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Original Article

The effects of 40-, 60- and 90-minute nap durations on physical and physiological performance after sleep deprivation: A experimental study on male university soccer players

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ABSTRACT

Aim: This study investigates the effects of various nap durations (40, 60, and 90 min) on physical and physiological performance in response to sleep deprivation in competitive soccer players.

Methods: 16 male soccer players were tested in a counterbalanced experimental design with four experimental visits containing the following conditions: three nap conditions (40-, 60-, and 90 min naps) and a no-nap control. All participants were subjected to partial sleep deprivation with less than 5 h of sleep before each experimental session. Physical performance was assessed through the countermovement jump (CMJ) and 20m repeated sprint ability (RSA) tests. Physiological measures were maximal heart rate (HRmax), venous lactate concentration (Lac) and rating of perceived exertion (RPE) and were measured before and after the nap. Two-way repeated measures ANOVA uncovered significant interactions between nap condition and time in all physical and physiological measures ($p < 0.05$).

Result: Findings revealed that 90 min nap condition elicited the most significant improvement with higher CMJ scores, faster RSA performance (TST, MST, BST) and decreased HRmax, Lac, and RPE parameters ($p < 0.001$) compared to the control and shorter nap duration conditions.

Conclusion: These results imply that a 90 min nap is most beneficial to soccer players' physical and physiological performance following sleep deprivation.

Introduction

Sleep is a biological necessity essential to physical recuperation and optimal physiological functioning. Athletes in high-performance environments such as competitive soccer are frequently subjected to Partial Sleep Deprivation (PSD) due to intensive training patterns, travel schedules, and psychosocial stressors.[1,2] Sleep deprivation has been described to impair multiple physiological measures such as cardiovascular function, metabolic homeostasis, and neuromuscular coordination that are important to maintain high-level performance.[3,4]

One promising countermeasure to mitigate the adverse effects of PSD is daytime napping. Scientific research proved that naps of varying duration enhance physical and physiological recuperation, reduce fatigue, and enhance performance.[5,6] It is duration-dependent in effectiveness and is enhanced with longer naps, especially those reaching the most recuperative Slow Wave Sleep (SWS) and Rapid Eye Movement (REM) stages.[7] The sleep of human beings is divided into cyclic phases consisting of non-rapid eye movement (NREM) sleep, light sleep (N1-N2) and slow-wave sleep (SWS; N3), and rapid eye movement sleep (REM). The average duration of a sleep cycle is 90–110 min, and the initial part of the cycle is characterized by SWS, and the latter is introduced by REM sleep.[2,7]

Shorter naps of about 30–40 min are mostly composed of light stages of NREM and do not regularly provide access to SWS, which provides a limited physiological rest but less sleep inertia. Mid-day naps (around 60–65 min) could permit some partial access to SWS and enable partial neuromuscular and metabolic relaxation. By contrast, longer naps of about 90 min allow one to complete a complete sleep cycle, which includes SWS and REM sleep that are essential to muscle glycogen restoration, rebalancing of the autonomic nervous system, motor memory consolidation, and cognitive rest.[6,8] Narrative and scoping reviews of athletes replicate these findings, also both noting hopeful results as well as methodological heterogeneity.[9–11]

More recent systematic reviews and meta-analyses suggest that

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daytime napping can have positive effects on sport-related performance outcomes, but effects are influenced by nap length, outcome, and participant factors. Many large syntheses have reported overall small-to-moderate positive effects of napping upon physical and cognitive functioning, as well as subjective fatigue reduction, but report significant heterogeneity between studies.[12–15] A number of controlled and randomized trials show that extended naps (e.g., ~90 min) can bring significant improvements in sprint and repeated-sprint ability, vertical jump, and perceptual measures following sleep deprivation.[13,16]

Thus, the choice of 40-, 60-, and 90 min durations of naps in the current study was based on the theoretical framework of sleep physiology, as these durations of rest corresponded to increasingly more availability to restful sleep phases. In this design, determinants of performance recovery after partial sleep deprivation can be studied depending on the duration of the naps and the possibility of deep sleep stages. In spite of increased evidence of napping as a recovery intervention, there has been little empirical investigation of the relative effectiveness of different napping lengths to recover physical and physiological function in elite sportspeople during competition.

The present study investigates the effects of three nap periods (40, 60, and 90 min) following sleep deprivation on physical and physiological performance in competitive soccer players. It aims to provide practical implications to coaches and athletes in attempts to improve performance through sleep-based recovery strategies. The findings provide the tactical use of daytime napping that allows access to deeper sleep phases such as SWS and REM, as a recovery method.

Methodology

Research design

This research utilized a counterbalanced, randomized experimental design to examine how varying periods of napping (40, 60, and 90 min) impact physical and physiological performance after PSD. Participants completed four experiment trials, three different nap periods and one of no nap, with at least a 72 h recovery period between trials. All assessments were conducted during pre- and post-nap periods.

