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ORIGINAL RESEARCH

Impact of 30-minute and 90-minute Naps on Aerobic and Anaerobic Intermittent Performance in Collegiate Soccer Players

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Purpose: This study aims to investigate the effects of 30-minute and 90-minute naps on collegiate soccer players' aerobic and anaerobic performance following a normal night of sleep, and to compare the performance differences between the two nap durations.
Patients and Methods: A total of 25 male collegiate soccer players (age: 20 ± 1 years, height: 180.4 ± 5.6 cm, weight: 72.1 ± 4.2 kg, BMI: 22.1 ± 2.2 $kg \cdot m^{-2}$) participated in the RAST and 30–15. Intermittent fitness test (IFT) under three conditions: no nap (N0), 30-minute nap (N30), and 90-minute nap (N90).
Results: Post-nap assessments showed significant improvements in peak power per weight ($p = 0.007$, $\eta^2 = 0.13$), minimum power per weight ($p < 0.001$, $\eta^2 = 0.25$), and average power per weight ($p < 0.001$, $\eta^2 = 0.28$) in the RAST test, with no notable differences between the N30 and N90 groups. Additionally, the fatigue index (FI) in the N90 group significantly decreased compared to N0 ($p = 0.005$, $d = 0.86$). Both N30 and N90 groups exhibited higher VIFT values than the N0 group ($p < 0.001$, $\eta^2 = 0.23$). However, no significant changes were noted in average heart rate ($p = 0.198$) or perceived exertion (RPE) ($p = 0.376$) during the 30–15 IFT after napping.
Conclusion: Napping effectively enhances the aerobic and anaerobic performance of collegiate soccer players following a normal night of sleep. Implementing strategic napping may be beneficial for athletes seeking to optimize their performance before training or competition.
Keywords: nap, anaerobic, aerobic, fatigue, soccer

Introduction

Soccer is an intermittent sport that demands high aerobic and anaerobic capacity.[1] Players repeatedly engage in high-intensity sprints, often reaching maximum or near-maximum effort, followed by brief recovery periods of low-intensity walking or jogging. These repeated bursts of activity rely on the anaerobic system for quick energy release, particularly for explosive sprints and short-duration efforts. At the same time, soccer players rely on the aerobic system to maintain endurance throughout the game, particularly during longer running intervals and lower-intensity phases.

However, collegiate athletes often struggle with insufficient and poor-quality sleep due to the demanding schedules of training, competition, and academic responsibilities.[2] Research shows that collegiate soccer players demonstrate higher global sleep dysfunction and recovery challenges, which may lead to diminished performance and negative mental health consequences.[3] A systematic review suggests that insufficient sleep has a negative impact on soccer players' match performance, injury occurrence, and training load.[4] Furthermore, poor sleep quality has been shown to be negatively correlated with greater RPE during high-intensity play, resulting in greater perceived workload.[5] However, as sleep efficiency improved, college football players had significantly fewer decelerations in zone 4 (<-3.00 ms-2)[6] and better performance.[7] When the athlete does not get adequate sleep, both recovery and performance may be impaired, leading to reduced anaerobic power, lower endurance and strength, and worse performance in high-intensity interval exercise.[8] More importantly, humans' performance typically declines after lunch (1:00 PM - 4:00 PM), a phenomenon known as the "Post-lunch Dip"[9] The extent of performance decline during this period is associated with insufficient sleep the previous

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night and overall fatigue levels. In response to these challenges, daytime naps have been proposed as an effective strategy for enhancing recovery and mitigating the negative impacts of inadequate sleep and PLD.[10]

Existing research has primarily focused on the impact of napping on anaerobic performance (with RAST and 5mSRT tests being typical examples[11–13]13), while discussions on aerobic intermittent capacity remain insufficient. Only two studies have examined the effects of napping on aerobic endurance following normal sleep, finding no improvement in aerobic endurance after a 30-minute nap,[14] while a significant enhancement was observed after a 40-minute nap.[15] Research by Ajjimaporn et al[11] indicated that a 20-minute nap could improve anaerobic sprint performance following sleep deprivation in soccer players. For athletes who had normal sleep, studies found that a 20-minute nap significantly enhanced anaerobic sprint performance, whereas a 90-minute nap led to decreased performance in subsequent tests.[12] Conversely, a narrative review suggested that longer naps (35–90 minutes) may provide greater benefits to athletes than shorter naps (20–30 minutes).[10] These discrepancies in findings may be related to participants' sleep conditions the previous night and the timing interval between napping and testing. Although there is a significant body of research on napping and exercise performance, there is still a lack of data on athletes who have had a normal night's sleep the previous evening (ie, there are no sleep restrictions).

Therefore, this study aims to explore the effects of two nap durations, 30 minutes and 90 minutes, on anaerobic and aerobic performance in collegiate soccer players who had normal sleep the previous night, and to compare the effects between these different nap durations. The study hypothesizes that, following a night of normal sleep, both 30-minute and 90-minute naps will enhance athletes' performance, with the expectation that the 90-minute nap will produce more pronounced improvements in both anaerobic and aerobic performance.

