on a soccer grass pitch (Table 2). Before commencing their respective programs, all participants underwent a 15-minute warm-up routine including 10 min of low-intensity running and 5 min of stretching and ballistic movements. The SIT program for soccer players was developed based on a previous review study by Boullosa and colleagues[10]. It consisted of four sets of 10 × 5-second (i.e., ~ 30-m distance) all-out running with a 1:3 recovery between efforts and a 3-minute rest between sets. Following each SIT session, the participants engage in a 10-minute cool-down period, which involves 5 min of light running and 5 min of stretching exercises. Consequently, every SIT session for soccer players comprises a 15-minute warm-up, a 22-minute SIT session, and a 10-minute cool-down, totaling approximately 50 min. A strength and conditioning coach closely supervised all training sessions. This coach provided verbal encouragement to ensure that each participant exerted maximal effort. To clarify the training load, the rating of perceived exertion (RPE) was recorded using the Borg 0–10 RPE Scale around ten minutes following training sessions[24]. The RPE was measured after each SIT sessions. In addition, the RPE and the training time (i.e., minutes) were recorded to clarify workload parameters[25].

## Data analysis

Statistical calculations were conducted using SPSS software version 26.0 (IBM®, Chicago, IL). Results are expressed as mean ± *SD*. Shapiro-Wilk's tests checked the normality of the distribution. To determine differences between groups, a 3 (MSIT, ESIT, CON) × 2 (8AM, 5PM) × 2 (pre, post) analysis of variance (ANOVA) by Bonferroni post-hoc test was utilized. The significance level was set at 0.05. Customized Excel spreadsheets

| | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|---|---|---|---|---|---|---|---|
| Morning session (8AM) | Video or multidisciplinary activities | SIT for morning group | Recovery | SIT for morning group | Video or multidisciplinary activities | SIT for morning group | Recovery |
| Evening session (5PM) | Technical-tactical training | SIT for evening group | Specific soccer training (i.e. small sided games) | SIT for evening group | Technical-tactical training | SIT for evening group | Recovery |

**Table 2.** An overview the training program for a one-week example during the experimental period.

were employed for the calculation of all effect size (ES) statistics. Hedge's g, utilizing pooled standard deviation, was specifically chosen to compute the ES for all measures. The magnitude of the ES statistics was categorized as follows: < 0.2: Trivial, 0.2–0.6: Small, 0.6–1.2: Moderate, 1.2–2.0: Large, 2.0–4.0: Very large, and > 4.0: Nearly perfect[26]. Additionally, the ES is presented alongside the 95% confidence interval (CI) for all analyzed measures. To compare sRPE and training loads between the MSIT and ESIT groups, the t-test was employed.

## Results

In the current study, every subject exhibited absolute compliance, achieving a perfect 100% rate. Moreover, there were no reported injuries in relation to the training interventions employed. Before the training, there were no notable differences observed between the groups. Furthermore, the CON group did not display significant changes in their variable measures from pre- to post-training ($p > 0.05$). Following the 7-week training duration, both the MSIT and ESIT groups demonstrated significant differences compared with the pre-intervention with ES ranging small to very large as well as CON group that showed trivial ES in all physical and physiological performance tests conducted in the morning and evening testing sessions ($p < 0.05$) (Table 3).

In the CMVJ test, the MSIT group exhibited moderate ES improvements, whereas the ESIT group displayed only small ES improvements (Fig. 1A). Similarly, in the 20-m sprint performance, the MSIT group indicated moderate ES, in contrast to the small ES observed in the ESIT group (Fig. 1B). Furthermore, the MSIT group demonstrated a very large ES regarding the magnitude of changes in the Yo-Yo IR1, while the ESIT group achieved a large ES (Fig. 2B). Additionally, the MSIT group showed large ES improvements, compared to the moderate ES improvements noted in the ESIT group for both the PPO (Fig. 3B) and APO (Fig. 3C) following the training intervention.