Participants

16 male soccer players from the MASUM team of Universiti Pendidikan Sultan Idris (UPSI) were recruited to participate in this study. Participants age ranged from 20 to 24 years. Table 1 shows the demographic data of the participants. Through a purposive sampling technique, soccer players who have represented UPSI in MASUM-level competitions were selected since it warrants that respondents have gained experience, a level of skill, and familiarity with competitive soccer necessary for yielding valid and reliable information concerning the effects of naps on soccer-specific performance metrics.

A priori estimation of the sample size was calculated in relation to past studies directly about the use of repeated-measures designs and a subset of 10 to 20 subjects using a nap intervention on an athletic population.[6,8] The number of 16 individuals who completed all the experimental conditions aspects satisfied and surpassed the sample size which is normally considered in similar research studies and gave the study enough statistical power to identify differences within a subject in regard to the nap conditions.

The inclusion and exclusion criteria for participants include:

Inclusion criteria

- Participants must be soccer players at the UPSI MASUM team, actively training approximately three times per week.
- Participants must be in medically fit condition, not taking any supplements during the study period, and have no history of sleep disturbances or disorders.
- Participants must be male and aged between 20 to 24 years.
- Participants must have competed more than one MASUM-level competition within one calendar year.

Exclusion criteria

- Voluntary withdrawal from the study.
- Participants not completing the experimental visits at least (one visit) will be excluded from the study.

Partial sleep deprivation (PSD) protocol

Sleep and nap duration were objectively monitored using wrist-worn actigraphy (MotionWatch8, CamNtech Inc., USA), which has demonstrated acceptable validity for sleep–wake estimation in field-based sport research. One day before the trials, the participants fitted with ActiGraph (MotionWatch8, CamNtech Inc. USA) to record their sleep pattern to ensure their wakeup's time consistently throughout the study. Activity during sleep and naps were recorded until the end of the study trials. To ensure that participants were sleep-deprived in this study, they were monitored by the researcher and placed in one room. All the participants were instructed to sleep from 3.00 am until 7.30 am, to prevent sleep before the time is allowed, they provided and allowed to watch movies and play video games. They also requested to avoid any strenuous activity for 24 h prior to testing and refrain from heavy meals, caffeine or nicotine within 2 to 3 h of testing.

Experimental protocol

Nap sessions were conducted in a controlled sleep laboratory environment with standardized ambient temperature, reduced light exposure, minimal noise, and researcher supervision to ensure compliance with assigned nap durations. On arrival, height and body mass were measured. The participants filled in the Pittsburgh Sleep Quality Index (PSQI) and received baseline physiological measurements. The standard warm-ups were then carried out, preceded by a series of trials: vertical jump, and 6 × 20 m RSA test. During the RSA test, Heart Rate (HR), Rating of Perceived Exertion (RPE), and blood lactate (Lac) were recorded.

Participants then received one of the four nap conditions. Naps were monitored using ActiGraph (MotionWatch8, CamNtech Inc., USA) worn on the non-dominant wrist. Post-nap, a 30 min buffer was allowed to minimize sleep inertia. The same physical and physiological tests were repeated after the nap. All post-nap performance tests were administered following a standardized 30 min wake buffer to minimize sleep inertia effects, and testing was conducted at the same time of day across all experimental sessions to control for circadian variation. The study

Table 1
Subject's measurements demographic data.

Subject No.	Gender	Height	Weight	BMI	Age
1	Male	160	55	21.50	21
2		170	65	22.50	25
3		163	60	22.60	23
4		169	56	19.60	21
5		169	62	21.70	19
6		172	74	25.00	19
7		156	50	20.50	21
8		164	50	18.60	21
9		173	58	19.40	19
10		170	66	22.80	25
11		176	59	19.00	27
12		173	69	23.10	19
13		180	68	21.00	21
14		169	52	18.20	20
15		176	70	22.60	21
16		164	58	21.60	25

assessed the effects of different nap durations on physical and physiological performance using validated protocols and standardized instruments as shown in Fig. 1.

Physical performance assessment

Two primary tests were used to evaluate explosive power and anaerobic capacity:

Vertical jump (VJ) test

Lower-body explosive strength was measured using the My Jump 2 smartphone application, a validated tool that calculates jump height based on flight time. Participants executed jumps using a standardized hands-on-hips technique to eliminate arm-swing influence and ensure consistency.

Repeated sprint ability (RSA) test

Sprint recovery consisted of 30 s of active recovery involving light walking back to the start line, consistent with established RSA testing protocols. Participants completed six 20 m straight-line sprints, each separated by 30 s of active recovery. Performance metrics captured included Total Sprint Time (TST), Mean Sprint Time (MST), Best Sprint Time (BST), and Fatigue Index (FI). All sprint times were recorded using Fusion electronic timing gates (Fusion Ltd., Australia) to ensure high measurement accuracy.

