Is daytime napping an effective strategy to improve sport-related cognitive and physical performance and reduce fatigue? A systematic review and meta-analysis of randomised controlled trials

Arthur Eumann Mesas [1,2] Sergio Núñez de Arenas-Arroyo [1]
Vicente Martinez-Vizcaino [1,3] Miriam Garrido-Miguel [1,4]
Ruben Fernández-Rodríguez [1] Bruno Bizzozero-Peroni [1,5]
Ana I Torres-Costoso [1,6]

Check for updates

ABSTRACT

Objective To estimate the association between daytime napping and cognitive and physical sport performance and fatigue after normal sleep and partial sleep deprivation (less sleep duration than necessary).
Design Systematic review and meta-analysis.
Data sources The PubMed, Scopus, Web of Science, Cochrane Central, SportDiscus and PsycINFO databases.
Eligibility criteria for selecting studies Randomised controlled trials on the effect of daytime napping on sport performance and fatigue available from inception to 2 December 2022. Standardised mean differences (SMD) and their 95% compatibility intervals (CI) were estimated with the DerSimonian-Laird method through random effect models.
Results In the 22 included trials, 291 male participants (164 trained athletes and 127 physically active adults) aged between 18 and 35 years were studied. When performed after a normal night of sleep, napping from 12:30 hours to 16:50 hours (with 14:00 hours being the most frequent time) improved cognitive (SMD=0.69, 95% CI: 0.37 to 1.00; I^2=71.5%) and physical performance (SMD=0.99, 95% CI: 0.67 to 1.31; I^2=89.1%) and reduced the perception of fatigue (SMD=−0.76, 95% CI: −1.24 to −0.28; I^2=89.5%). The positive effects of napping were also confirmed after partial sleep deprivation. Overall, the benefits were higher with a nap duration between 30 and <60 min and when the time from nap awakening to test was greater than 1 hour.
Conclusions After a night of normal sleep or partial sleep deprivation, a daytime nap between 30 and <60 min has a moderate-to-high effect on the improvement of cognitive performance and physical performance and on the reduction of perceived fatigue.
PROSPERO registration number CRD42020212272.

INTRODUCTION

It is well established that nocturnal sleep must be of sufficient duration and good quality for optimal performance in sports activities.[1] Recent evidence reported that napping during the day, in addition to compensating for the debit caused by partial sleep deprivation in the previous night, may have further beneficial effects even after a good night's

WHAT IS ALREADY KNOWN?

⇒ Recent systematic reviews have supported the favourable effects of daytime napping on sports performance and subjective ratings of fatigue in both normal sleep and partial sleep deprivation conditions, but no meta-analysis has yet been conducted to estimate the magnitude of these benefits.

WHAT ARE THE NEW FINDINGS?

⇒ Postlunch (approximately at 14:00 hours) napping from 30 to <60 min has a high supplemental beneficial effect on physical performance and promotes a moderate improvement in cognitive performance and a reduction in perceived fatigue after sports activity.

⇒ A minimum time of 60 min after awakening from the nap is required to avoid the benefits of the nap on sports performance being attenuated by sleep inertia.

⇒ Although evidence from studies conducted under partial sleep deprivation suggests benefits similar to those observed after normal sleep, no solid recommendation can yet be stated about whether daytime napping compensates for the loss in sports performance resulting from partial sleep deprivation.

sleep.[2–4] Naps can be used to alleviate the effects of partial sleep deprivation due to, for example, stress and anxiety about the next day's competition, jetlag because of transmeridional travel, training and matches at unusual times, or as a regular practice to enhance rest by distributing total sleep between night and day periods.[5–8] In fact, it has been suggested that napping can be an effective non-invasive strategy in the above-mentioned situations, although the benefits may vary according to the extent of previous partial sleep deprivation and the specific needs of recovery for each sport modality; other relevant factors are nap duration and timing (eg, midmorning, postlunch), time from nap awakening to sport activity, the individual profile of the sport practitioner and the method (ie, objective or subjective) used to assess napping.[1 3 9]

Additionally, the effects of napping may be different depending on the parameter used to measure sport performance. Several criteria related to performance on a sport activity are available, such as cognitive performance (eg, reaction time, short-term memory, attention and alertness),[10–13] physical performance (eg, speed, strength and endurance)[13–18] and perception of fatigue or exhaustion.[10 18–20] As the relative weight of each of these performance-related parameters varies according to the sport modality, it is relevant to estimate the effects of napping on each specific group of parameters.

Three recent systematic reviews[3 9 21] and two narrative reviews[2 7] reported positive effects of napping on sport performance, such as improving physical (eg, jump, strength, running repeated-sprint) and cognitive performance (eg, attention and reaction time), lowering perceived fatigue, enhancing the recovery process and counteracting the negative effect of partial sleep deprivation on physical and cognitive performance. However, to the best of our knowledge, no meta-analysis of clinical trials has yet estimated the magnitude of these effects, which is crucial to support the development of recommendations that are sufficiently applicable in practice.

Therefore, the objective of this systematic review and meta-analysis was to synthesise the evidence from randomised controlled trials and estimate the standardised mean difference (SMD) of daytime napping on cognitive performance, physical performance and the perception of fatigue in physically active adults and athletes. In addition, the quantitative implications of nap duration and wash-out time (from nap awakening to the start of the sport activity) on these effects were explored.

METHODS

This systematic review and meta-analysis was performed according to the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[22] and the PERSiST guidance.[23] The PRISMA checklist is available in online supplemental material 2. The protocol was registered in PROSPERO (CRD42020212272).

Information sources and search strategy

The PubMed, Scopus, Web of Science, Cochrane Central, Sport-Discus and PsycINFO databases were searched for randomised controlled trials on the association between daytime napping and sport performance and fatigue published from inception to 2 December 2022. No language restriction was applied.

Eligibility criteria

The search criteria according to the PICO(S) strategy were as follows: (1) Participants: adults (18 years and older) stated as athletes of any sport modality or physically active (ie, non-athletes regularly practising exercises) individuals; (2) Intervention: napping or daytime sleep of any duration, after normal sleep or partial sleep deprivation (ie, less sleep duration than necessary, which, for young adults and adults, ranges from 7 to 9 hours)[24]; (3) Comparison: non-napping in the same sleep condition (ie, normal sleep or partial sleep deprivation); (4) Outcome: cognitive or physical performance, or perception of fatigue (considered a complex and multidimensional outcome from the lassitude/exhaustion of physical or mental capacity)[25 26] and (5) Study design: randomised controlled trial.

The exclusion criteria were as follows: study participants younger than 18 years; participants not clearly described as athletes or physically active individuals; studies conducted exclusively during or after Ramadan (because the observance of

Ramadan may affect sleep-wake patterns in athletes and physically active individuals)[27]; reviews, observational studies, case series, qualitative studies and non-eligible publication types, such as editorials, letters to the editor, erratum, study protocols and preprint papers. No filter or exclusion criteria regarding gender were applied in the literature search.

Selection process and data collection

The search strategy included the terms "napping", "daytime sleep", "sport performance" and "fatigue" and their variations, which were combined with Boolean operators and adapted to the appropriate syntax for each database. The detailed syntax can be found in online supplemental material table S2.

The articles identified in each source were combined in a single database, and duplicates were eliminated with EndNote V.X9 software (Clarivate, The EndNote Team, Pennsylvania, USA). The article selection process was carried out independently by two reviewers (AEM and SNdA-A), and any discrepancies were resolved by consulting a third reviewer (AIT-C). Initially, the titles and abstracts were all screened, and studies that clearly did not meet the inclusion criteria were discarded. The remaining studies were then retrieved from the full text, and finally, those meeting the inclusion criteria were included. The reference lists of the literature reviews found were analysed for any original studies that had not been identified in the original search.

From the included studies, the following data were extracted by one reviewer (AEM) and confirmed by a second reviewer (SNdA-A), and any discrepancies were resolved by consulting a third reviewer (AIT-C): authors, year, country, study design, sample size, participant characteristics (gender, age, athletes or physically active individuals), intervention characteristics (nap duration and sleep assessment method), outcome (sport performance test applied, test schedule and time from nap awakening to test) and main results. In some studies,[10 12 14 15 28–35] data were extracted from graphs using PlotDigitizer online software (www.plotdigitizer.com). It was not necessary to contact the authors to ask for additional data. An included study that was written in Japanese[35] was translated into English by a native Japanese speaker.