Although both groups demonstrated significant within-group improvements in Illinois CoD speed (large ES) (Fig. 2) and $VO_{2max}$ (moderate ES) (Fig. 3A), no significant differences ($p > 0.05$) were observed between MSIT and ESIT.

Table 4 presents the mean RPE for the SIT sessions (sRPE), along with the training load calculated as sRPE multiplied by training duration in minutes. Throughout the training period, both the MSIT and ESIT groups exhibited similar sRPE values and training loads, with no significant differences ($p > 0.05$) observed between the morning and evening SIT regimens.

## Discussion

The objective of this study was to investigate the effects of a 7-week SIT conducted in the morning compared to the evening on the physical and physiological performance adaptations of male soccer players during the preparatory phase, particularly in the preseason of the annual training cycle. The results of this study indicated that both the MSIT and ESIT are effective in enhancing the physical and physiological performance of soccer

| Variables | Groups | Morning testing session | | Δ% | Interaction | Evening testing session | | Δ% | Interaction |
|---|---|---|---|---|---|---|---|---|---|
| | | Pre-test | Post-test | | | Pre-test | Post-test | | |
| CMVJ (cm) | MSIT | 40.8 ± 3.5 | 45.1 ± 3.4*† | 10.5 | | 42.1 ± 3.2 | 46.1 ± 3.5*† | 9.5 | |
| | ESIT | 41.2 ± 3.6 | 43.1 ± 3.5* | 4.6 | P = 0.001 | 42.5 ± 3.2 | 44.3 ± 3.3* | 4.2 | P = 0.001 |
| | CON | 40.8 ± 3.4 | 41.1 ± 3.6 | NA | | 42.5 ± 3.2 | 42.2 ± 3.0 | NA | |
| 20-m sprint (sec) | MSIT | 3.98 ± 0.27 | 3.72 ± 0.25*† | -6.5 | | 3.83 ± 0.29 | 3.61 ± 0.32*† | -5.7 | |
| | ESIT | 3.97 ± 0.25 | 3.86 ± 0.28* | -2.7 | P = 0.001 | 3.82 ± 0.28 | 3.68 ± 0.26* | -3.6 | P = 0.001 |
| | CON | 3.99 ± 0.23 | 3.97 ± 0.26 | NA | | 3.84 ± 0.30 | 3.83 ± 0.29 | NA | |
| Illinois CoD (sec) | MSIT | 18.77 ± 0.52 | 18.02 ± 0.55* | -4 | | 18.33 ± 0.45 | 17.52 ± 0.55* | -4.4 | |
| | ESIT | 18.82 ± 0.57 | 18.11 ± 0.53* | -3.7 | P = 0.114 | 18.28 ± 0.48 | 17.45 ± 0.61* | -4.5 | P = 0.247 |
| | CON | 18.79 ± 0.49 | 18.77 ± 0.38 | NA | | 18.29 ± 0.42 | 18.26 ± 0.39 | NA | |
| Yo-Yo IR1 (distance) | MSIT | 1340 ± 120 | 1650 ± 140*† | 23.1 | | 1485 ± 180 | 1920 ± 220*† | 29.2 | |
| | ESIT | 1310 ± 130 | 1540 ± 150* | 17.1 | P = 0.001 | 1460 ± 185 | 1800 ± 230* | 23.2 | P = 0.001 |
| | CON | 1300 ± 140 | 1320 ± 150 | NA | | 1450 ± 180 | 1440 ± 170 | NA | |
| $VO_{2max}$ (ml.kg$^{-1}$.min$^{-1}$) | MSIT | 47.3 ± 3.3 | 50.2 ± 4.1* | 6.1 | | 49.5 ± 3.5 | 53.6 ± 4.2* | 8.2 | |
| | ESIT | 46.5 ± 3.8 | 49.5 ± 4.4* | 6.4 | P = 0.237 | 49.4 ± 4.1 | 53.4 ± 4.7* | 8.1 | P = 0.897 |
| | CON | 47.4 ± 3.9 | 47.5 ± 3.6 | NA | | 49.2 ± 3.6 | 49.4 ± 3.7 | NA | |
| PPO (w) | MSIT | 766 ± 43 | 845 ± 48*† | 10.3 | | 807 ± 39 | 879 ± 41*† | 8.9 | |
| | ESIT | 755 ± 58 | 821 ± 63* | 8.7 | P = 0.042 | 795 ± 65 | 852 ± 62* | 7.1 | P = 0.037 |
| | CON | 751 ± 48 | 766 ± 51 | NA | | 805 ± 54 | 810 ± 58 | NA | |
| APO (w) | MSIT | 430 ± 38 | 488 ± 40*† | 13.4 | | 471 ± 34 | 521 ± 37*† | 10.6 | |
| | ESIT | 441 ± 55 | 476 ± 48* | 7.9 | P = 0.038 | 482 ± 51 | 509 ± 48* | 5.6 | P = 0.041 |
| | CON | 443 ± 39 | 454 ± 42 | NA | | 477 ± 38 | 490 ± 41 | NA | |