Physiological performance assessment

Three physiological parameters were monitored during and after performance testing:

Heart rate (HR)

Heart rate was monitored continuously using a Polar FT1 chest strap monitor (Polar Electro, Finland), with maximum heart rate (HRmax) recorded during RSA testing to assess cardiovascular load.

Rating of perceived exertion (RPE)

Perceived physical effort was evaluated using the Borg CR10 scale after each sprint repetition during the RSA test.

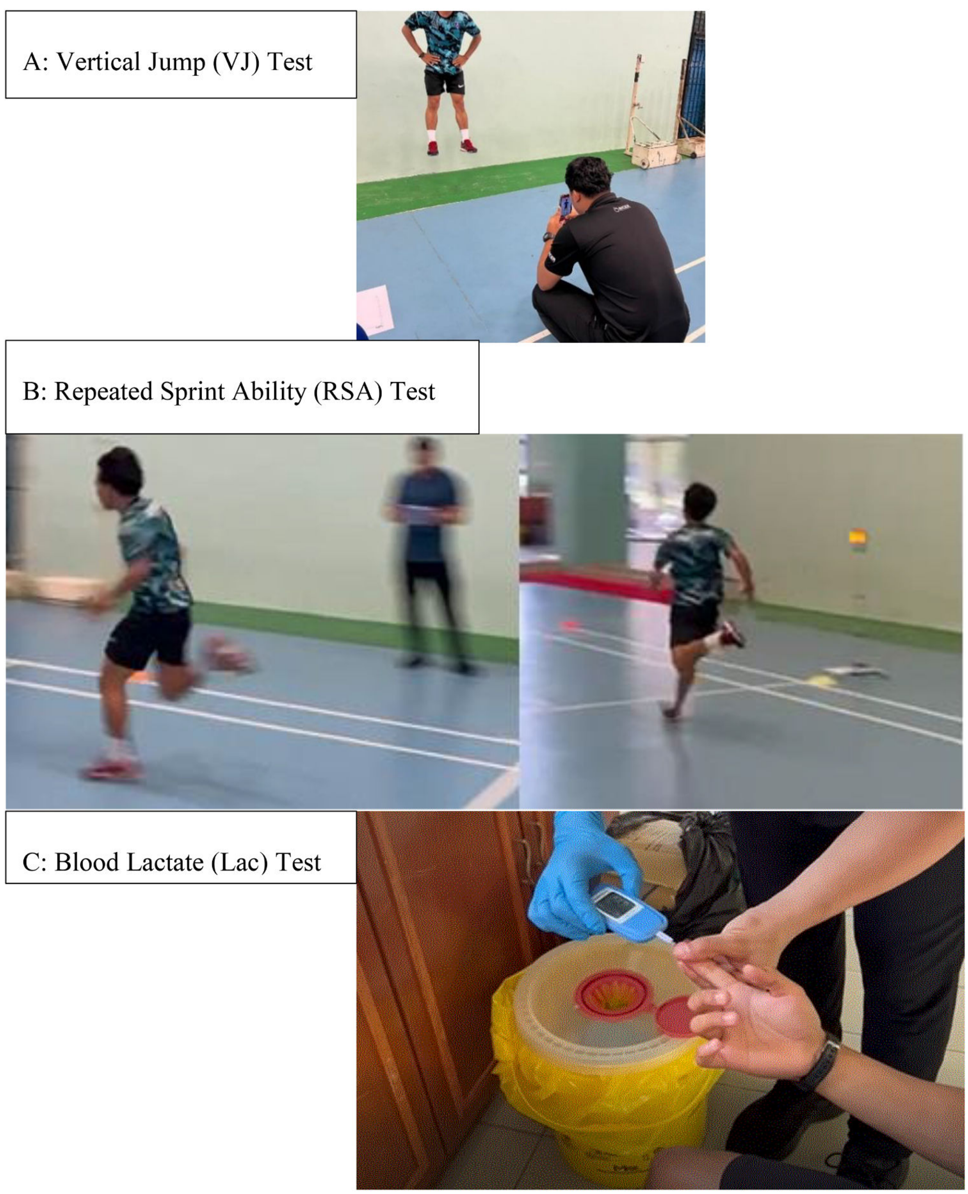

Fig. 1. Assessment Tool (A) VJ test. (B) RSA test. (C) Lac measurement using fingertip blood sampling with lactate pro analyzer.

Blood lactate (Lac)

A 0.5 µL fingertip blood sample was collected before and 3 min after the RSA protocol using the Lactate Pro portable analyzer (Arkray, Japan). Lactate concentration served as a marker of anaerobic metabolism and muscular fatigue.

Data collection

ActiGraph devices (MotionWatch8, CamNtech Inc., USA) were used to measure objective sleep and nap, whereas subjective sleep quality was determined by the Pittsburgh Sleep Quality Index (PSQI, Malay version). Nap interventions were carried out in an environment controlled at the Sleep Laboratory, Faculty of Sports Science and Coaching, UPSI. Pre- and post-nap testing was carried out by following a standard order, and participants were observed during the process to ensure adherence to partial sleep deprivation and nap procedures.