Risk of bias assessment

Two researchers (SNdA-A and AIT-C) independently conducted a quality assessment, following the Cochrane Collaboration's tool for assessing the risk of bias (RoB 2.0 tool).[36] Any disagreement was resolved through discussion, and if a consensus could not be reached, a third reviewer (VM-V) was consulted. The RoB 2.0 tool covers bias in five domains: randomisation process, deviations from intended interventions, missing outcome data, measurement of the outcome and selection of the reported result. Overall, a trial was considered at 'low risk of bias' if all domains were judged as 'low risk', 'some concerns' if there was at least one domain rated as having 'some concerns' and 'high risk of bias' if there was at least one domain judged as 'high risk'.

Synthesis methods

Considering that partial sleep deprivation has implications for both sleep requirements and sport performance, analyses were performed separately for studies reporting that the previous night was considered normal sleep and for those reporting that the sleep duration time was restricted, generating partial sleep deprivation as described above.

Because of the diversity and specificity of sport performance parameters, it would not be feasible to analyse each parameter

as an outcome. Therefore, we combined the parameters into three major groups. The first group was (1) cognitive performance, comprising indicators of cognitive function such as attention, alertness and reaction time. Another group was defined as (2) physical performance and included all tests that measured strength, endurance, speed, distance and power. The last group was (3) fatigue, including different instruments assessing the perception of fatigue or exhaustion after the sport activity.

In nine studies with data from different nap durations,[10 13 16 28 32 33 37–39] each duration was analysed separately and contrasted with the non-nap reference group. In a study that analysed daytime napping with the same duration but performed at different times in the afternoon (13 hours, 14 hours and 15 hours),[14] it was decided to include in the analysis only data from the nap taken at 14 hours, as this was the most frequent napping time among the studies included. One of the studies[28] had data of interest for time periods before, during and after Ramadan, but only data from before Ramadan were taken into account for this study. When data were available for more than one parameter corresponding to the same dimension of sport performance (eg, total distance and higher distance from the 5 m shuttle run test to evaluate physical performance), pooled estimates were calculated with random effect models.[40]

For each study, we calculated the mean change score[41] by subtracting the baseline value from the value recorded as close as possible to the end of the intervention or control period. Next, we checked whether normality could be assumed for these variables, and thus, meta-analysis was allowed. First, we observed that practically in all studies, the authors tested the normality of their outcome variables through specific tests, such as the Shapiro-Wilks test. Second, we calculated the mean/SD ratio of the change score for each intervention group (ie, nap and no-nap) in the normal sleep condition (online supplemental material table S5). Three of the studies had a mean/SD ratio <2, indicating skewness.[34 37 39] In two of them,[34 37] it was assumed that, as reported by the authors, normality had been verified with statistical tests. Regarding the other study, because this information was missing and because there were no data to calculate the mean/SD ratio, that study[39] was retained in the main analyses, and we were attentive to its influence on the results by excluding it in the sensitivity analyses. For sleep deprivation, meta-regression was not performed because this method is not recommended when fewer than 10 studies are available.[42]

Random effect models were used to estimate the SMD and the 95% compatibility intervals (95% CIs)[43] of the sport performance or fatigue group according to the mean change score ±SD in each nap and non-nap condition.[40] The SMD was used to estimate the effect size because the included studies provided outcome values using different scales to measure sports performance and fatigue.[42] In one study, the SD was estimated based on the SE and sample size.[31] In three studies,[32 38 39] the SMD (95% CI) was calculated based on the p value and Cohen's d statistics using the corresponding z score.

Study heterogeneity was assessed using the I^2 statistic[44] and classified as not important (0%–40%), moderate (30%–60%), substantial (50%–90%) and considerable (75%–100%). The corresponding p values were considered, particularly when heterogeneity was found in the overlapping zones of these intervals.[42]

Heterogeneity was explored through subgroup analyses by nap duration (<30 min, 30 to <60 min and 60 min or more)[45]; time from nap awakening to sport activity or test (≤60 min, >60 min), due to the potential effect of sleep inertia[2]; study population (athletes, as stated by the authors or with more than 7 hours/

week, and physically active or exercising less than 7 hours/week) and the method used to assess napping (objective, as measured with polysomnography, actigraphy or electroencephalogram, or subjective, as self-reported by the study participant). Moreover, for studies in a normal sleep condition, random effects (Sidik-Jonkman method) meta-regression models were used to examine whether trial-level covariates (mean age of participants—ranging from 18.3 to 35.0 years, nap duration—ranging from 10 to 120 min and time from nap awakening to test—ranging from 15 to 270 min) influenced heterogeneity. Meta-regression was not performed with studies in a partial sleep deprivation condition because this method is not recommended when fewer than 10 studies are available.[42] More information on meta-regression in normal sleep can be found in online supplemental material (meta-regression).

To assess the robustness of summary estimates and to detect whether any single study accounted for a large proportion of heterogeneity, sensitivity analyses were performed using the leave-one-out method, and new SMD (95% CI) were generated by removing the included studies one-by-one from the analyses. Finally, we evaluated publication bias through visual inspection of funnel plots and Egger's regression asymmetry test to assess small study effects.[46] Publication bias was not assessed for studies in partial sleep deprivation because this method is not recommended when fewer than 10 studies are available.[42]

The criterion proposed by Cohen[47] to classify the effect size estimator (ie, SMD) as small (SMD=0.2), medium (SMD=0.5) or large (SMD=0.8) was considered. STATA SE V.15 software (StataCorp) was used for the statistical procedures. In accordance with recent recommendations,[43] we used the expression 'high compatibility' instead of 'statistically significant', which was assumed when the p value was <0.10.

RESULTS
Study selection
As depicted in figure 1, from the 3421 studies initially identified, 90 were selected for the full-text evaluation, of which 68 did not meet the inclusion criteria and were excluded. The complete list of the articles excluded and the reasons for each is presented in online supplemental material table S3. Thus, 22 studies were finally included.[10–20 28–35 37–39]

Characteristics of the included studies
The characteristics of the included studies and their main results are summarised in table 1. Almost two-thirds (n=14 studies)[10 12 14 16 20 28–32 34 37–39] of the included studies were carried out in Tunisia, two in France,[11 18] two in the UK,[17 19] two in Japan,[13 35] one in Thailand[15] and one in Australia.[33] The sample size varied from 7 to 20 participants in each trial, totalling 291 male participants (164 trained athletes and 127 physically active adults) aged between 18 and 35 years. Some studies reported the usual duration of night-time sleep between 7 and 9 hours,[11 12 16 18–20 28 33 35 37] and some reported applying the Pittsburgh Sleep Quality Index to ensure that the participants usually had good sleep quality.[14 28 30 31] Nap duration was self-reported in 12 studies[10 16 17 20 28–32 37–39]; 5 studies used polysomnography[11 13 18 33 35]; 3 studies assessed sleep parameters with actigraphy or accelerometers[12 19 34] and 1 used electroencephalograms.[15] All studies were randomised crossover trials with a time between nap and non-nap conditions varying from 2 to 7 days. All studies evaluated post lunch nap time, ranging from 12:30 to 16:50 hours, with 14:00 hours being the most frequent time. Regarding nap duration, nine studies[10 13 16 28 32 33 37–39] tested two
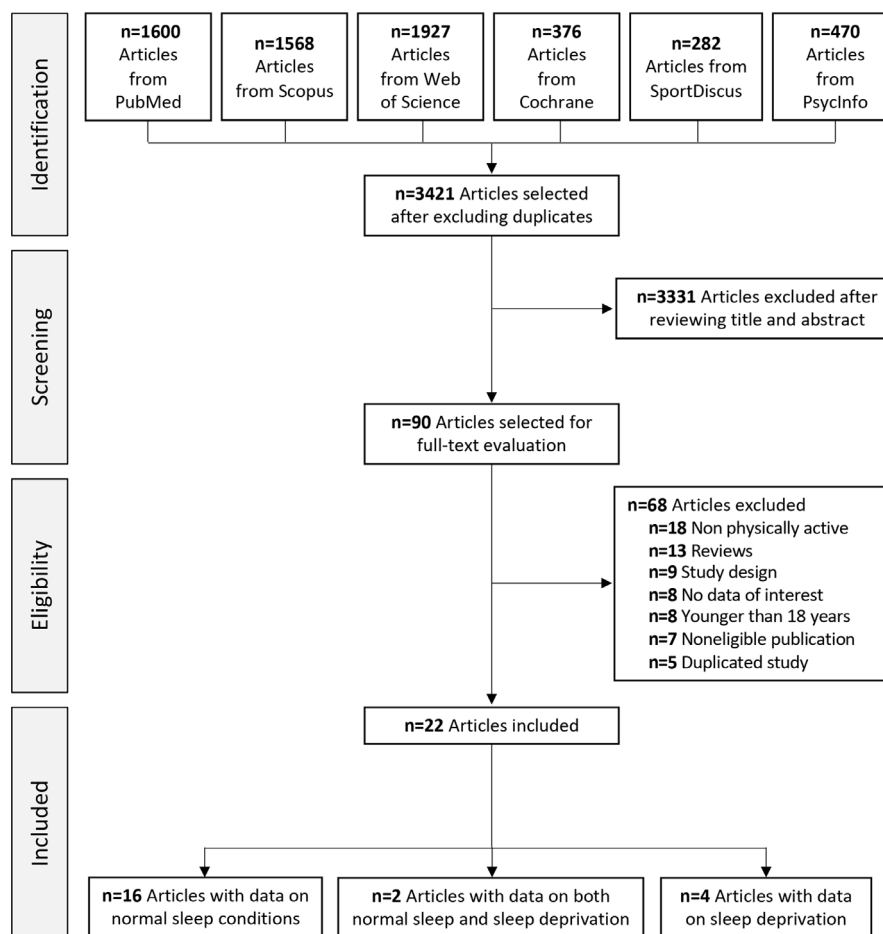
Figure 1 Flow diagram of the study selection.

or more different nap durations ranging from 20 to 120 min, and the other studies considered only a single duration varying from 10 to 60 min.