**Table 3**. Changes in the variables from pre to post 7 weeks of training for both the morning and evening testing sessions (Mean ± SD). *Denotes significant differences vs. pre and CON ($p < 0.05$), †denotes significant differences vs. ESIT ($p < 0.05$).

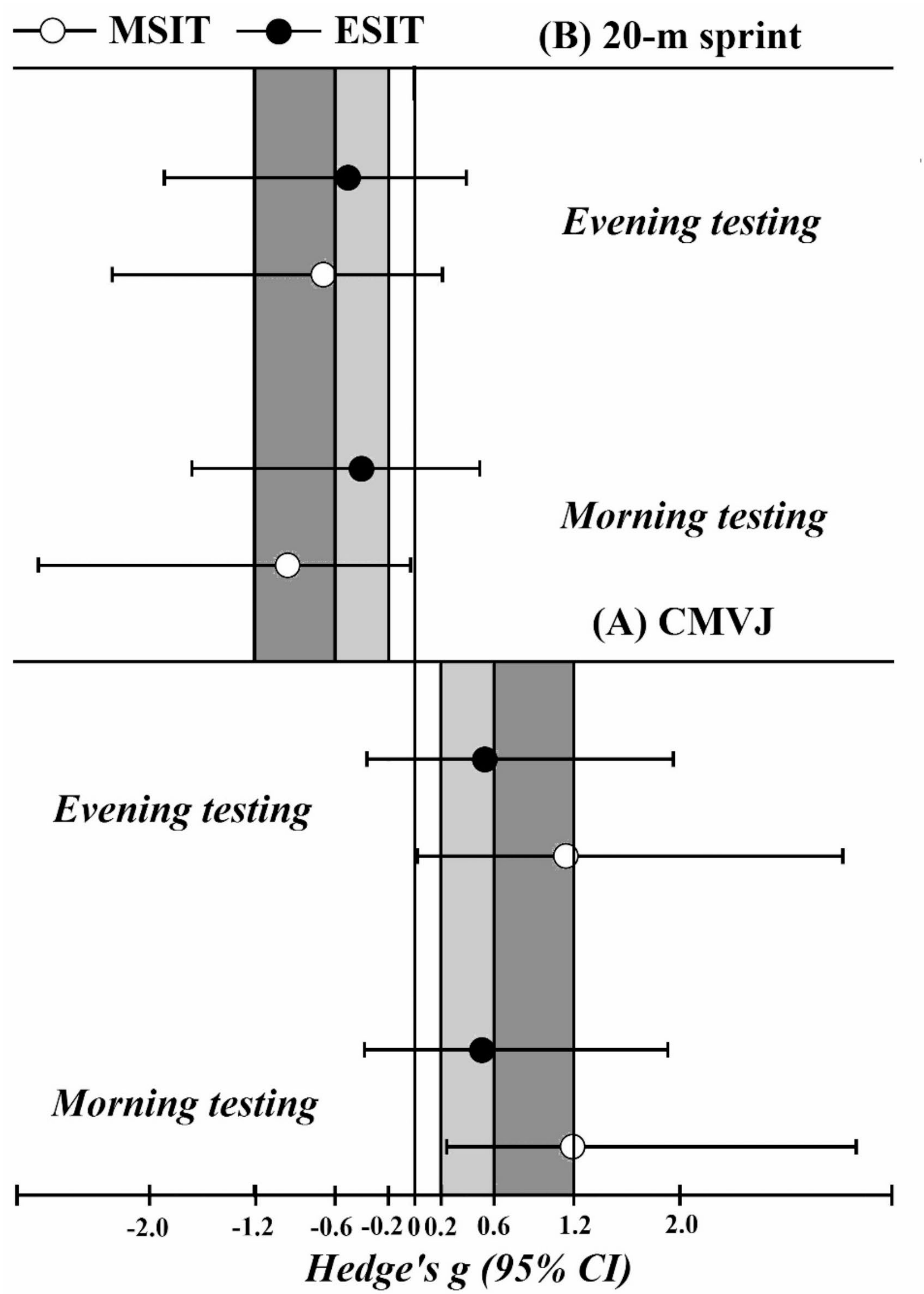


**Fig. 1**. The magnitude of training effects (ES with 95% CI) on (**A**) 20-m sprint and (**B**) countermovement jump (CMVJ) performance for the morning sprint interval training (MSIT) and evening sprint interval training (ESIT) groups at both morning and evening testing sessions.

players. Furthermore, participating in morning SIT is more advantageous than evening SIT, leading to greater improvements in the CMVJ (moderate vs. small ES), 20-m sprint (moderate vs. small ES), Yo-Yo IR1 (very large vs. large ES), PPO and APO (large vs. moderate ES).

The findings of this research suggest that a 7-week regimen of morning and evening SIT is an effective training approach for improving CMVJ performance during both 8AM and 5PM testing sessions. Our results are