Statistical analysis

IBM SPSS Statistics was used to analyze data. Prior to analysis, datasets were screened for completeness, outliers, and adherence to normality assumptions using the Shapiro-Wilk test. A two-way repeated measures ANOVA was used to examine the interaction effects between nap duration (no nap, 40, 60, and 90 min) and time (pre- and post-test) on each dependent variable. Where violations of sphericity were detected, Greenhouse-Geisser ($\varepsilon < 0.75$) or Huynh-Feldt ($\varepsilon > 0.75$) corrections were applied accordingly. Post hoc pairwise comparisons were conducted using Bonferroni-adjusted significance levels to control for familywise error across multiple comparisons using the Bonferroni adjustment method. Statistical significance was set at $p < 0.05$.

Partial eta squared (η^2) was calculated as a measure of effect size for ANOVA outcomes. Where applicable, 95% confidence intervals were estimated for mean differences. Assumptions of normality and sphericity were verified prior to analysis.

Results

Descriptive statistics for all physical and physiological variables across experimental conditions are presented in Table 2, while inferential statistics and effect sizes are summarized in Tables 3 and 4.

Physical and physiological performance outcomes

Physical performance - CMJ and 20m-RSA (TST, MST, BST, and FI)

After sleep deprivation, physical and physiological performance outcomes of nap periods of 40, 60, and 90 min were compared with repeated measures ANOVA. The measure of physical performance variables considered were CMJ and repeated sprint ability parameters such as Total Sprint Time TST, BST, MST, and FI. The physiological outcomes assessed were HRmax, RPE, and Lac.

As Table 2 indicates, descriptive statistics yielded post-nap performance improvement, in particular, in the condition of 90 min. Significant effects were noted in all physical performance parameters, with p-values of <0.001 and large effect sizes (η^2 of .430 to .863) as noted in Table 3. CMJ post-nap performance was significantly superior following naps of 90 min in comparison to post-no-nap and those of lesser duration ($p < 0.001$). Likewise, all of the RSA indices (TST, BST, MST, FI) exhibited superior sprint performance following the 90 min nap condition.

The post-hoc analysis of Bonferroni as shown in Table 4, confirmed that post-90 min naps produced superior CMJ and RSA results to all of the other conditions ($p < 0.05$) and that the sprint time was fastest and the index of fatigue was lowest with the nap of 90 min.

Physiological outcome (HRmax, PRE and Lac)

In terms of physiological responses, significant interaction effects

Table 2
Descriptive statistics of the CMJ and 20m-RSA (TST, MST, BST and FI) tests across the different experimental sessions.

Variables	Measurement Conditions	Mean ± SD (cm)
Physical		
CMJ (cm)	No nap-Pre	34.079 ± 4.132
	No Nap -Post	33.426 ± 4.385
	Nap 40 min - Pre	33.970 ± 4.226
	Nap 40 min - Post	35.626 ± 4.421
	Nap 60 min - Pre	34.091 ± 4.277
	Nap 60 min - Post	36.912 ± 4.047
	Nap 90 min - Pre	34.173 ± 4.329
	Nap 90 min - Post	38.651 ± 3.899
RSA		
	Measurement Conditions	**Mean ± SD (sec)**
TST (cm)	No nap-Pre	19.219 ± 1.034
	No Nap -Post	20.412 ± 1.545
	Nap 40 min - Pre	19.375 ± 0.999
	Nap 40 min - Post	18.355 ± 1.463
	Nap 60 min - Pre	19.399 ± 1.143
	Nap 60 min - Post	18.005 ± 1.508
	Nap 90 min - Pre	19.415 ± 1.089
	Nap 90 min - Post	16.655 ± 1.164
	Measurement Conditions	**Mean ± SD (sec)**
BST (cm)	No nap-Pre	3.278 ± 0.312
	No Nap -Post	3.445 ± 0.287
	Nap 40 min - Pre	3.307 ± 0.293
	Nap 40 min - Post	3.035 ± 0.330
	Nap 60 min - Pre	3.297 ± 0.237
	Nap 60 min - Post	2.990 ± 0.368
	Nap 90 min - Pre	3.408 ± 0.313
	Nap 90 min - Post	3.655 ± 0.264
	Measurement Conditions	**Mean ± SD (sec)**
MST (cm)	No nap-Pre	3.286 ± 0.312
	No Nap -Post	3.856 ± 0.287
	Nap 40 min - Pre	3.274 ± 0.293
	Nap 40 min - Post	3.013 ± 0.330
	Nap 60 min - Pre	3.270 ± 0.237
	Nap 60 min - Post	2.978 ± 0.368
	Nap 90 min - Pre	3.287 ± 0.313
	Nap 90 min - Post	2.786 ± 0.264
	Measurement Conditions	**Mean ± SD**
FI (cm)	No nap-Pre	6.752 ± 1.074
	No Nap -Post	7.804 ± 1.476
	Nap 40 min - Pre	6.626 ± 1.188
	Nap 40 min - Post	5.459 ± 1.069
	Nap 60 min - Pre	6.689 ± 1.233
	Nap 60 min - Post	5.085 ± 0.930
	Nap 90 min - Pre	6.696 ± 1.358
	Nap 90 min - Post	4.213 ± 0.773
Physiological		
	Measurement Conditions	**Mean ± SD (bpm)**
HRmax	No nap-Pre	181.75 ± 3.088
	No Nap -Post	185.63 ± 2.247
	Nap 40 min - Pre	181.31 ± 2.983
	Nap 40 min - Post	174.56 ± 2.632
	Nap 60 min - Pre	181.63 ± 3.138
	Nap 60 min - Post	173.25 ± 3.130
	Nap 90 min - Pre	181.38 ± 2.849
	Nap 90 min - Post	168.19 ± 2.316
	Measurement Conditions	**Mean ± SD**
RPE	No nap-Pre	15.56 ± 0.629
	No Nap -Post	15.75 ± 0.683
	Nap 40 min - Pre	15.44 ± 0.629
	Nap 40 min - Post	13.38 ± 0.500
	Nap 60 min - Pre	15.56 ± 0.512
	Nap 60 min - Post	13.06 ± 0.574
	Nap 90 min - Pre	15.50 ± 0.730
	Nap 90 min - Post	12.13 ± 0.500
	Measurement Conditions	**Mean ± SD (mmol/L)**
Lac	No nap-Pre	9.244 ± 1.611
	No Nap -Post	9.894 ± 1.177
	Nap 40 min - Pre	9.238 ± 1.582
	Nap 40 min - Post	7.325 ± 0.478
	Nap 60 min - Pre	9.250 ± 1.619
	Nap 60 min - Post	7.088 ± 0.422
	Nap 90 min - Pre	9.269 ± 1.572
	Nap 90 min - Post	6.063 ± 0.511