Material and Methods

Participants

The sample size calculation was conducted using G*Power software. Based on a previous study, a significance level (α) of 0.05, statistical power of 0.8, and Cohen's d value of 0.54 were set. By retaining the minimum correlation between repeated measures (GPx; R = 0.44),[10] the minimum sample size for this study was determined to be 12 participants. Considering potential sample loss during the experiment, the final sample included 25 male university soccer players (age = 20.2 ± 1.4 years, height = 180.4 ± 5.6 cm, weight = 72.1 ± 4.2 kg, BMI = 22.1 ± 2.2 $kg \cdot m^{-2}$, body fat = 11.9±8.5%). All participants were national-level 1 athletes, training for no less than 10 hours per week. The MEQ (Morningness-Eveningness Questionnaire) and PSQI (Pittsburgh Sleep Quality Index) were used as participant selection criteria to exclude individuals with extreme sleep chronotypes (extreme evening-type and extreme morning-type) and those with sleep disorders (PSQI score > 5). This was done to prevent these factors from interfering with the study results. This study was approved by the Ethics Review Committee of Wuhan Sports University (Approval No: 2023070) and adhered to the ethical guidelines of the Declaration of Helsinki. All participants signed informed consent forms after being fully informed about the study design and potential risks.

Study Protocols

Before the formal test, participants' physical measurements were collected, including height (cm), weight (kg), BMI ($kg \cdot m^{-2}$) and body fat (%), and they were familiarized with the testing procedures. This study employed a randomized crossover design, where all participants completed three different testing conditions in random order: no nap (N0), 30-minute nap (N30), and 90-minute nap (N90), with a washout period of 72 hours between each test.[16]

During the week prior to testing, participants underwent an acclimatization phase in which they wore an actigraph to monitor nighttime sleep and familiarize themselves with sleeping while wearing the device. In addition, it has been suggested that at least one week of sleep assessment needs to be included to ensure that chronic sleep deprivation is not a confounding factor.[10] After the study began, participants wore the actigraph to record their sleep data on the night before each test. This ensured that there were no significant differences in sleep patterns and no sleep deprivation prior to each testing session. On the test day, participants were asked to complete lunch before 12:30 PM. At 12:50 PM, N90 group entered a standardized bedroom (temperature 20–23°C, completely dark and quiet) and acclimated to the environment for 10 minutes before starting their 90-minute nap at 1:00 PM (ending at 2:30 PM). To facilitate napping, participants were instructed to lie in a comfortable, semi-reclined position, close their eyes, and relax, even if they did not fall asleep. For N30, participants entered the bedroom at 1:50 PM, and began a 30-minute nap at 2:00 PM. After the nap, participants were awakened by the researchers and immediately filled out a subjective sleep quality rating (ranging from "0" indicating no sleep to "5" indicating uninterrupted deep sleep). To mitigate potential sleep inertia, all participants had a recovery time of 1 hour after nap.[17] In no-nap condition, participants remained awake in a comfortable armchair, with the option to watch videos or play games until 3:00 PM. Subsequently, all participants performed a standardized 10-minute warm-up before beginning the exercise tests. On the day of the experiment, participants were asked to maintain normal dietary and sleep habits the night before the test and to avoid caffeine-containing beverages or other stimulants. All performance tests were conducted at the same time (3:00 PM) to minimize disruptions from circadian rhythms. After a 10-minute standardized warm-up, participants first performed the RAST. After 20-minute recovery, they proceeded to the 30–15IFT.[18] All tests took place on the grass field of the participants' university, with an average temperature of 30.3 ± 3.1°C and humidity of 60.4 ± 14.5%. Figure 1 presents the study protocol.

Previous Night Sleep

Sleep variables in previous days were monitored using the Actigraph GT3x, which was worn on the non-dominant wrist. Compared to the PSG, the sensitivity, specificity, and accuracy of the Actigraph GT3x were 90%, 46%, and 84%, respectively.[19] The device was set to a sampling frequency of 30 hz and recorded activity counts in 1-minute epochs. Sleep variables were calculated using the Sadeh algorithm, which has high accuracy among young individuals under 30 years of age.[20] The collected sleep variables included: bedtime (hh), wake-up time (hh), sleep latency (min), total sleep duration (h), wake time after sleep onset (min), and sleep efficiency (%).

Running-Based Anaerobic Sprint Test

The Running-Based Anaerobic Sprint Test (RAST) is an intermittent test widely used to measure anaerobic capacity in running-based sports.[21] In the RAST test, participants complete six 35-meter sprints, with a 10-second interval between each sprint. Following previously recommended methods, peak power per weight (PP/kg), minimum power per weight (MP/kg), average power per weight (AP/kg), and fatigue index (FI) were calculated.[21] The relevant formulas are as follows:

$$\text{Power (P)} = \text{weight} \times \text{distance}^2 / \text{time}^3$$
$$\text{Power per weight (P/kg)} = \text{P} / \text{weight (kg)}$$
$$\text{Fatigue index} = (\text{Pmax} - \text{Pmin}) / \text{total time of the 6 sprints.}$$