Cognitive performance was mostly measured with digital cancellation or reaction time tests (12 out of 14 studies). The 5 m run test was the most frequently used test (8 of 21 studies) to evaluate physical performance. Among the studies considering fatigue, the rate of perceived exertion test was mostly applied (12 of 18 studies). The specific tests used in each study and considered for the present analyses are presented in online supplemental material table S4.

Main results from the meta-analyses

The main analyses showed that after a normal night of sleep, napping improved cognitive (SMD=0.69, 95% CI: 0.37 to 1.00; I^2=71.5%) (figure 2A) and physical performance (SMD=0.99, 95% CI: 0.67 to 1.31; I^2=89.1%) (figure 2B) and reduced the perception of fatigue (SMD=−0.76, 95% CI: −1.24 to −0.28; I^2=89.5%) (figure 2C). In the subgroup analyses, the benefits of napping were overall clearer for nap durations between 30 and <60 min, when the time from nap awakening to test was more than 60 min, in physically active non-athlete individuals and when naps were self-reported (figure 2D–F items).

Likewise, daytime napping after partial sleep deprivation also showed a positive effect, with a high compatibility of an improvement in cognitive (SMD=1.61, 95% CI: 0.05 to 3.16; I^2=83.1%) (figure 3A) and physical performance (SMD=0.91, 95% CI: 0.51 to 1.31; I^2=88.2%) (figure 3B) and perceived

fatigue reduction (SMD=−0.96, 95% CI: −1.80 to –0.13; I^2=86.4%) (figure 3C). The results of subgroup analyses in the partial sleep-deprived condition, although much less precise due to the scarcity of studies, were similar to those observed in normal sleep (figure 3D–F items). As an exception, the SMD of napping on physical performance after partially deprived sleep was higher when napping was objectively measured than when it was self-reported (figure 3E).

Meta-regression models after normal sleep (figure 4A–I items) showed that cognitive performance (p=0.044) (figure 4C) and physical performance (p=0.004) (figure 4F) improved, while fatigue decreased (p=0.050) (figure 4I) as the time from nap awakening to test increased.

Risk of bias

The overall risk of bias assessment showed that 72.7% of studies presented some concerns, and 27.3% were scored as high risk. The complete report of the risk of bias assessment is available in online supplemental material figure S1.

Publication bias

Publication bias was observed for the nap effects after normal sleep on cognitive (p=0.022) and physical (p=0.001) performance and fatigue (p=0.020) (online supplemental material figure S2).

Sensitivity analyses

Finally, sensitivity analyses indicate that, in general, after normal sleep, there is no change in the direction or level

Table 1 Characteristics of the randomised controlled trials

Authors, year	Country	Study population*	Sample size	Mean age (year) ±SD	Napping start time	Nap duration groups (min)	Time from nap awakening to test (min) (nap duration)	Wash-out intervention-control	Sleep assessment	Night-time sleep condition (criteria)	Cognitive performance	Physical performance	Fatigue
Abdessalem et al[14] 2019	Tunisia	Physically active (≥3 hours/week)	18	20.5±3.0	14 hours‡	0, 25	COGN: 150 (25), PHYS, FATG: 165 (25)	NR	SR	Normal (sleep-satiated, PSQI ≥5)	(−)	(+)	(−)
Ajimaporn et al[15] 2020	Thailand	Trained soccer players (>9 hours/week)	11	20.0±1.0	14 hours	0, 20	All: 100 (20)	2 days	EEG	Partially deprived (5.5 hours less)	(−)	(?)	(−)
Blanchfield et al[19] 2018	UK	Trained runners	11	35.0±12.0	14:00-16:50	0, 20	All: 50 (20)	5–9 days	ACT/SR	Normal (≈7.5 hours, sleep efficiency >92%)	NR	(+)	(−)
Boukhris et al[37] 2019	Tunisia	Physically active (≥3 h/week)	17	21.3±3.4	14 hours	0, 25, 35, 45	All: 155 (25), 145 (35), 135 (45)	3 days	SR	Normal (≈7 hours)	NR	(+)	(−)
Boukhris et al[16] 2020	Tunisia	Amateur team sport players (≥8 hours/week)	14	20.3±3.0	14 hours	0, 40, 90	All: 140 (40), 90 (90)	3 days	SR	Normal (7–9 hours)	(+)	(+)	(?)
Boukhris et al[28] 2022	Tunisia	Physically active (≥4 hours/week)	15	21.0±3.0	14 hours	0, 25, 45	All: 155 (25), 135 (45)	NR	SR	Normal (only Before Ramadan)	NR	(+)	(?)
Brotherton et al[17] 2019	UK	Resistance-trained athletes	15	22.7±2.5	13 hours	0, 60	COGN: 180 (60), PHYS, FATG: 210(60)	7 days	SR	Two nights partially deprived (4.5 hours less)	(+)	(?)	(?)
Daaloul et al[20] 2019	Tunisia	Karate athletes	13	23.0±2.0	13 hours	0, 30	All: 30 (30)	7 days	SR	Normal (>7 hours)/ Partially deprived (3 hours less)	(+)	(?)	(−)
Hammouda et al[38] 2018	Tunisia	Professional judokas	9	18.5±0.9	13 hours (90), 14:10 (20)	0, 20, 90	All: 30 (20, 90)	7 days	SR	Partially deprived (4.5 hours less)	NR	(+)	NR
Hsouna et al[10] 2019	Tunisia	Physically active (≥3 hours/week)	20	21.1±3.6	14 hours	0, 25, 35, 45	All: 155 (25), 145 (35), 135 (45)	3 days	SR	Normal (NR)	(?)	(?)	(+)
Hsouna et al[31] 2020*	Tunisia	Physically active (≥3 hours/week)	12	21.1±3.2	14 hours	0, 25	All: 155 (25)	3 days	SR	Normal (NR)	(−)	(+)	(−)
Hsouna et al[30] 2020†	Tunisia	Physically active (≥3 hours/week)	14	22.0±3.0	14 hours	0, 35	All: 145 (35)	3 days	SR	Normal (NR)	(−)	(+)	(−)
Hsouna et al[29] 2022	Tunisia	Amateur soccer players (≥10 hours/week)	12	23.0±3.0	14 hours	0, 40	All: 140 (40)	3 days	SR	Normal (late evening soccer match on the previous night)	NR	(+)	(?)
Petit et al[18] 2014	France	Highly trained athletes	16	22.2±1.7	13 hours	0, 20	All: 130 (20)	NR (two nights/wk)	PSG	Normal (≈ 8 hour)	NR	(−)	(−)
Petit et al[11] 2018	France	Highly trained athletes	16	22.2±1.7	13 hours	0, 20	All: 130 (20)	NR	PSG	Normal (≈ 8 hours)	(?)	NR	NR
Romdhani et al[32] 2020	Tunisia	Highly trained judokas	9	18.8±1.1	13 hours (90), 14:10 (20)	0, 20, 90	All: 30 (20), 30 (90)	7 days	SR	Partially deprived (4 hours less)	(?)	(+)	(−)
Romdhani et al[39] 2021	Tunisia	Highly trained judokas	14	20.4±1.2	13 hours (90), 14:10 (20)	0, 20, 90	All: 30 (20), 30 (90)	7 days	SR	Normal (≈ 8.5 hours)	(?)	(?)	NR
Romyn et al[33] 2022	Australia	Semiprofessional soccer players	12	18.3±1.0	14 hours (120), 15 hours (60)	0, 60, 120	All: 15 (60, 120)	1 day	PSG	Normal (7–9 hours)	(−)	(−)	(−)
Souabni et al[34] 2022	Tunisia	Elite basketball players	12	26.3±5.2	13 hours	0, 40	All: 80 (40)	3 days	ACT/SR	Normal (NR)	NR	(+)	(−)
Souissi et al[12] 2020	Tunisia	Physically active students	14	20.5±1.5	13 hours	0, 30	All: 270 (30)	4 days	ACT/SR	Normal (8 hour)/partially deprived (3 hours less)	(+)	(+)	(+)
Tanabe et al[13] 2020	Japan	Physically active (≥1 h/week)	7	21.1±0.4	12:30 (90), 13:30 (30)	0, 30, 60, 90	All: 60 (30, 60, 90)	3 days	PSG	Normal (NR)	(?)	(−)	NR
Yamamoto and Hayashi[25] 2006	Japan	Physically active (≥10 hours/week)	10	20.3±1.1	14 hours	0, 10	All: 50	2 days	PSG	Normal (≈ 7 hours)	NR	(+)	(+)