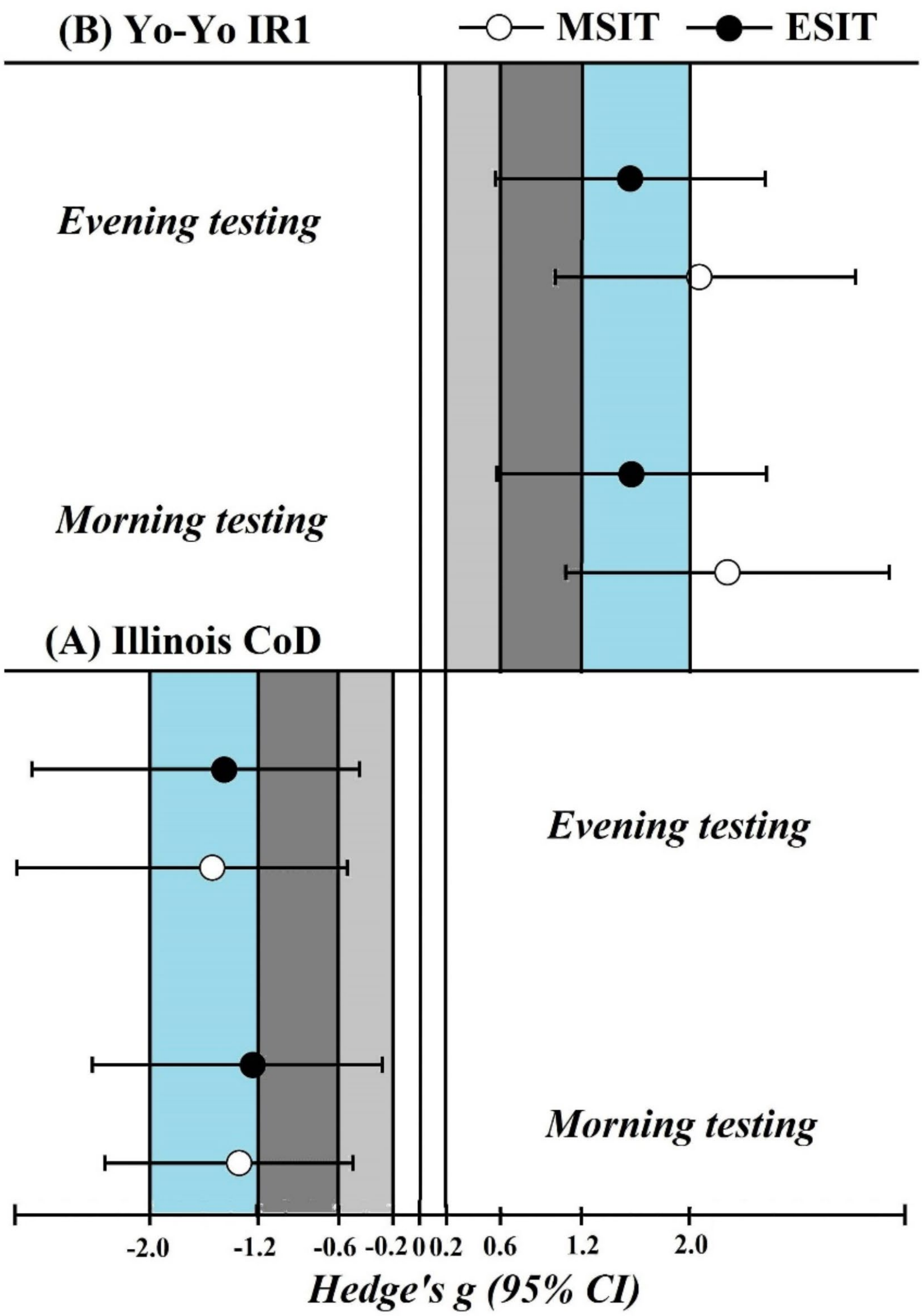


**Fig. 2**. The magnitude of training effects (ES with 95% CI) on (**A**) Yo-Yo IR1 performance and (**B**) Illinois changes of direction (CoD) for the morning sprint interval training (MSIT) and evening sprint interval training (ESIT) groups at both morning and evening testing sessions.

consistent with previous studies[2,4,10,27,28] reporting positive transfer of SIT as a training modality for enhancing CMVJ performance. The improvements in CMVJ following SIT may be attributed to improved mechanical properties of the muscle-tendon and enhanced intermuscular coordination and alpha motor-neurons firing rate[5,28]. According to Buchheit and Laursen[12], interval training is a training modality that aims to enhance the