Table 3
Tests of within-subjects effects on CMJ and 20m-RSA (TST, MST, BST and FI) scores across measurement sessions.

Variables	Source	Type III Sum of Squares	df	Mean Square	*F*	P-value	η^2
Physical							
CMJ	time	370.655	3.396	109.141			
	error(time)	93.463	50.942	1.835	59.487	0.000	.799
RSA							
TST	time	370.655	2.894	109.141			
	error(time)	93.463	43.410	1.835	46.940	.001	.758
BST	time	8.086	3.215	2.515			
	error(time)	10.730	48.226	.222	11.304	0.000	.430
MST	time	11.332	2.179	5.201			
	error(time)	1.798	32.684	.055	94.543	0.000	.863
FI	time	148.378	2.967	50.015			
	error(time)	39.970	44.500	.898	55.684	0.000	.788
Physiological							
HRmax	time	3786.742	2.564	1476.814			
	error (time)	423.383	38.462	11.008	134.160	0.000	.899
PRE	time	234.469	3.898	60.156			
	error(time)	38.531	58.465	.659	91.277	0.000	.859
Lac	time	215.367	1.315	163.805			
	error(time)	64.116	19.722	3.251	50.385	0.000	.771

were also found across all parameters. As indicated in Table 2, HRmax, RPE, and Lac levels were lower following nap interventions. According to Table 3, repeated measures ANOVA confirmed significant reductions in HRmax, RPE, and Lac post-nap, particularly under the 90 min nap condition (all $p < 0.001$; η^2 from .771 to .899). The post-hoc comparisons presented in Table 4 again revealed that the nap of 90 min produced significantly lower values than both no-nap and brief nap conditions ($p < 0.05$).

In total, the 90 min nap time outperformed both the shorter naps and no-nap condition at improving both the physical performance (CMJ and RSA) and decreasing physiological stress (HRmax, RPE, and Lac) in sleep-deprived soccer players.

Discussion

Physical performance - CMJ and 20m-RSA (TST, MST, BST, and FI)

The study examined the effects of napping at 40, 60, and 90 min on the performance of athletes in high-intensity, short-duration activities, such as vertical jumps and sprints. CMJ tests are widely used to evaluate these parameters because they are sensitive to fatigue and recovery states. Significant improvements in jump height post 40, 60, and 90 min naps were observed for the CMJ test at 38.65 ± 3.89 cm, higher than post-no-nap conditions of 33.42 ± 4.38 cm ($p < 0.001$). In contrast, the 40- and 60 min naps showed significant improvements compared to the no-nap condition. These findings underscore the crucial role of sleep in promoting synaptic plasticity and muscle coordination, which are important for high-intensity performance. Muscle coordination is a important energy form for high-intensity activities with short durations, such as vertical jumps.[17] Sleep deprivation suppresses glycogen synthesis but napping in 90 min blocks, enabling its replenishment and promoting muscle power and explosiveness.[18] Further, the facilitation of neuromuscular recovery, motor memory consolidation, and increased muscle contraction efficiency has been achieved with deeper stages of sleep accessed during the 90 min nap, namely SWS and REM.[18]