*All study participants were men.
†The list of the specific tests used in each study for each dimension of sport performance can be found in online supplemental material table S4.
‡Data available for daytime napping taken at 13 hours and 15 hours were not used in the present analyses.
§The signals in the outcomes analysed and main results columns indicate: (+) The evidence of an association is highly compatible; (?) The results are mixed or the association is weakly compatible; (−) The evidence of an association or a fatigue indicator, nap duration or normal sleep or partial sleep deprivation condition.
ACT, accelerometer; COGN, cognitive performance; EEG, electroencephalogram; FATG, fatigue; NR, not reported; PHYS, physical performance; PSG, polysomnography; PSQI, Pittsburgh Sleep Quality Index; RCT, randomised controlled trial; SR, self-reported.

Cognitive performance (Normal Sleep)

A

Study	Nap duration	Time from nap awakening to test	SMD (95% CI)	% Weight
Petit et al, 2018	20 min	130 min	-0.06 (-0.44, 0.32)	7.37
Romdhani et al, 2021	20 min	30 min	1.15 (0.46, 1.84)	5.90
Abdessalem et al, 2019	25 min	150 min	0.40 (-0.26, 1.06)	6.05
Hsouna et al, 2019	25 min	155 min	0.86 (0.21, 1.51)	6.10
Hsouna et al, 2020a	25 min	155 min	-0.02 (-0.82, 0.78)	5.37
Daaloul et al, 2019	30 min	30 min	0.15 (-0.55, 0.84)	5.87
Soussi et al, 2020	30 min	270 min	3.76 (1.67, 5.84)	1.77
Tanabe et al, 2020	30 min	60 min	1.10 (0.32, 1.91)	5.39
Hsouna et al, 2019	35 min	145 min	1.48 (0.78, 2.18)	5.85
Hsouna et al, 2020b	35 min	145 min	1.18 (0.38, 1.99)	5.35
Boukhris et al, 2020	40 min	140 min	0.52 (-0.23, 1.27)	5.59
Hsouna et al, 2019	45 min	135 min	1.79 (1.06, 2.52)	5.69
Romyn et al, 2022	60 min	15 min	0.30 (-0.51, 1.10)	5.35
Tanabe et al, 2020	60 min	60 min	0.89 (0.01, 1.78)	4.98
Boukhris et al, 2020	90 min	90 min	0.66 (-0.10, 1.43)	5.55
Romdhani et al, 2021	90 min	30 min	0.37 (-0.07, 0.81)	7.10
Tanabe et al, 2020	90 min	60 min	0.88 (0.10, 1.65)	5.48
Romyn et al, 2022	120 min	15 min	-0.73 (-1.56, 0.10)	5.24
Overall, DL ($I^2 = 71.5\%$, p = 0.000)			0.69 (0.37, 1.00)	100.00

D

Variable and subgroups	Heterogeneity (I2, %)	Number of studies	Number of participants	SMD (95% CI)
Nap duration				
<30 min	68.8	5	80	0.44 (-0.05, 0.94)
30 to <60 min	70.3	6	82	1.19 (0.61, 1.76)
60 to 120 min	51.7	4	47	0.39 (-0.03, 0.82)
Time from nap awakening to test				
≤60 min	59.6	4	46	0.51 (0.11, 0.91)
>60 min	78.5	7	108	0.86 (0.37, 1.35)
Study population				
Athletes	57.6	5	69	0.29 (-0.05, 0.64)
Physically active	60.8	6	85	1.04 (0.63, 1.45)
Sleep (nap) assessment method				
Objective	75.8	5	63	0.60 (0.12, 1.08)
Subjective	61.8	6	91	0.78 (0.39, 1.17)

Physical performance (Normal Sleep)

B

Study	Nap duration	Time from nap awakening to test (min)	SMD (95% CI)	% Weight
Yamamoto and Hayashi, 2006	10 min	50	0.25 (-0.62, 1.13)	3.36
Blanchfield, 2018	20 min	50	0.04 (-0.80, 0.87)	3.43
Petit et al, 2014	20 min	130	0.05 (-0.44, 0.54)	4.07
Romdhani et al, 2021	20 min	30	0.62 (0.36, 0.88)	4.37
Abdessalem et al, 2019	25 min	165	0.48 (0.01, 0.95)	4.10
Boukhris et al, 2019	25 min	155	0.45 (-0.04, 0.93)	4.08
Boukhris et al, 2022	25 min	165	2.15 (0.55, 3.74)	2.11
Hsouna et al, 2019	25 min	155	1.55 (0.84, 2.25)	3.68
Hsouna et al, 2020a	25 min	155	1.28 (0.66, 1.90)	3.84
Daalcul et al, 2019	30 min	30	-0.10 (-0.64, 0.44)	3.99
Soussi et al, 2020	30 min	270	1.80 (0.82, 2.78)	3.15
Tanabe et al, 2020	30 min	60	0.05 (-0.42, 0.52)	4.10
Boukhris et al, 2019	35 min	145	0.39 (-0.09, 0.87)	4.09
Hsouna et al, 2019	35 min	145	2.00 (1.24, 2.76)	3.58
Hsouna et al, 2020b	35 min	145	1.97 (1.33, 2.60)	3.81
Boukhris et al, 2020	40 min	140	0.83 (0.38, 1.28)	4.13
Hsouna et al, 2022	40 min	140	6.10 (4.75, 7.44)	2.49
Souabni et al, 2022	40 min	80	2.53 (0.58, 4.49)	1.66
Boukhris et al, 2019	45 min	135	0.87 (0.37, 1.36)	4.06
Boukhris et al, 2022	45 min	145	3.83 (2.98, 4.68)	3.40
Hsouna et al, 2019	45 min	135	1.99 (1.23, 2.75)	3.58
Romyn et al, 2022	60 min	15	0.04 (-0.36, 0.44)	4.20
Tanabe et al, 2020	60 min	60	-0.02 (-0.49, 0.45)	4.10
Boukhris et al, 2020	90 min	90	1.22 (0.68, 1.76)	3.99
Romdhani et al, 2021	90 min	30	0.35 (0.05, 0.65)	4.33
Tanabe et al, 2020	90 min	60	0.17 (-0.30, 0.64)	4.10
Romyn et al, 2022	120 min	15	0.18 (-0.22, 0.58)	4.20
Overall, DL ($I^2 = 89.1\%$, p = 0.000)			0.99 (0.67, 1.31)	100.00

E

Variable and subgroups	Heterogeneity (I2, %)	Number of studies	Number of participants	SMD (95% CI)
Nap duration				
<30 min	65.2	9	133	0.64 (0.32, 0.97)
30 to <60 min	93.2	10	138	1.74 (1.01, 2.46)
60 to 120 min	67.2	4	47	0.30 (0.00, 0.60)
Time from nap awakening to test				
≤60 min	32.2	6	67	0.22 (0.05, 0.39)
>60 min	90.0	11	164	1.60 (1.10, 2.10)
Study population				
Athletes	89.8	8	104	0.77 (0.32, 1.23)
Physically active	88.5	9	127	1.13 (0.68, 1.58)
Sleep (nap) assessment method				
Objective	58.4	8	96	0.29 (0.07, 0.51)
Subjective	91.1	9	135	1.55 (1.01, 2.08)

Fatigue (Normal Sleep)