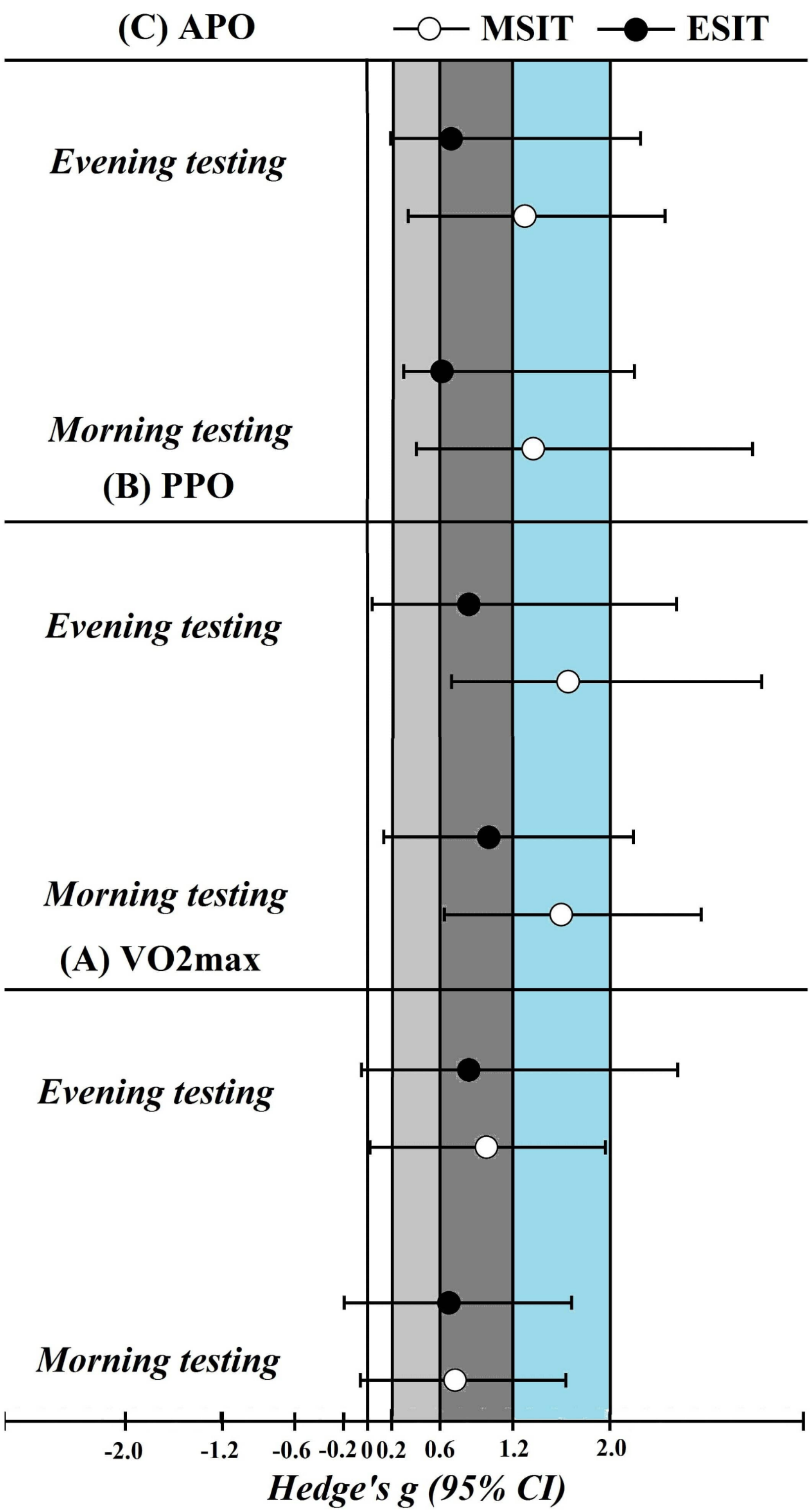


**Fig. 3**. The magnitude of training effects (ES with 95% CI) on (**A**) maximum oxygen uptake ($VO_{2max}$), (**B**) peak power output (PPO), and (**C**) average power output (APO) for the morning sprint interval training (MSIT) and evening sprint interval training (ESIT) groups at both morning and evening testing sessions.

neuromuscular systems by increasing the rate of force development and firing rate leading to gains in CMVJ in the soccer players.

Importantly, the MSIT group demonstrated more adaptations in CMVJ performance than the ESIT group. Previous research has predominantly focused on evening SIT for soccer players to enhance jump performance[2,4,10,27,28], based on the premise that evening training is linked to improved core body temperature,

| Groups | sRPE (scale) | Training time (min) | Training load* |
|---|---|---|---|
| MSIT | 6.8 ± 0.7 | 22 | 3141.6 |
| ESIT | 7.2 ± 0.8 | 22 | 3326.4 |

**Table 4**. Training workload parameters. *sRPE* sessions rating of perceived exertion. *Training load = RPE × training time.

circadian rhythms, and hormonal fluctuations, all of which may facilitate optimal adaptations[14–16]. However, our findings reveal that MSIT is more effective than ESIT for CMVJ performance. This may be explained by the heightened levels of neural activation and rapid firing rates that engage fast motor units during morning SIT[29]. The short duration of SIT (i.e., 5 s) with all-out condition requires a high degree of arousal and activation of the nervous system[10,28], as well as the neuromuscular junction, which are essential for muscle force production during running[12]. Furthermore, the increased testosterone levels observed in the morning, as opposed to the evening[30], may create favorable anabolic conditions that influence neuromuscular transmission and regulate choline acetyltransferase mRNA levels[31]. This modulation can result in changes in neurotransmission at the neuromuscular junction[31], leading to enhanced engagement of muscle fibers during morning SIT sessions and potentially greater improvements in CMVJ performance.