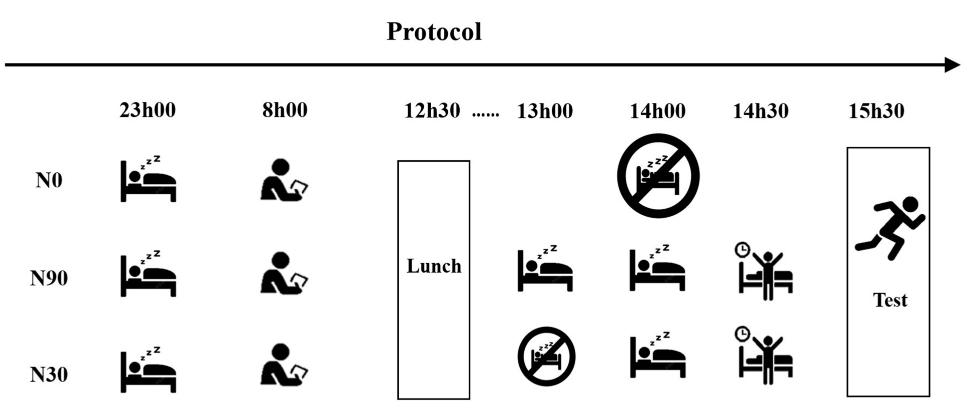

Figure 1 Study protocol.

30-15 Intermittent Fitness Test

This study employed the 30–15 Intermittent Fitness Test (30–15 IFT) to assess the aerobic power of soccer players. The 30–15 IFT consists of a 30-second incremental shuttle run followed by 15 seconds of passive recovery.[21] Participants shuttle run between markers spaced 40 meters apart, with the running speed set by a pre-recorded audio file, starting at 8 km/h. After each 45-second phase (30 seconds of running + 15 seconds of recovery), the speed increases by 0.5 km/h. During the test, researchers provided standardized verbal encouragement to motivate participants to complete as many laps as possible. The test concludes when participants reach exhaustion and voluntarily stop or fail to reach the next 3-meter zone as indicated by the audio signal three times in a row, recording the running speed of that lap as the participant's maximum speed (V_{IFT}). After finishing the 30–15 IFT, participants immediately reported their rating of perceived exertion (RPE) using the Borg 6–20 scale.[22] Heart rate was recorded using the Polar Team system (Polar Electro, Kempele, Finland) at 1-second intervals, with the average heart rate used as an analytical indicator.

Statistical Analyses

All statistical analyses were performed using SPSS version 20. The normality of the data was assessed using the Shapiro–Wilk test, and all data are presented as mean ± standard deviation. An independent samples *t*-test was conducted to compare subjective sleep quality differences between the N30 and N90 groups. For sleep variables from the previous night and performance test results, one-way ANOVA was used for analysis, and effect size (Eta-squared, η^2) was calculated. When ANOVA showed significant main effects or interaction effects, Bonferroni post-hoc tests were conducted to examine group differences further. Additionally, Cohen's d was calculated to assess the magnitude of differences between the two groups, with effect sizes classified as small ($0.2 < d \leq 0.5$), medium ($0.5 < d \leq 0.8$), and large ($d \geq 0.8$).[23] The mean difference (MD) and 95% confidence intervals (95% CI) were reported to clarify differences between groups further. The significance level was set at $p < 0.05$.

Results

Previous Night's Sleep and Sleep Quality During the Nap

Participants' previous night's sleep variables and sleep quality during the nap are presented in Table 1. One-way ANOVA showed no significant differences in sleep variables and no evidence of sleep deprivation. The independent samples *t*-test results indicated no significant differences in subjective nap quality between the N30 and N90 groups (p = 0.96).

Running-Based Anaerobic Sprint Test

The One-way ANOVA analysis is presented in Table 2 and the post hoc test is presented in Table 3. ANOVA test showed significant effect on PP/kg ($F = 5.37$, $p = 0.007$, $\eta^2 = 0.13$), MP/kg ($F = 11.90$, $p < 0.001$, $\eta^2 = 0.25$), AP/kg ($F = 14.22$, $p < 0.001$, $\eta^2 = 0.28$), and FI ($F = 2.47$, $p = 0.006$, $\eta^2 = 0.06$). PP/kg increased after N30 (p = 0.043, d = 0.88, MD = 0.84, 95% CI, 0.02 to 1.55) and N90 (p = 0.009, d = 0.74, MD = 1.04, 95% CI, 0.21 to 1.86) (Figure 2). MP/kg increased after N30 (p < 0.001, d = 1.03, MD = 0.97, 95% CI, 0.38 to 1.55) and N90 (p < 0.001, d = 1.14, MD = 1.05, 95% CI, 0.46 to 1.63) (Figure 3). AP/kg increased after N30 (p < 0.001, d = 1.17, MD = 0.96, 95% CI, 0.45 to 1.51) and N90 (p < 0.001, d = 1.18, MD = 1.01, 95% CI, 0.48 to 1.53) (Figure 4). FI only lowered after N90 (p = 0.005, d = 0.86, MD = −5.38%, 95% CI, −9.41% to −1.35%) (Figure 5). There was no significant difference between N30 and N90 values.

Table 1 Previous Night's Sleep and Nap Quality

	N0	N30	N90	p
Total sleep time (h)	7.4±0.1	7.4±0.1	7.3±0.1	0.83
Sleep Latency (min)	26.0±3.1	34.3±5.1	40.3±6.2	0.84
Sleep Efficiency (%)	77.6±11.9	77.9±6.2	77.2±8.1	0.98
Wake After Sleep Onset (min)	8.9±4.8	9.0±2.3	9.1±3.8	0.99
Subject Nap Quality (a.u)	–	4±1	4±1	0.96

Note: a.u arbitrary units.