C

Study	Nap duration	Time from nap awakening to test (min)	SMD (95% CI)	% Weight
Yamamoto and Hayashi, 2006	10 min	50	-2.18 (-3.29, -1.08)	4.20
Romyn et al, 2022	120 min	15	0.94 (0.10, 1.78)	4.63
Blanchfield, 2018	20 min	50	0.32 (-0.52, 1.17)	4.63
Petit et al, 2014	20 min	130	0.01 (-0.69, 0.70)	4.85
Abdessalem et al, 2019	25 min	165	-0.21 (-0.87, 0.44)	4.90
Boukhris et al, 2019	25 min	155	0.24 (-0.24, 0.72)	5.11
Boukhris et al, 2022	25 min	165	1.07 (0.53, 1.62)	5.04
Hsouna et al, 2019	25 min	155	-1.76 (-2.50, -1.03)	4.79
Hsouna et al, 2020a	25 min	155	0.59 (-0.06, 1.24)	4.91
Daaloul et al, 2019	30 min	30	-0.29 (-1.07, 0.48)	4.73
Soussi et al, 2020	30 min	270	-3.92 (-5.19, -2.66)	3.93
Boukhris et al, 2019	35 min	145	-0.13 (-0.60, 0.35)	5.12
Hsouna et al, 2019	35 min	145	-1.90 (-2.64, -1.15)	4.77
Hsouna et al, 2020b	35 min	145	-1.27 (-1.84, -0.69)	5.00
Boukhris et al, 2020	40 min	140	-0.75 (-1.52, 0.02)	4.74
Hsouna et al, 2022	40 min	140	-3.25 (-7.94, 1.43)	0.88
Souabni et al, 2022	40 min	80	-0.04 (-0.78, 0.70)	4.78
Boukhris et al, 2019	45 min	135	-0.56 (-1.05, -0.07)	5.10
Boukhris et al, 2022	45 min	145	-2.08 (-3.16, -1.01)	4.25
Hsouna et al, 2019	45 min	135	-3.81 (-4.84, -2.77)	4.31
Romyn et al, 2022	60 min	15	0.35 (-0.46, 1.15)	4.68
Boukhris et al, 2020	90 min	90	-1.41 (-2.24, -0.59)	4.65
Overall, DL ($I^2 = 89.5\%$, p = 0.000)			-0.76 (-1.24, -0.28)	100.00

F

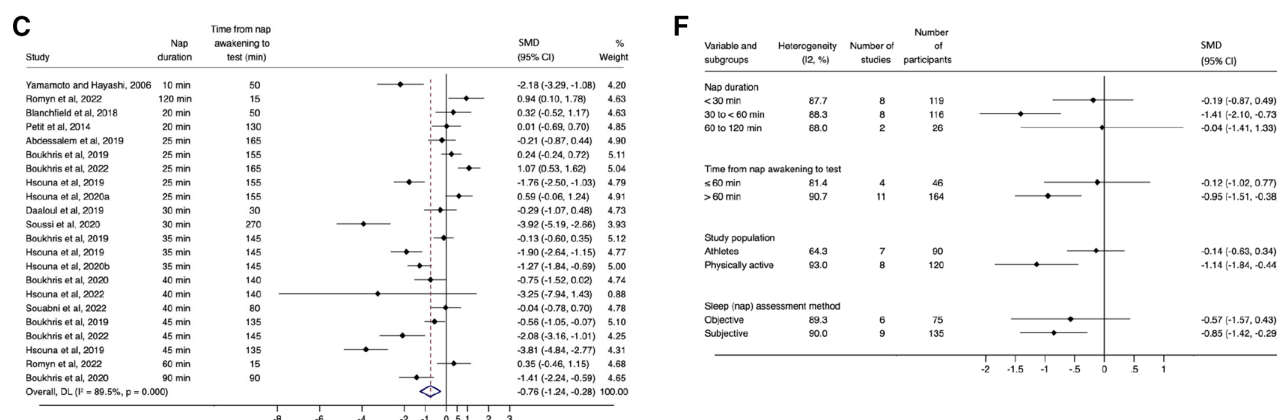| Variable and subgroups	Heterogeneity (I2, %)	Number of studies	Number of participants	SMD (95% CI)
Nap duration				
<30 min	87.7	8	119	-0.19 (-0.87, 0.49)
30 to <60 min	88.3	8	116	-1.41 (-2.10, -0.73)
60 to 120 min	68.0	2	26	-0.04 (-1.41, 1.33)
Time from nap awakening to test				
≤60 min	81.4	4	46	-0.12 (-1.02, 0.77)
>60 min	90.7	11	164	-0.95 (-1.51, -0.38)
Study population				
Athletes	64.3	7	90	-0.14 (-0.63, 0.34)
Physically active	93.0	8	120	-1.14 (-1.84, -0.44)
Sleep (nap) assessment method				
Objective	89.3	6	75	-0.57 (-1.57, 0.43)
Subjective	90.0	9	135	-0.85 (-1.42, -0.29)

Figure 2 Forest plot of the effects of daytime napping after normal sleep on cognitive and physical performance and fatigue in total and by subgroups.

of compatibility of the overall effect of napping on the outcomes analysed when any of the included studies are omitted (online supplemental material figure S3). Conversely, the global effect of napping after sleep deprivation was less compatible with changes in cognitive performance when any of the included studies except Ajjimaporn et al[15] were individually removed. Furthermore, in the partial sleep deprivation condition, the effect of napping on fatigue showed
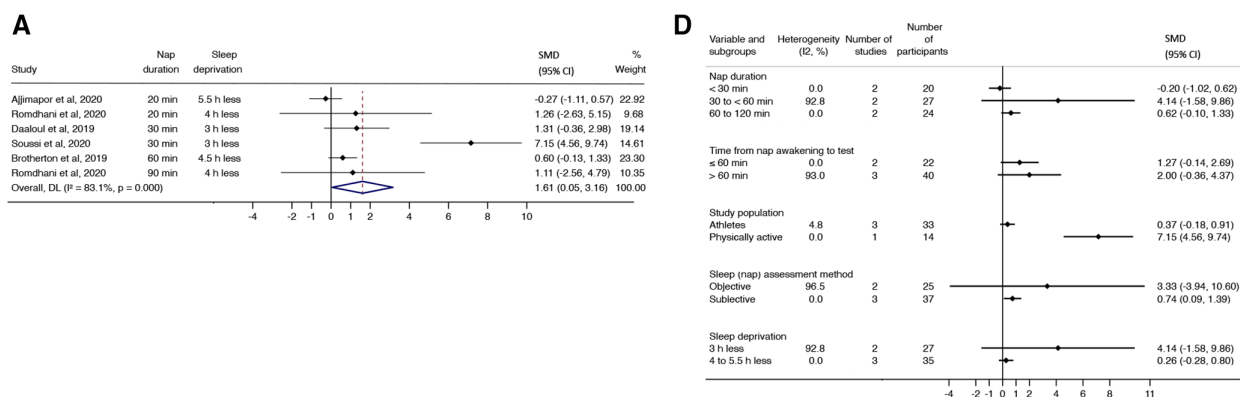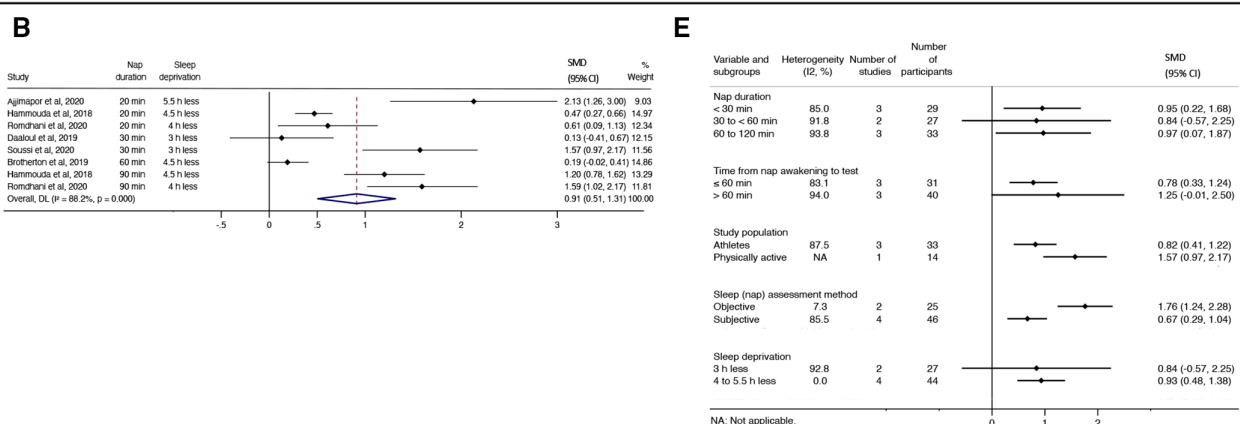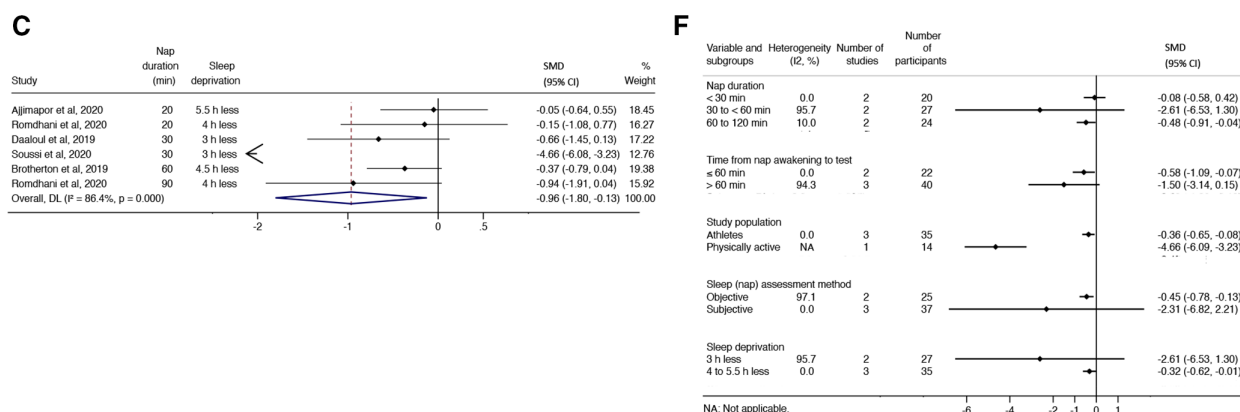
Figure 3 Forest plot of the effects of daytime napping after partial sleep deprivation on cognitive and physical performance and fatigue in total and by subgroups.