These findings align with the work of Ayhan, who observed that a brief, 30 min nap following partial sleep deprivation significantly improved cognitive performance, short-term high-intensity physical output, and mood.[17] Sleep deprivation suppresses glycogen synthesis but napping in 90 min blocks, enabling its replenishment and promoting muscle power and explosiveness.[1] Further, the facilitation of neuromuscular recovery, motor memory consolidation, and increased muscle contraction efficiency has been achieved with deeper stages of sleep accessed during the 90 min nap, namely SWS and REM.[18]

In addition to improving CMJ performance, nap manipulations significantly improved all RSA parameters (TST, MST, BST, and FI). The significant improvements in performance were observed to occur after the 90 min condition. Overall, TST was reduced following the 90 min nap condition compared with the no-nap condition, suggesting faster sprints. However, the 40- and 60 min naps further contributed toward improvements in TST, though less pronounced compared to improvements instituted after a 90 min nap condition, at p = 0.001. These findings are supported by Souabni et al.[19], who affirm that longer naps positively impact anaerobic activities because of energy and neuromuscular coordination facilitation.

Suppiah et al.[20] reported that sleeping did not significantly affect mean times to sprint the 10- and 20 m distances or the best times to sprint 2 m and 10 m, respectively, from a standing position in adolescent athletes. In this context, the effect of napping on shuttle run performance showed no consistency; therefore, sleep can affect these physical parameters different.

The significant enhancement of the TST during the experiment follows the length of rest in every nap period, the rest for 90 min resulted in the highest increase. Much longer napping than this study resulted in significant positivity influencing sprint performances through reduced time, time spent in tension, and recovery rate improvements, although there is complete contradiction to this inference found by Suppiah et al.[20]. These results provide invaluable insight into sleep as an optimizer of athletic performance.

The results substantiate the effectiveness of a 90 min nap, a significant recovery intervention in mitigating impairment induced by sleep deprivation, thereby establishing the importance of providing an opportunity for restorative sleep in any context of PSD. For instance, improvements in jump CMJ and RSA following 90 min-napping in TST MST, BST, and FI revealed that rest contributed to mitigating muscle and perceptible fatigue levels for subsequent optimal performance.

Physiological (HRmax, PRE and Lac)

This study found that longer naps provide a greater degree of physiological recuperation after exertion, particularly after a 90 min nap intervention. This supports previous studies that have demonstrated that adequate sleep plays a fundamental role in physiological recovery, particularly in cardiovascular and metabolic domains. Deep and REM stages of sleep are critical for autonomic rebalancing and the removal of lactate through glial cells. The findings also support the cardiovascular and metabolic recovery theory by Mah et al., which suggests that longer nap advances faster and more effective recovery after exercise, favoring overall athletic performance.[3] The study also found that napping significantly reduced HRmax post-sleep deprivation, particularly after a

Table 4
Pair Wise comparisons of CMJ and 20m-RSA (TST, MST, BST and FI) scores across the measurement sessions.

Measurement Sessions	Conditions		Mean Difference	P-value
Physical				
CMJ				
Pre-Test	No nap	Nap 40 min	.109	.252
		Nap 60 min	-.012	.223
		Nap 90 min	-.094	.263
	Nap 40	Nap 60 min	-.121	1.000
		Nap 90 min	-.203	1.000
	Nap 90	Nap 40 min	.203	1.000
		Nap 60 min	.082	1.000
Post-Test	No nap	Nap 40 min	-2.199	.001
		Nap 60 min	-3.486*	.001
		Nap 90 min	-5.224*	.001
	Nap 40	Nap 60 min	-1.286	.129
		Nap 90 min	-3.025*	.001
	Nap 90	Nap 40 min	3.025*	.001
		Nap 60 min	1.739*	.016
*. The mean difference is significant at the 0.05 level.				
RSA (TST)				
Pre-Test	No nap	Nap 40 min	-.156	.733
		Nap 60 min	-.180	.888
		Nap 90 min	-.196	.821
	Nap 40	Nap 60 min	-.024	1.000
		Nap 90 min	-.040	1.000
	Nap 90	Nap 40 min	.040	1.000
		Nap 60 min	.016	1.000
Post-Test	No nap	Nap 40 min	2.057	.003
		Nap 60 min	2.407*	.000
		Nap 90 min	3.757*	.001
	Nap 40	Nap 60 min	.351	.433
		Nap 90 min	1.700*	.000
	Nap 90	Nap 40 min	-1.700*	.001
		Nap 60 min	-1.349*	.007
*. The mean difference is significant at the 0.05 level.				
RSA (BST)				
Pre-Test	No nap	Nap 40 min	-.029	.502
		Nap 60 min	-.019	.511
		Nap 90 min	-.129	541
	Nap 40	Nap 60 min	.010	1.000
		Nap 90 min	-.101	1.000
	Nap 90	Nap 40 min	.101	1.000
		Nap 60 min	.111	1.000
Post-Test	No nap	Nap 40 min	.411	.007
		Nap 60 min	.455	.006
		Nap 90 min	.801*	.001
	Nap 40	Nap 60 min	.044	.364
		Nap 90 min	.390*	.002
	Nap 90	Nap 40 min	-.390*	.002
		Nap 60 min	-.346*	.002
*. The mean difference is significant at the 0.05 level.				
RSA (MST)				
Pre-Test	No nap	Nap 40 min	.012	.450
		Nap 60 min	016	.244
		Nap 90 min	-.001	.219
	Nap 40	Nap 60 min	.004	1.000
		Nap 90 min	-.013	1.000
	Nap 90	Nap 40 min	.013	1.000
		Nap 60 min	.017	1.000
Post-Test	No nap	Nap 40 min	.842*	.000
		Nap 60 min	.878*	.000
		Nap 90 min	1.070*	.000
	Nap 40	Nap 60 min	.279	.364
		Nap 90 min	.004	.002
	Nap 90	Nap 40 min	-.228*	.004
		Nap 60 min	-.192*	.014
*. The mean difference is significant at the 0.05 level.				
RSA (FI)				
Pre-Test	No nap	Nap 40 min	.126	.261
		Nap 60 min	.063	.238
		Nap 90 min	.056	.226
	Nap 40	Nap 60 min	-.063	1.000
		Nap 90 min	-.071	1.000
	Nap 90	Nap 40 min	.071	1.000
		Nap 60 min	.007	1.000