Table 2 One-Way ANOVA Test of RAST and 30–15IFT After N0, N30, and N90

	N0	N30	N90	F	p	η^2
PP/kg (W/kg)	9.60±1.23#,*	10.44±0.55	10.64±1.56	5.37	0.007	0.13
MP/kg (W/kg)	6.71±1.13#,*	7.67±0.68	7.75±0.62	11.90	<0.001	0.25
AP/kg (W/kg)	8.06±1.07#,*	9.04±0.52	9.06±0.55	14.22	<0.001	0.28
FI (%)	30.08%±7.90%*	26.44%±4.74%	24.70±4.07	2.37	0.006	0.06
V_{IFT} (km/h)	18.9±0.9	20.1±1.3	20.2±1.0	10.64	<0.001	0.23
HR (bpm)	152.2±4.6	151.8±5.6	149.6±5.8	1.66	0.198	0.04
RPE	17.7±1.1	17.7±1.2	17.3±1.3	0.99	0.376	0.03

Notes: #Significant difference compared to the N30; *Significant difference compared to the N90.
Abbreviations: PP/kg, peak power per weight; MP/kg, minimum power per weight; AP/kg, average power per weight; FI, fatigue index; V_{IFT}, maximum speed of 30–15 IFT; HR, heart rate; RPE, Rating of Perceived Exertion.

Table 3 Post Hoc Test of PP/kg, MP/kg, FI, and V_{IFT}

	N30 vs N0				N90 vs N0				N30 vs N90			
	p	d	MD	95% CI	p	d	MD	95% CI	p	d	MD	95% CI
PP/kg	0.043	0.88	0.84	0.02 to 1.67	0.009	0.74	1.04	0.21 to 1.86	1.00	0.17	−0.19	−1.02 to 0.63
MP/kg	<0.001	1.03	0.97	0.38 to 1.55	<0.001	1.14	1.05	0.46 to 1.63	1.00	0.12	−0.08	−0.67 to 0.50
AP/kg	<0.001	1.17	0.98	0.45 to 1.51	<0.001	1.18	1.01	0.48 to 1.53	1.00	0.04	−0.25	−1.53 to −0.48
FI	0.09	0.56	−3.64%	−7.67% to −3.90%	0.005	0.86	−5.38%	−9.41% to −1.35%	0.88	0.39	1.74%	−2.29% to 5.77%
V_{IFT}	<0.001	1.06	1.16	−0.43 to 1.89	<0.001	1.32	1.22	−0.49 to 1.95	1.00	0.05	−0.06	−0.79 to 0.67

30-15 Intermittent Fitness Test

There was a significant effect of napping affected on V_{IFT} ($F = 10.64$, $p < 0.001$, $\eta^2 = 0.23$). V_{IFT} was significantly improved after N30 ($p < 0.001$, $d = 1.06$, MD = 1.16, 95% CI, −0.43 to 1.89) and after N90 ($p < 0.001$, $d = 1.32$, MD = 1.22, 95% CI, −0.49 to 1.95). There were no significant differences between N30 and N90 ($p = 1.00$, $d = 0.05$, MD = −0.06, 95% CI, −0.79 to 0.67) (Figure 6). Daytime naps had no significant effects on average heart rate ($F = 1.66$, $p = 0.198$, $\eta^2 = 0.04$) or RPE ($F = 0.99$, $p = 0.376$, $\eta^2 = 0.03$) during the 30–15 IFT.

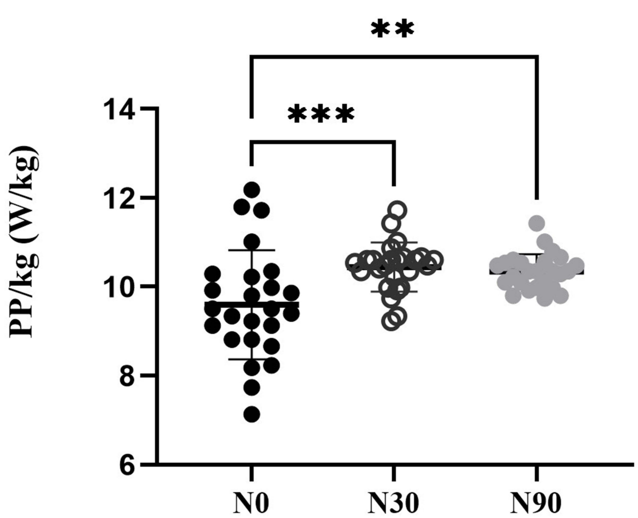

Figure 2 Peak power per weight after N0, N30, and N90. Significant difference in comparison with N0 values: **p≤0.01; ***p≤0.001.

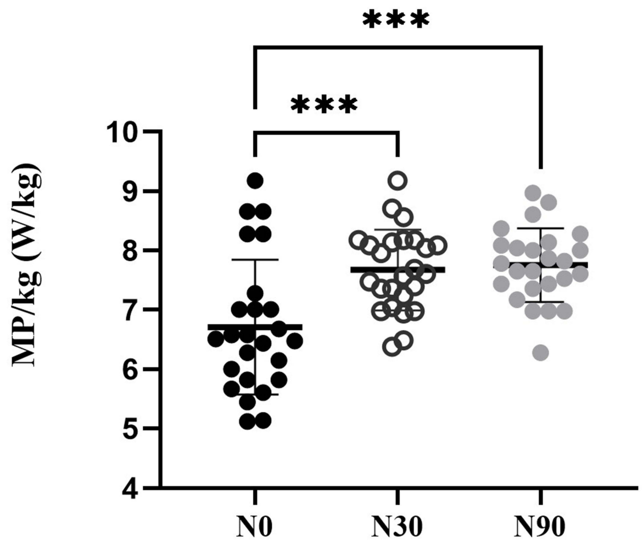

Figure 3 Minimum power per weight after N0, N30, and N90: ***p≤0.001.