low compatibility of changes by omitting the study by Brotherton et al.[17]

DISCUSSION
Main findings
This meta-analysis supports that daytime napping exerts a highly beneficial effect on the improvement of physical performance among athletes and physically active young men. In addition, a moderate improvement after daytime napping was observed in cognitive performance and in the reduction of perceived fatigue after a sport activity. These results were clearer for a nap duration between 30 and <60 min and when the time after nap awakening to test was equal to or greater than 60 min. Moreover, greater benefits were observed in physically
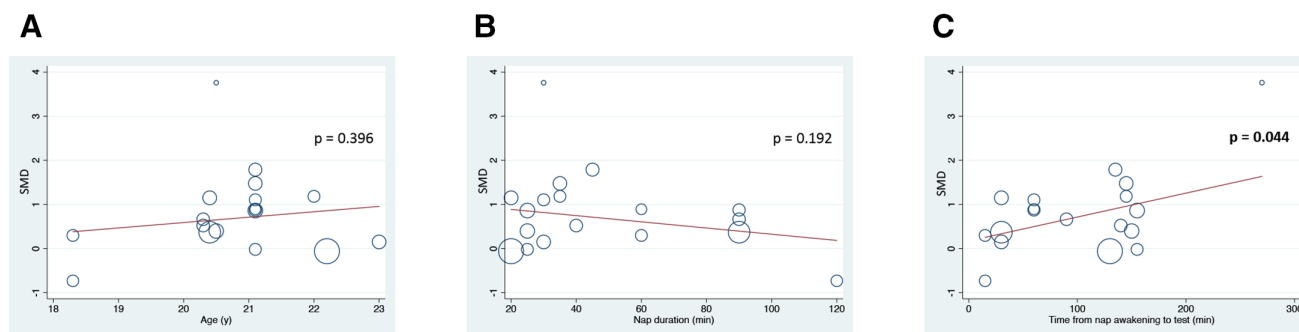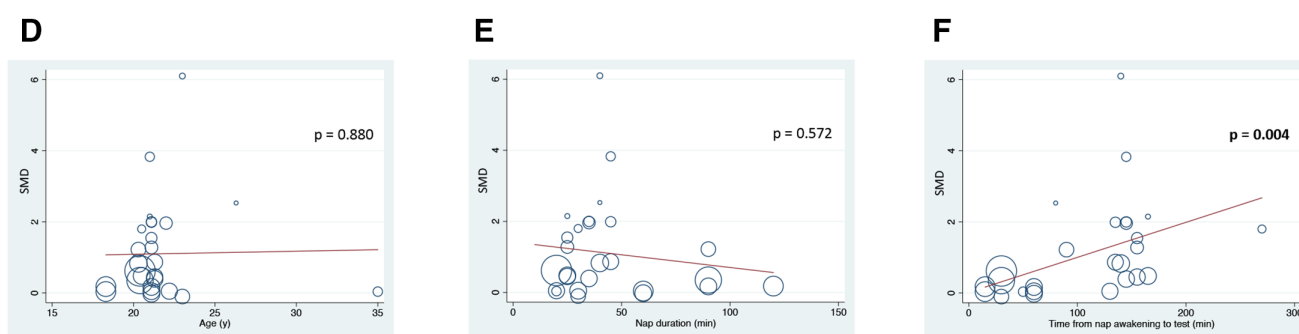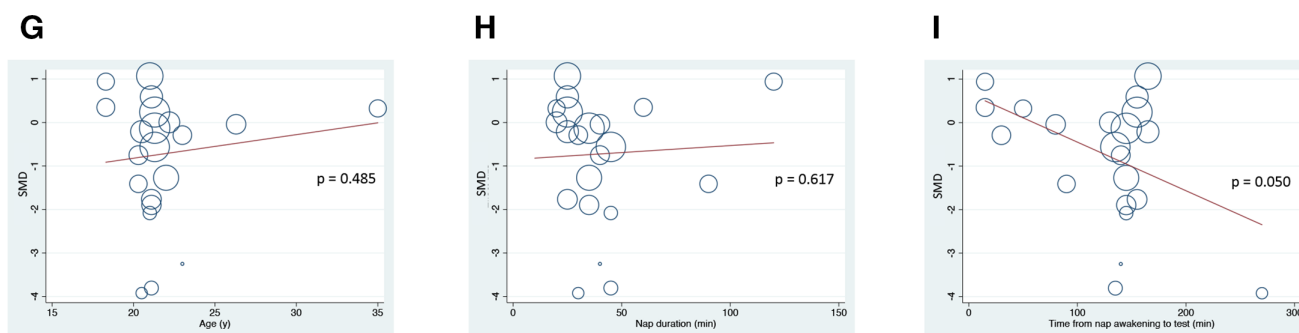
Figure 4 Meta-regression of age, nap duration and time from nap awakening to test on the effect of daytime napping on cognitive and physical performance and fatigue in a normal sleep condition.

active individuals than in athletes, as well as when naps were self-reported than when they were objectively measured. Importantly, evidence is more robust for daytime napping taken after a normal sleep night, meaning that napping could provide a supplemental benefit on sport performance even under optimal sleep conditions. The evidence from studies under partial sleep deprivation goes in the same favourable direction to napping, although their results are less robust and based on fewer studies. Therefore, although the available studies point in that direction, it cannot yet be affirmed that daytime napping is sufficient to compensate for the lower sport performance resulting from partial sleep deprivation.

Nap duration and time from nap awakening to the start of the sport activity

Our results are partially in agreement with previous systematic reviews on the same subject. Souabni et al[9] concluded that daytime napping (particularly a 90 min nap) seemed to be an advantageous strategy to improve the recovery process and counteract the negative effect of partial sleep deprivation on physical and cognitive performance. Similarly, in a narrative review, Botonis et al[2] stated that compared with short-term naps (20–30 min), long-term naps (>35–90 min) appear to provide superior benefits to athletes. Lastella et al[3] recommended that athletes consider napping between 20 and 90 min and should

allow 30 min to reduce sleep inertia prior to training or competition to obtain better performance outcomes, but they did not specify whether these parameters should change in normal sleep or partial sleep deprivation. In our study, the most appropriate nap duration after normal sleep was between 30 and less than 60 min. Moreover, our data support that from nap awakening to sport practice, a minimal 60 min interval is needed, possibly to avoid the undesirable effect of sleep inertia.[33] In addition to updating the findings from previous reviews, the present meta-analysis provides estimates (SMD) of the magnitude of the benefits of napping specific for each group of sport performance indicators (ie, physical, mental and fatigue reduction) and explores the quantitative implications of nap duration and the time from nap awakening to the start of the sport activity on these effects.