This research demonstrates that a 7-week schedule of morning and evening SIT serves as an effective strategy for improving sprint performance in testing sessions held at both 8 AM and 5 PM. These outcomes are consistent with prior studies that underscore the beneficial role of SIT in enhancing sprint capabilities[2,4,10,27,28]. Possible explanations for the observed improvements in 20-m sprint performance may involve specific training methodologies, including short sprint trials (i.e., 5 s)[4]. Indeed, to enhance sprint performance, it is essential to boost horizontal acceleration, and SIT appears to be effective in achieving this goal[28]. Furthermore, enhancements in both stride length and frequency attributed to SIT may serve as an additional mechanism for improving sprinting speed among soccer players[32]. The greater improvements in sprint performance observed with MSIT compared to ESIT (i.e., moderate versus small ES) may be linked to increased muscle fiber activation due to elevated testosterone levels in the morning, as well as the release of neurotransmitters during SIT[31]. On the other hand, the increased neural activation and the utilization of fast motor units during SIT might be another factor contributing to improved sprint performance[11]. Additionally, it seems that morning SIT is linked to increased muscle glycogen levels, which allows for greater energy storage and subsequently enhances sprint adaptations[33].

It is commonly observed that sprint performance is superior in the evening, largely due to the role of core body temperature and the circadian system, along with CLOCK-driven pathways[14]. Evidence from cross-sectional studies indicates that evening performance in sprints is better than that in the morning, implying that evening training may foster more adaptations[12,17]. Conversely, morning training may alter the daily variations in short-term maximal performance and assist in regulating the circadian system and CLOCK-driven pathways that influence sprint performance adaptations[15,16]. Nonetheless, these conclusions are still speculative, and additional research is essential to clarify the specific physiological adaptations linked to morning SIT.

The research findings revealed that both the MSIT and ESIT effectively contribute to improvements in CoD ability in collegiate soccer players throughout the preseason phase. This is consistent with prior studies that have documented the advantageous transfer of SIT to CoD speed performance in soccer players[4,27,28]. The possible explanation for these findings could be due to activation of fast-twitch muscle fibers stimulated by SIT contributes to the enhancement of linear speed and the ability to change sprint directions[12]. Additionally, the fastest alterations in muscle actions of the leg extensor muscles, involving eccentric to concentric movements with minimal ground contact time are crucial for improving CoD speed ability[32]. Notably, both the morning and evening SIT groups exhibited similar (i.e., large ES) improvements in CoD following the training period. Consequently, both training sessions, whether conducted in the morning or evening, resulted in similar enhancements in CoD performance assessments after the intervention. Therefore, it is suggested that collegiate soccer players utilize SIT in either the morning or evening to effectively enhance their CoD performance.

The results of the present study suggest that a 7-week SIT is an effective training method for enhancing Yo-Yo IR1, $VO_{2max}$, PPO and APO. Both the training groups exhibited similar adaptive changes during the 8AM and 5PM testing sessions after 7 weeks of training period in $VO_{2max}$. However, in the Yo-Yo IR1, PPO and APO, the MSIT indicated greater training effects then the ESIT in both the 8AM and 5PM testing session following the training period. These findings are consistent with previous studies highlighting the positive impact of SIT as a training approach for enhancing Yo-Yo IR1, and physiological parameters ($VO_{2max}$, PPO and APO) of soccer players involving mechanisms related to improved oxygen delivery and utilization by the active muscles during aerobic activities[2,4,7,10]. Therefore, implementing SIT in the morning may be advantageous for collegiate soccer players, as it can enhance repeated running performance and anaerobic power output, ultimately improving soccer-related performance during matches. It is advisable to incorporate morning SIT into the training regimen to maximize performance adaptations in repeated sprints and power-based activities[34,35]. As a result, players are likely to experience greater advantages from morning SIT rather than evening sessions when the focus is on maximizing anaerobic power output and repeated sprint performance. Nonetheless, no notable differences were found in cardiorespiratory fitness ($VO_{2max}$) between morning and evening SIT, suggesting that both training times yield effective adaptive responses in $VO_{2max}$[35].