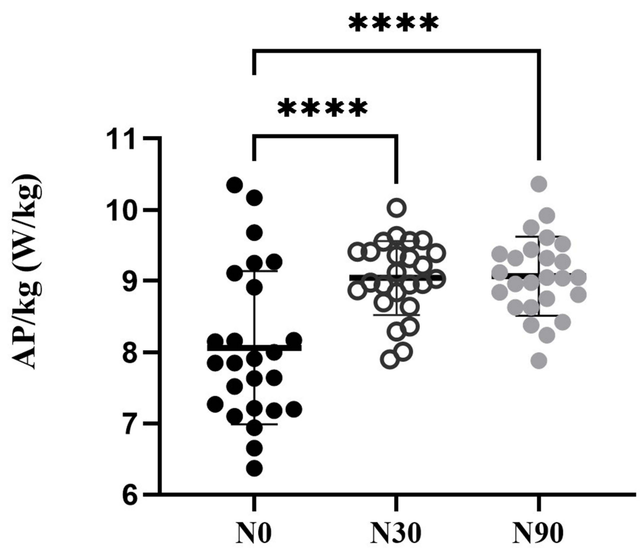

Figure 4 Average power per weight after N0, N30, and N90: ****p≤0.0001.

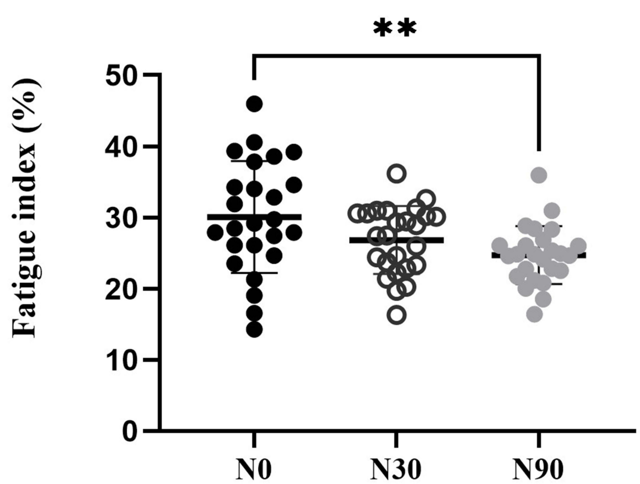

Figure 5 Fatigue index after N0, N30, and N90: **p≤0.01.

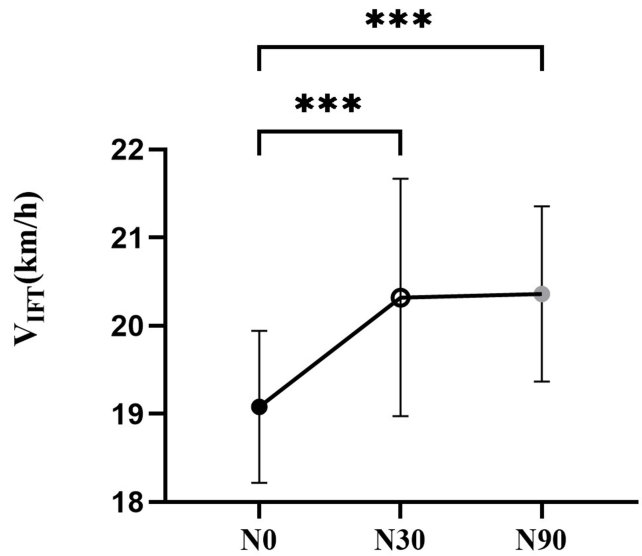

Figure 6 V_{IFT} after N0, N30, and N90: ***p≤0.001.

Discussion

This study assessed the impact of different nap durations (30-minute and 90-minute) on collegiate soccer players' performance in RAST and 30–15 IFT. Sleep variables of all participants prior to tests (including total sleep time, sleep latency, sleep efficiency, and wake after sleep onset) did not exhibit significant differences, and there was no sleep deprivation before any tests. The results indicated that both 30-minute and 90-minute naps significantly enhanced the players' anaerobic sprint performance compared to no-nap conditions. Specifically, there were significant increases in peak power per weight, minimum power per weight, and average power per weight of RAST, while only the 90-minute nap lowered the fatigue index. Furthermore, both 30-minute and 90-minute naps significantly improved the aerobic performance of collegiate soccer players. Following the naps, the athletes' maximum running speed (V_{IFT}) increased, while average heart rate and perceived exertion (RPE) did not show significant changes.

To our knowledge, this study is the first to explore the effects of napping on the 30–15IFT performance of collegiate soccer players. The results indicate that post-nap, athletes' VIFT (maximum exercise intensity) improved, suggesting that their aerobic intermittent performance was enhanced. More importantly, there were no significant changes in the athletes' Rate of Perceived Exertion (RPE) or average heart rate after napping. In physical performance tests, RPE reflects internal load, representing the subjective fatigue level of athletes, while average heart rate represents external load, serving as an objective indicator of exercise intensity.[24] Despite the athletes achieving higher V_{IFT} during the tests, the lack of increases in both RPE and average heart rate suggests that napping may help improve recovery, allowing athletes to perform better without an additional cardiovascular burden.