Table 4 (*continued*)

Measurement Sessions	Conditions		Mean Difference	P-value
Post-Test	No nap	Nap 40 min	2.345*	.000
		Nap 60 min	2.719*	.000
		Nap 90 min	3.591*	.000
	Nap 40	Nap 60 min	.374	.227
		Nap 90 min	1.246*	.000
	Nap 90	Nap 40 min	-1.246*	.000
		Nap 60 min	-.872*	.001
*. The mean difference is significant at the 0.05 level.				
Physiological				
HRmax				
Pre-Test	No nap	Nap 40 min	.438	.391
		Nap 60 min	.125	.374
		Nap 90 min	.375	.344
	Nap 40	Nap 60 min	-.313	1.000
		Nap 90 min	-.063	1.000
	Nap 90	Nap 40 min	.063	1.000
		Nap 60 min	-.250	1.000
Post-Test	No nap	Nap 40 min	11.063*	.000
		Nap 60 min	12.375*	.000
		Nap 90 min	17.438*	.000
	Nap 40	Nap 60 min	1.313	.152
		Nap 90 min	6.375*	.000
	Nap 90	Nap 40 min	-6.375*	.000
		Nap 60 min	-5.063*	.000
*. The mean difference is significant at the 0.05 level.				
PRE				
Pre-Test	No nap	Nap 40 min	.125	.182
		Nap 60 min	.000	.176
		Nap 90 min	.063	.168
	Nap 40	Nap 60 min	-.125	1.000
		Nap 90 min	-.063	1.000
	Nap 90	Nap 40 min	.063	1.000
		Nap 60 min	-.063	1.000
Post-Test	No nap	Nap 40 min	2.375*	.000
		Nap 60 min	2.688*	.000
		Nap 90 min	3.625*	.000
	Nap 40	Nap 60 min	.313	.104
		Nap 90 min	1.250*	.000
	Nap 90	Nap 40 min	-1.250*	.000
		Nap 60 min	-.938*	.002
*. The mean difference is significant at the 0.05 level.				
Lac				
Pre-Test	No nap	Nap 40 min	.006	.093
		Nap 60 min	.000	.081
		Nap 90 min	-.025	.083
	Nap 40	Nap 60 min	-.013	1.000
		Nap 90 min	-.031	1.000
	Nap 90	Nap 40 min	.031	1.000
		Nap 60 min	.019	1.000
Post-Test	No nap	Nap 40 min	2.569*	.000
		Nap 60 min	2.806*	.000
		Nap 90 min	3.831*	.000
	Nap 40	Nap 60 min	.237	.062
		Nap 90 min	1.262*	.000
	Nap 90	Nap 40 min	-1.262*	.000
		Nap 60 min	-1.025*	.002
*. The mean difference is significant at the 0.05 level.				

90 min nap intervention, which indicates a positive impact on cardiovascular recovery. This lowered HRmax indicates an improvement in cardiovascular efficiency, allowing the heart to sustain levels of physical exertion with less effort after a nap. This further enhances efficiency, reflecting theories of recovery based on parasympathetic dominance and balance of the autonomic nervous system.

The study explores the physiological benefits of incorporating both short sleep stages (SWS and REM) into athletes' routines, particularly after partial sleep deprivation, to promote heart rate recovery and optimize performance outcomes. The 90 min nap is found to be particularly beneficial as it helps athletes manage their HRmax, which is crucial for coping with physical stress imposed by exercise. Shorter naps, such as 40- and 60 min naps, do not show significant improvements in HRmax, suggesting that SWS and REM stages may not have been fully engaged in autonomic processes for optimal heart rate recovery.