Daytime napping and cognitive performance

In the compilation of all studies of daytime napping and cognitive performance in normal sleep conditions, a medium SMD with substantial heterogeneity was observed. Among the studies analysing this relationship in partial sleep deprivation, the global estimate was highly in favour of napping, although in the sensitivity analysis, this result was not sustained when omitting any study. Notably, the study by Souissi et al[12] found a considerably larger effect of a 30 min nap (after sleeping 5 hours at night instead of 8 hours) on the increase in vigilance (the number cancellation test) and on the reduction in reaction time compared with the other studies analysing similar outcomes under partial sleep deprivation conditions. This is possibly due to the characteristics of the participants because while Souissi et al[12] studied healthy young trained males, in the other studies, all participants were professional athletes. Compared with non-athletes, athletes have a higher basal performance level due to a more controlled routine of training and rest schedules.[48] Thus, the magnitude of the effect of napping on sport performance is possibly clearer in non-athletes than in athletes because in the latter, only small improvements could be achieved.

Furthermore, subgroup analyses revealed that in a normal sleep condition, cognitive performance improved only after 30 to <60 min of nap duration. It is possible that naps longer than 30 min may be more compatible to generate improvements in cognitive function by favouring longer durations in non-rapid eye movement (NREM) sleep stages (ie, N2 and N3) or even allowing a full sleep cycle (NREM-REM).[49] In this regard, it has been observed that the restorative effect of sleep correlated with time spent in NREM sleep and with electroencephalographic slow wave energy, which is thought to reflect renormalisation of synaptic strength.[50] Among studies on the effect of napping on cognitive performance after partial sleep deprivation, only the results from the study of Souissi et al[12] were compatible with such an effect. Therefore, it is not yet appropriate to speculate whether and to what extent daytime napping is able to compensate for the deterioration in brain functions resulting from partial sleep deprivation during the previous night. It is known that sleep deprivation promotes neurocognitive deficits, dysregulation of physiological functions regulated by the circadian rhythm (eg, temperature, blood pressure), and incomplete muscle recovery, which may accumulate over time in chronic partial sleep loss (restriction or deprivation).[51–53]

Daytime napping and physical performance

A similar pattern of benefits of napping was observed in our results for different parameters of physical performance, such as strength, endurance and speed, both after normal sleep and partial sleep deprivation. Although considerable heterogeneity was detected between the studies included in the normal sleep and partial sleep deprivation analyses, the SMD was high in both cases. Such concordant heterogeneity is possibly because SMD was smaller in some studies with athletes than in others studying physically active individuals (ie, non-athletes regularly practising exercises). As discussed before, it is necessary to consider that the margin for improvement in physical performance is smaller in trained athletes than in non-athletes. It is also necessary to highlight that professional athletes report poorer sleep quality and hygiene than an age-matched cohort of non-athletes.[54] Thus, the presence of chronic sleep-related problems may represent a barrier to the potential beneficial effects of napping on physical performance.

With respect to the duration of the nap, benefits in physical parameters were observed in all nap durations studied after a normal sleep night, although these benefits were higher for 30 to <60 min. However, we observed that when the time from nap awakening increased, the benefits of naps on physical performance also increased. On the one hand, daytime napping promotes muscle relaxation and structural and functional recovery.[55] On the other hand, an approximate minimum time of 60 min after nap awakening might be recommended to overcome the inertia of sleep and, therefore, reach optimal physical performance.[3]

Daytime napping and perceived fatigue

The effects of napping on perceived fatigue were mostly compatible in studies whose participants were non-athletes. In addition, the studies by Souissi et al[12] and Hsouna et al[10] reported a benefit associated with daytime napping that was considerably greater than the others with respect to reducing fatigue at the end of sports activity. It is remarkable that the study by Souissi et al[12] applied the longest time between the end of the nap and the sport activity (270 min) compared with the other studies (from 15 to 165 min), and an association with this time interval was observed for perceived fatigue for normal sleep but not for partial sleep deprivation. It can be suggested that the participants of that study[12] were less likely to feel the effects of fatigue because they were less affected by the perception of drowsiness compared with those who woke up from the nap and had to exercise after a short wash-out time (ie, <1 hour).

In the subgroup analysis by nap duration after normal sleep, a significantly high SMD on perceived fatigue was observed only for naps between 30 and <60 min. Similar to what was said about cognitive performance, while a short nap allows sleep to reach the superficial levels of sleep, which would be sufficient for partial relaxation, a nap of longer duration that includes more time in deeper sleep stages may be required to mitigate the perception of fatigue and physical and mental exhaustion resulting from the sport activity.

Limitations

As potential limitations of the present findings, considerable unexplained heterogeneity was detected. This could be partially justified because our results are based on the pooling estimates of different performance parameters, and SMD had to be used.[42] Therefore, the interpretation of standardised measures requires caution because the SD may vary over study populations. It is also important to note that the study samples were generally small, which could lead to small sample bias.[56] In addition, different methods were used to certify that the participants slept during

the nap period (self-report, actigraphy, polysomnography and electroencephalography). More than half of the studies included in this review are based solely on the participants' report that they had slept within the allotted time. Therefore, we do not rule out possible reporting bias because self-reported sleep data do not closely correspond with objective measures of sleep as assessed using actigraphy[57 58] and polysomnography.[59] In this sense, it is possible that reporting bias (added to the reduced number of studies in each subgroup) may have had some influence on the differences found in the effect of napping on sports performance, in the same way as has been observed in physical performance when comparing results in normal sleep (in which the effect is greater in studies with subjectively measured sleep) with partial sleep deprivation (in which the effect is greater in studies with objectively measured sleep). In addition, athletes underestimate sleep quantity during daytime nap opportunities,[60] and in comparison with non-athlete controls, elite athletes showed significantly shorter sleep latencies.[61] Furthermore, the present results are restricted to young males and cannot be extrapolated to males of other ages and to females. Finally, we detected significant publication bias in studies of normal sleep conditions for all outcomes and in studies on partial sleep deprivation for physical performance. Therefore, the corresponding findings should be confirmed as more studies become available with varying sample sizes and favourable, neutral or unfavourable results on the association studied.

Considering the above limitations, some recommendations aimed at improving the quality and broadening the generalisability of future research on the effects of napping and sports performance are presented in online supplemental material table S6. In summary, these are suggestions based on the available evidence focused on methodological aspects such as population, exposure (napping), the results (sports performance) and study design.

CONCLUSIONS

In addition to updating the results from previous systematic reviews, we extend knowledge by quantifying the effect of the benefits of napping on different dimensions of sport performance, both under normal sleep and partial sleep deprivation conditions. We concluded that post lunch napping from 30 to <60 min after optimal sleep conditions has a moderate-to-high supplemental beneficial effect on improving cognitive and physical performance and fatigue reduction. Importantly, our findings suggest that a minimum time of 60 min after awakening from napping is required to avoid nap benefits being attenuated by sleep inertia. In addition, because there are fewer studies with sleep-deprived individuals, no firm recommendation can be drawn as to whether daytime napping compensates for the loss in sport performance resulting from partial sleep deprivation. These results apply only for young males aged 18–35 years and physically active individuals or athletes, and extrapolation from other populations requires further evidence.

ORCID iDs
Arthur Eumann Mesas http://orcid.org/0000-0002-0088-8607
Sergio Núñez de Arenas-Arroyo http://orcid.org/0000-0001-7774-8437
Vicente Martinez-Vizcaino http://orcid.org/0000-0001-6121-7893
Miriam Garrido-Miguel http://orcid.org/0000-0003-4617-616X
Ruben Fernández-Rodríguez http://orcid.org/0000-0001-7504-1534
Bruno Bizzozero-Peroni http://orcid.org/0000-0003-0614-5561
Ana I Torres-Costoso http://orcid.org/0000-0001-8961-3169