The data from our study indicate that after 30-minute and 90-minute naps, the peak power per weight, minimum power per weight, and average power per weight of RAST were significantly higher than in the no-nap condition (N0). This result is consistent with previous research, suggesting that both short and long naps can enhance subsequent anaerobic intermittent performance after normal nighttime sleep.[10,11] Peak power in the RAST test is primarily influenced by the athlete's phosphocreatine reserves and their utilization efficiency.[25] Studies have shown that PCr levels decline during wakefulness and restore to baseline levels after a 20-minute nap.[26] When athletes can more effectively derive chemical energy from high-energy phosphate pools, they can produce greater mechanical work, thereby increasing running power,[25] which may be one of the main benefits of napping. Additionally, we found significant increases in both minimum power per weight and average power per weight after both N30 and N90. This change indicates an improvement in the players' overall anaerobic power output, along with enhanced fatigue resistance and recovery capabilities. However, some studies have noted that napping does not significantly affect short-duration maximal efforts.[14,27] This discrepancy may be attributed to the duration and nature of the tests; unlike the RAST, shorter maximal

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tests such as the Wingate and 20-meter sprints do not induce significant fatigue responses,[13,16] suggesting that high-intensity intermittent exercise of long duration is more likely to benefit from naps. Furthermore, Boukhris et al[17] demonstrated a significant correlation between improvements in 5mSRT following a nap and changes in parasympathetic nervous system activity. Enhanced parasympathetic activation contributes to energy regeneration and replenishment by slowing heart rate, inducing coronary vasoconstriction, and increasing dopamine and gastrointestinal secretion.[28] This suggests that napping may enhance the recovery of energy reserves by promoting parasympathetic nervous activity, thereby improving athletic performance.[29]

Notably, the fatigue index in N90 lowered significantly, by approximately 5.38%. The fatigue index is an important reference indicator in the RAST, reflecting the level of fatigue experienced by athletes during repeated sprints.[21] Data indicate that the fatigue index significantly decreased only after a 90-minute nap, suggesting that longer naps may alleviate fatigue experienced by athletes in the RAST. Slow-wave sleep aids in physical recovery and also alleviates stress and anxiety,[30] promoting the metabolism of carbohydrates and fats in the process; thus, a 90-minute nap may yield greater metabolic recovery effects.[29] Although this study did not directly measure the participants' sleep stages, polysomnographic recordings indicate that short naps (20–30 minutes) and longer naps (90 minutes) may include varying amounts of REM sleep, depending on the duration of the nap.[31,32] During REM sleep, all muscle groups are relaxed, enhancing the efficiency of muscle contractions upon waking and thereby improving athletic performance.[33] Some studies suggest that a 90-minute nap can elevate cortisol levels upon waking, which helps promote energy supply; this may explain the delayed fatigue onset experienced by the N90 group.[29] Moreover, Boukhris et al[17] found that a 90-minute nap led to a decrease in oral temperature, allowing athletes to perform subsequent repeated sprints at a lower body temperature, thus delaying fatigue and reducing the fatigue index. Therefore, a 90-minute nap enhances anaerobic intermittent performance by promoting metabolic and energy recovery, thereby delaying the onset of fatigue during exercise. In contrast to our findings, Romdhani et al[29] reported that a 90-minute nap after a normal night's sleep resulted in a decrease in peak power during the RAST. In their study, athletes began the RAST 30 minutes after the nap ended, which may have been insufficient to counteract sleep inertia from the 90-minute nap, resulting in poorer performance compared to the no-nap condition. In contrast, our study allowed for a 1-hour interval between the nap and the test, providing adequate time for the benefits of napping to manifest. Generally, the longer the nap duration, the stronger the sleep inertia. Therefore, following a 90-minute nap, it may be essential to allow at least 1 hour or more to overcome sleep inertia and mitigate any negative impact of napping on subsequent athletic performance.

Upon examining the scatter plots, it is evident that the data points following the N0 condition (no nap) exhibit a wider spread for the RAST parameters (PP, MP, AP, FI), whereas the data points under the N30 and N90 conditions are more tightly clustered, reflecting smaller individual variances. This can be attributed to the fact that under the N0 condition, participants were solely dependent on their baseline recovery and preparedness, which are influenced by various individual factors. In the absence of a nap, participants' baseline levels of physical and mental fatigue varied considerably, and each participant experienced the post-lunch dip (PLD) to different extents leading to a larger degree of individual variability in performance outcomes. In contrast, naps serve as a restorative mechanism that helps mitigate accumulated physical and mental fatigue, and also attenuate the negative effects of PLD on performance. By partially or fully restoring the participants' physical and psychological preparedness, naps enable athletes to perform at levels that more accurately reflect their true capabilities. This leads to a more compact distribution of performance data, suggesting a reduction in the interference caused by fatigue and an enhancement of the athletes' ability to demonstrate their authentic athletic potential. This pattern underscores the potential of napping as an effective recovery strategy in sports, emphasizing its role in minimizing fatigue-related disruptions and facilitating performance outcomes that are more indicative of an athlete's maximal functional capacity.