The study also found a marked decrease in Relative Pain Index (RPE) across nap durations, with the most significant decline observed after the 90 min nap. This suggests that athletes considered physical activities less tiring and stressful, which aligns with psychophysiological recovery theories. This effect could be related to deeper stages of sleep reached during a 90 min nap, namely SWS and REM sleep, which are essential for cognitive performance, mood stabilization, and mental fatigue reduction.

The lactate level findings agreed with the reducing values of RPE, as minimal increases in Lac levels, significantly lowered after the 90 min nap, mark anaerobic metabolic activity and indicate muscular fatigue. Lower lac concentrations after the nap indicate better metabolic clearance for recovery and, in this manner, reduce physical strain and thereby lower perceived exertion.

However, the inability to combine full SWS and REM cycle stages with shorter nap options explains the smaller absolute reductions observed in RPE amplitude, underlining the enhanced restorative effect of a full 90 min sleep. Longer naps are more effective in facilitating lactate clearance by including, besides SWS and REM stages, the deeper stages of sleep that are essential for ideal metabolic restoration and muscle recovery.

Reduced lactate levels following a nap support existing theories around metabolic recovery, suggesting improved oxygen uptake and replenishment of energy substrates, which in turn promotes more efficient lactate clearance. Longer naps that encompass both SWS and REM stages appear to facilitate greater metabolic restoration and mitigate muscle fatigue associated with lactate buildup. In contrast, shorter naps seem less effective in producing these benefits.

In conclusion, the study highlights the strategic value of integrating longer naps into athletes' routines, especially after partial sleep deprivation, to promote heart rate recovery and optimize performance outcomes.

Reduced lactate levels following a nap support existing theories around metabolic recovery, suggesting improved oxygen uptake and replenishment of energy substrates, which in turn promotes more efficient lactate clearance. Notably, longer naps that encompass both SWS and REM stages appear to facilitate greater metabolic restoration and mitigate muscle fatigue associated with lactate buildup. In contrast, shorter naps seem less effective in producing these benefits. SWS facilitates cellular repair and muscle glycogen replenishment, both critical to reducing lactate buildup and preventing muscle fatigue. In high-intensity physical performance, such as sprinting and jumping, lactate buildup impairs muscle function; thus, the ability of naps to support lactate clearance directly correlates with enhanced recovery and sustained athletic performance. Results have indicated that longer nap duration affords greater lactate clearance because both SWS and REM sleep stages are contained.[1]

Conclusion

The findings indicated that nap duration following 90 min sleep deprivation (SD) significantly improved physical and physiological performance after partial sleep deprivation among competitive soccer players. The vertical jump height and repeated sprint ability improved remarkably following the 90 min nap, as revealed by decreases in TST, MST, BST, and FI scores. Physiological parameters, including HRmax, RPE, and Lac, also decreased dramatically, indicating improved cardiovascular efficiency, decreased perceived exertion, and enhanced recovery at the metabolic level. Such findings confirm the efficacy of planned, longer-duration naps as a recovery protocol to address the deteriorating impact of sleep deprivation on physical performance.

Limitations and strengths

The limitation of the study included utilizing a small sample of 16 male college athletes, which limits the findings of the study to diverse populations. The use of ActiGraph for Verification of sleep stage (e.g., SWS or REM) data as opposed to polysomnography (PSG) posits a limitation. The absence of heart rate variability (HRV) and cognitive performance measures represents a limitation, as these variables are commonly used to assess autonomic and neurocognitive recovery following sleep interventions. Future studies should incorporate HRV and cognitive assessments to provide a more comprehensive evaluation of recovery processes. Whereas, the study employed a randomized study design that enhances internal validity and minimizes inter-individual variability. Also. The utilization of CMJ and RSA provides high ecological validity for soccer performance.

Future recommendation

Future studies should examine if analogous nap-related advantages extend to female sports participants and competitors in endurance- or skill-sport activities. Incorporating PSG would assist in confirming sleep stage transitions and more clearly associating them with performance shifts. Longitudinal investigation would reveal whether frequent nap strategies yield cumulative advantages or progressively smaller rewards.

Author contributions

Ashraf Ahmed Alazzam: Contributed to conceptualization, validation, formal analysis, and investigation; was responsible for original manuscript draft, content review and editing, visualization, and project managing.

Asmadi Bin Ishak: Contributed to conceptualization, methodology, and validation; participated in formal analysis, investigation, provision of resources, and curation of data; was involved in writing original draft, manuscript review and editing, visualization, and supervision.

Declarations

This study applied for ethical approval from Sultan Idris Education University's Research Ethics Committee before main data collection (Ethical Ref. no. 2023-0805-02).

Data availability

The data supporting this study are available from the corresponding author upon reasonable request.

Conflicts of interest

The authors declare no competing interests.

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