Previous research has shown that aerobic and aerobic capacities tend to be higher in the evening compared to the morning[36], suggesting that the time of day can influence fluctuations in aerobic and aerobic capacities. However, Shiotani et al.[37] reported that eight weeks of training in the morning induced cardiovascular adaptations in the morning, which is in line with our findings. Overall, it appears that training in the morning can have an impact on the daily variations in the circadian system and CLOCK-driven pathways that affect aerobic and anaerobic pathways adaptations in both the central and peripheral components of aerobic activities[38]. Furthermore, the enhanced adaptations observed in the Yo-Yo IR1 and anaerobic power output from morning SIT may be attributed to the glycogen levels present in the muscles[33]. It is essential to note that performing SIT requires a high level of glycogen storage, as well as arousal and motivation during trials and it seems that engaging in evening SIT appears to correlate with reduced levels of glycogen by utilizing this in the daily activities and conducting morning SIT is associated with lower central and peripheral fatigue, thereby increasing glycogen availability to muscle fibers[10,27]. This, in turn, facilitates greater force production during morning SIT, leading to improved adaptations in repeated running and anaerobic power output performance[31]. Nevertheless, these assertions remain speculative, and additional research is needed to identify the specific adaptations that occur in these areas following a training regimen conducted at a particular time of day.

### Limitations
The present study has several methodological limitations that should be addressed. To begin with, the number of athletes involved, specifically 30 soccer players, is relatively small, which may limit the study's statistical power. However, a priori power analysis was performed, suggesting that this sample size is adequate for achieving sufficient statistical power. Additionally, the findings are confined to collegiate male soccer players, indicating a need for further research to explore whether these results can be generalized to female athletes and players of different age groups. Furthermore, the SIT groups did not directly investigate the underlying mechanisms of adaptation through laboratory assessments. Future studies are encouraged to utilize laboratory measurements to identify the specific adaptations that contribute to performance improvements associated with morning SIT. In light of these limitations, we recognize the necessity for additional research to either validate or dispute our results.

### Practical applications
From a practical perspective, the findings of our study indicate that incorporating SIT is an appropriate strategy for training during the preparatory phase for collegiate male soccer players. Both morning and evening training sessions have proven effective in facilitating performance adaptations. Notably, the results demonstrate that MSIT is more beneficial than ESIT, suggesting that implementing SIT in the morning, followed by soccer training in the evening, may be more advantageous for soccer players. It is advisable for professionals in the soccer field to consider morning SIT, as it could lead to positive enhancements in physical performance during both morning and evening assessments, thereby playing a crucial role in optimizing game performance.

## Conclusion
This study demonstrates that both morning and evening SIT significantly improve soccer players' physical and physiological performance, with superior gains observed in the MSIT. Morning SIT resulted in greater adaptive changes than evening SIT in key performance metrics, including CMVJ, 20-m sprint, Yo-Yo IR1, PPO, and APO. The findings highlight the importance of incorporating training timing into soccer conditioning programs, as morning SIT appears to optimize neuromuscular and metabolic adaptations, potentially leading to better on-field performance. Based on these results, it is recommended that conditioning workouts, particularly SIT, be scheduled in the morning to maximize physical performance adaptations, while team practices emphasizing technical and tactical development are conducted in the afternoon. This approach aligns with the observed diurnal variations and ensures adequate recovery between sessions.

## Data availability
The corresponding author will readily provide the raw data supporting the conclusions of this article without hesitation or reservation.

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## Author contributions
B.Y. and L.L. contributed equally to every aspect of this experiment, including conceptualization, study design, supervision, data collection, statistical analysis, interpretation, writing, and reviewing. All authors reviewed and endorsed the final version of the manuscript.

## Declarations

## Competing interests
The authors declare no competing interests.

## Additional information
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