The performance tests utilized in this study are all field-based intermittent performance assessment tools, with the RAST focusing on anaerobic performance and the 30–15 IFT concentrating on aerobic performance. Previous research has shown that the 30–15 IFT has a significant correlation with the sprinting ability and change of direction (COD) capability of soccer players,[34] effectively simulating the movement patterns and characteristics present in soccer matches. Therefore, the conclusions of this study hold certain reference values for the population of college soccer players. The results indicate that both 30-minute and 90-minute naps can effectively enhance soccer players' anaerobic and aerobic intermittent performance. Thus, soccer players can incorporate napping into their daily routines on training or competition days and allow sufficient time to overcome sleep inertia, leading to better performance in subsequent activities.

When interpreting the results of this study, it is important to note its limitations. First, all participants' napping behaviors and quality were obtained through self-reports, without objective monitoring using actigraphy. Given that actigraphy has limited validity for assessing short naps,[20] future research should consider using polysomnography to more objectively measure nap duration, quality, and, crucially, sleep stages. Second, in this study, naps and performance tests were conducted in the afternoon. Whether naps have an effect on aerobic and anaerobic performance at other times of the day (morning, midday, or evening) requires further investigation. Finally, although this study did not implement sleep deprivation interventions for participants, actigraphy data indicated that the athletes had low sleep efficiency at night. Therefore, the conclusions may not apply to athletes who have good sleep quality and more adequate sleep duration.

Conclusion

Following a normal night's sleep, both 30-minute and 90-minute naps can enhance the anaerobic and aerobic performance of college soccer players. Furthermore, the 90-minute nap is more effective than the 30-minute nap in reducing fatigue during anaerobic performance and in maintaining anaerobic power. No significant difference between the two nap durations in terms of enhancing aerobic capacity. Overall, both 30-minute and 90-minute naps can effectively improve the anaerobic and aerobic performance of collegiate soccer players. Even with sufficient sleep the previous night, athletes can enhance their training or competition performance by strategically scheduling daytime naps. Besides, athletes must allow enough time between napping and exercising to overcome potential sleep inertia. Generally, the longer the nap, the longer the time required to fully awaken.

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Author Contributions

Anran Xu: Conceptualization, Methodology, Validation, Software, Formal analysis, Writing – original draft, Writing – review and editing, Visualization.

Ning Wang: Conceptualization, Investigation, Data curation, Writing – review and editing.

Xiaotian Li: Project administration, Investigation, Supervision, Writing – review and editing.

Yang Gao: Resources, Funding acquisition, Supervision.

All authors drafted, substantially revised, or critically reviewed the article, and agreed on the final version of the manuscript. Furthermore, all authors have agreed on the journal to which the manuscript will be submitted and take responsibility for all aspects of the work. They ensure any questions related to the accuracy or integrity of the work are appropriately addressed.

Disclosure

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References

1. Silva VGD. Repeated-sprint ability determined in game in elite male Brazilian football players. *Int J Performance Anal Sport*. 2018;2018:1–11.
2. Halson SL, Walsh NP, Sargent C, et al. Sleep and the athlete: narrative review and 2021 expert consensus recommendations. British. *J Sports Med*. 2021;55(7):356–368.
3. Benjamin CL, Curtis RM, Huggins RA, et al. Sleep dysfunction and mood in collegiate soccer athletes. *Sports Health*. 2020;12(3):234–240. doi:10.1177/1941738120916735
4. Clemente FM, Afonso J, Costa J, Oliveira R, Pino-Ortega J, Rico-González M. Relationships between sleep, athletic and match performance, training load, and injuries: a systematic review of soccer players. *Healthcare*. 2021;9(7):808. doi:10.3390/healthcare9070808
5. Clemente FM. Associations between wellness and internal and external load variables in two intermittent small-sided soccer games. *Physiol Behav*. 2018;197:9–14. doi:10.1016/j.physbeh.2018.09.008
6. Silva KP, Sims I, Jesse N, et al. Effect of sleep efficiency on relative external workload in collegiate division 1 soccer players: 611. *Med Sci Sports Exercise*. 2024;56(10S):200. doi:10.1249/01.mss.0001054268.89684.74
7. Mah CD, Mah KE, Kezirian EJ, Dement WC. The effects of sleep extension on the athletic performance of collegiate basketball players. *Sleep*. 2011;34:943–950. doi:10.5665/SLEEP.1132

8. Craven J, McCartney D, Desbrow B, et al. Effects of acute sleep loss on physical performance: a systematic and meta-analytical review. *Sports Med*. 2022;52(11):2669–2690. doi:10.1007/s40279-022-01706-y
9. Bes F, Jobert M, Schulz H. Modeling napping, post-lunch dip, and other variations in human sleep propensity. *Sleep*. 2009;32(3):292–298.
10. Botonis PG, Koutouvakis N, Toubekis AG. The impact of daytime napping on athletic performance - A narrative review. *Scand J Med Sci Sports*. 2021;31(12):2164–2177. doi:10.1111/sms.14060
11. Ajjimaporn A, Ramyarangsi P, Siripornpanich V. Effects of a 20-min nap after sleep deprivation on brain activity and soccer performance. *Int J Sports Med*. 2020;41(14):1009–1016. doi:10.1055/a-1192-6187
12. Romdhani M, Dergaa I, Moussa-Chamari I, et al. The effect of post-lunch napping on mood, reaction time, and antioxidant defense during repeated sprint exercice. *Biol Sport*. 2021;38(4):629–638. doi:10.5114/biolsport.2021.103569
13. Abdessalem R, Boukhris O, Hsouna H, et al. Effect of napping opportunity at different times of day on vigilance and shuttle run performance. *Chronobiol Int*. 2019;36(10):1334–1342. doi:10.1080/07420528.2019.1642908
14. Suppiah HT, Low CY, Choong G, Chia M. Effects of a short daytime nap on shooting and sprint performance in high-level adolescent athletes. *Int J Sports Physiol Perform*. 2019;14(1):76–82. doi:10.1123/ijspp.2018-0107
15. Blanchfield AW, Lewis-Jones TM, Wignall JR, Roberts JB, Oliver SJ. The influence of an afternoon nap on the endurance performance of trained runners. *Eur J Sport Sci*. 2018;18(9):1177–1184. doi:10.1080/17461391.2018.1477180
16. Boukhris O, Abdessalem R, Ammar A, et al. Nap opportunity during the daytime affects performance and perceived exertion in 5-m shuttle run test. *Front Physiol*. 2019;10:779. doi:10.3389/fphys.2019.00779
17. Boukhris O, Trabelsi K, Hill DW, et al. Physiological response and physical performance after 40 min and 90 min daytime nap opportunities. *Res Sports Med*. 2023;31(6):881–894. doi:10.1080/15438627.2022.2079979
18. Manske R, Reiman M. Functional performance testing for power and return to sports. *Sports Health*. 2013;5(3):244–250. doi:10.1177/1941738113479925
19. A SJ, Botsis T, Walsh J, King S, Straker LM, Eastwood PR. Assessing sleep using hip and wrist actigraphy. *Sleep Biol Rhythms*. 2015;13(2):172–180. doi:10.1111/sbr.12103
20. Galland B, Meredith-Jones K, Terrill P, et al. Challenges and emerging technologies within the field of pediatric actigraphy. *Front Psychiatry*. 2014;5:99.
21. Zagatto AM, Beck WR, Gobatto CA. Validity of the running anaerobic sprint test for assessing anaerobic power and predicting short-distance performances. *J Strength Cond Res*. 2009;23(6):1820–1827. doi:10.1519/JSC.0b013e3181b3df32
22. Gunnar Borg. *Borg's Perceived Exertion and Pain Scales*. Champaign, IL:Human Kinetics; 1998.
23. Cohen J. A power primer. *Psychol Bull*. 1992;112(1):155–159. doi:10.1037/0033-2909.112.1.155
24. Little T, Williams AG. Measures of exercise intensity during soccer training drills with professional soccer players. *J Strength Cond Res*. 2007;21(2):367–371.
25. Hirvonen J, Rehunen S, Rusko H, Härkönen M. Breakdown of high-energy phosphate compounds and lactate accumulation during short supramaximal exercise. *Eur J Appl Physiol Occup Physiol*. 1987;56(3):253–259. doi:10.1007/BF00690889
26. Gordji-Nejad A, Matusch A, Li S, et al. Phosphocreatine levels in the left thalamus decline during wakefulness and increase after a nap. *J Neurosci*. 2018;38(49):10552–10565. doi:10.1523/JNEUROSCI.0865-18.2018
27. Daaloul H, Souissi N, Davenne D. Effects of napping on alertness, cognitive, and physical outcomes of karate athletes. *Med Sci Sports Exerc*. 2019;51(2):338–345. doi:10.1249/MSS.0000000000001786
28. Chouchou F. Réactivité du système nerveux autonome à des stimulations aversives au cours du sommeil chez l'homme (Doctoral dissertation, Lyon 1. 2011 L'Université Claude Bernard Lyon 1.
29. Romdhani M, Souissi N, Chaabouni Y, et al. Improved physical performance and decreased muscular and oxidative damage with postlunch napping after partial sleep deprivation in athletes. *Int J Sports Physiol Perform*. 2020;15(6):874–883.
30. Shapiro CM, Bortz R, Mitchell D, Bartel P, Jooste P. Slow-wave sleep: a recovery period after exercise. *Science*. 1981;214:1253–1254. doi:10.1126/science.7302594
31. Tanabe K, Nakazato K, Noi S. Effects of prophylactic naps on physical fitness/exercise ability and executive function in healthy young trained males. *Biol Rhythm Res*. 2020;51(3):421–440. doi:10.1080/09291016.2018.1533742
32. Petit E, Bourdin H, Tio G, Yenil O, Haffen E, Mougin E. Effects of a 20-min nap post normal and jet lag conditions on P 300 components in athletes. *Int J Sports Med*. 2018;39(7):508–516. doi:10.1055/a-0599-0888
33. Cai ZJ. A new function of rapid eye movement sleep: improvement of muscular efficiency. *Physiol Behav*. 2015;144:110–115. doi:10.1016/j.physbeh.2015.03.013
34. Silva AF, Alvurdu S, Akyildiz Z, Clemente FM. Relationships of final velocity at 30-15 intermittent fitness test and anaerobic speed reserve with body composition, sprinting, change-of-direction and vertical jumping performances: a cross-sectional study in youth soccer players. *Biology*. 2022;11(2):197. doi:10.3390/biology11020197