REFERENCES

1 Walsh NP, Halson SL, Sargent C, *et al*. Sleep and the athlete: narrative review and 2021 expert consensus recommendations. *Br J Sports Med* 2020;55:356–68.
2 Botonis PG, Koutouvakis N, Toubekis AG. The impact of daytime napping on athletic performance-a narrative review. *Scand J Med Sci Sports* 2021;31:2164–77.
3 Lastella M, Halson SL, Vitale JA, *et al*. To nap or not to nap? A systematic review evaluating napping behavior in athletes and the impact on various measures of athletic performance. *Nat Sci Sleep* 2021;13:841–62.
4 Romyn G, Lastella M, Miller DJ, *et al*. Daytime naps can be used to supplement night-time sleep in athletes. *Chronobiol Int* 2018;35:865–8.
5 Reilly T. How can travelling athletes deal with jet-lag? *Kinesiology* 2009;41:128–35.
6 Fullagar HHK, Duffield R, Skorski S, *et al*. Sleep and recovery in team sport: current sleep-related issues facing professional team-sport athletes. *Int J Sports Physiol Perform* 2015;10:950–7.
7 O'Donnell S, Beaven CM, Driller MW. From pillow to podium: a review on understanding sleep for elite athletes. *Nat Sci Sleep* 2018;10:243–53.
8 Janse van Rensburg DCC, Jansen van Rensburg A, Fowler P, *et al*. How to manage travel fatigue and jet lag in athletes? A systematic review of interventions. *Br J Sports Med* 2020;54:960–8.
9 Souabni M, Hammouda O, Romdhani M, *et al*. Benefits of daytime napping opportunity on physical and cognitive performances in physically active participants: a systematic review. *Sports Med* 2021;51:2115–46.
10 Hsouna H, Boukhris O, Abdessalem R, *et al*. Effect of different nap opportunity durations on short-term maximal performance, attention, feelings, muscle soreness, fatigue, stress and sleep. *Physiol Behav* 2019;211:112673.
11 Petit E, Bourdin H, Tio G, *et al*. Effects of a 20-min nap post normal and jet lag conditions on p300 components in athletes. *Int J Sports Med* 2018;39:508–16.
12 Souissi M, Souissi Y, Bayoudh A, *et al*. Effects of a 30 min nap opportunity on cognitive and short-duration high-intensity performances and mood states after a partial sleep deprivation night. *J Sports Sci* 2020;38:2553–61.
13 Tanabe K, Nakazato K, Noi S, *et al*. Effects of prophylactic naps on physical fitness/exercise ability and executive function in healthy young trained males. *Biological Rhythm Research* 2020;51:421–40.
14 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;36:1334–42.
15 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;41:1009–16.
16 Boukhris O, Trabelsi K, Ammar A, *et al*. A 90 min daytime nap opportunity is better than 40 min for cognitive and physical performance. *Int J Environ Res Public Health* 2020;17:13.
17 Brotherton EJ, Moseley SE, Langan-Evans C, *et al*. Effects of two nights partial sleep deprivation on an evening submaximal weightlifting performance; are 1 H powernaps useful on the day of competition? *Chronobiol Int* 2019;36:407–26.
18 Petit E, Mougin F, Bourdin H, *et al*. A 20-min nap in athletes changes subsequent sleep architecture but does not alter physical performances after normal sleep or 5-h phase-advance conditions. *Eur J Appl Physiol* 2014;114:305–15.

19   Blanchfield AW, Lewis-Jones TM, Wignall JR, *et al*. The influence of an afternoon nap on the endurance performance of trained runners. *Eur J Sport Sci* 2018;18:1177–84.

20   Daaloul H, Souissi N, Davenne D. Effects of napping on alertness, cognitive, and physical outcomes of Karate athletes. *Med Sci Sports Exerc* 2019;51:338–45.

21   Bonnar D, Bartel K, Kakoschke N, *et al*. Sleep interventions designed to improve athletic performance and recovery: a systematic review of current approaches. *Sports Med* 2018;48:683–703.

22   Page MJ, McKenzie JE, Bossuyt PM, *et al*. The Prisma 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.

23   Ardern CL, Büttner F, Andrade R, *et al*. Implementing the 27 Prisma 2020 statement items for systematic reviews in the sport and exercise medicine, musculoskeletal rehabilitation and sports science fields: the persist (implementing Prisma in exercise, rehabilitation, sport medicine and sports science) guidance. *Br J Sports Med* 2022;56:175–95.

24   Hirshkowitz M, Whiton K, Albert SM, *et al*. National sleep foundation's sleep time duration recommendations: methodology and results summary. *Sleep Health* 2015;1:40–3.

25   Roelands B, Kelly V, Russell S, *et al*. The physiological nature of mental fatigue: current knowledge and future avenues for sport science. *Int J Sports Physiol Perform* 2022;17:149–50.

26   Hancock PA, Desmond PA. *An overview of fatigue. stress, workload, and fatigue*. 2000: 581–95.

27   Trabelsi K, Ammar A, Glenn JM, *et al*. Does observance of ramadan affect sleep in athletes and physically active individuals? A systematic review and meta-analysis. *J Sleep Res* 2022;31:e13503.

28   Boukhris O, Hill DW, Ammar A, *et al*. Longer nap duration during ramadan observance positively impacts 5-m shuttle run test performance performed in the afternoon. *Front Physiol* 2022;13:811435.

29   Hsouna H, Boukhris O, Hill DW, *et al*. A daytime 40-min nap opportunity after a simulated late evening soccer match reduces the perception of fatigue and improves 5-m shuttle run performance. *Res Sports Med* 2022;30:502–15.

30   Hsouna H, Boukhris O, Trabelsi K, *et al*. A thirty-five-minute nap improves performance and attention in the 5-m shuttle run test during and outside ramadan observance. *Sports (Basel)* 2020;8:98.

31   Hsouna H, Boukhris O, Trabelsi K, *et al*. Effects of 25-min nap opportunity during ramadan observance on the 5-m shuttle run performance and the perception of fatigue in physically active men. *Int J Environ Res Public Health* 2020;17:3135.

32   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;15:874–83.

33   Romyn G, Roach GD, Lastella M, *et al*. The impact of sleep inertia on physical, cognitive, and subjective performance following a 1- or 2-hour afternoon nap in semiprofessional athletes. *Int J Sports Physiol Perform* 2022;17:1140–50.

34   Souabni M, Hammouda O, Souabni MJ, *et al*. 40-min nap opportunity attenuates heart rate and perceived exertion and improves physical specific abilities in elite basketball players. *Res Sports Med* 2022;2022:1–14.

35   Yamamoto T, Hayashi M. The effect of a brief nap on exercise performance. *Jpn J Physiol Psychol Psychophysiol* 2006;24:249–56.

36   Sterne JAC, Savović J, Page MJ, *et al*. Rob 2: a revised tool for assessing risk of bias in randomised trials. *BMJ* 2019;366:l4898.

37   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.

38   Hammouda O, Romdhani M, Chaabouni Y, *et al*. Diurnal napping after partial sleep deprivation affected hematological and biochemical responses during repeated sprint. *Biological Rhythm Research* 2018;49:1–13.

39   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;38:629–38.

40   DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials* 1986;7:177–88.

41   Fu R, Holmer HK, AHRQ Methods for Effective Health Care. *Change score or followup score? an empirical evaluation of the impact of choice of mean difference estimates*. Rockville (MD): Agency for Healthcare Research and Quality (US), 2015.

42   Higgins J, Thomas J, Chandler J, *et al*. Chapter 10: analysing data and undertaking meta-analyses. In: Cochrane Handbook for Systematic Reviews of Interventions version 63. United Kingdom: London: Cochrane Collaboration, 2022:

43   Greenland S, Mansournia MA, Joffe M. To curb research misreporting, replace significance and confidence by compatibility: a preventive medicine golden jubilee article. *Prev Med* 2022;164:107127.

44   Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med* 2002;21:1539–58.

45   Patterson PD, Liszka MK, Mcilvaine QS, *et al*. Does the evidence support brief (≤30-mins), moderate (31-60-mins), or long duration naps (61+ mins) on the night shift? A systematic review. *Sleep Med Rev* 2021;59:101509.

46   Page MJ, Sterne JAC, Higgins JPT, *et al*. Investigating and dealing with publication bias and other reporting biases in meta-analyses of health research: a review. *Res Synth Methods* 2021;12:248–59.

47   Cohen J. *Statistical power analysis for the behavioral sciences*. 2013.

48   Degens H, Stasiulis A, Skurvydas A, *et al*. Physiological comparison between non-athletes, endurance, power and team athletes. *Eur J Appl Physiol* 2019;119:1377–86.

49   Milner CE, Cote KA. Benefits of napping in healthy adults: impact of nap length, time of day, age, and experience with napping. *J Sleep Res* 2009;18:272–81.

50   Nissen C, Piosczyk H, Holz J, *et al*. Sleep is more than rest for plasticity in the human cortex. *Sleep* 2021;44:zsaa216.

51   Durmer JS, Dinges DF. Neurocognitive consequences of sleep deprivation. *Semin Neurol* 2005;25:117–29.

52   Dattilo M, Antunes HKM, Medeiros A, *et al*. Sleep and muscle recovery: endocrinological and molecular basis for a new and promising hypothesis. *Med Hypotheses* 2011;77:220–2.

53   Fullagar HHK, Skorski S, Duffield R, *et al*. Sleep and athletic performance: the effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. *Sports Med* 2015;45:161–86.

54   Cameron AFM, Perera N, Fulcher M. Professional athletes have poorer sleep quality and sleep hygiene compared with an age-matched cohort. *Clin J Sport Med* 2021;31:488–93.

55   Kölling S, Duffield R, Erlacher D, *et al*. Sleep-related issues for recovery and performance in athletes. *Int J Sports Physiol Perform* 2019;14:144–8.

56   Lin L. Bias caused by sampling error in meta-analysis with small sample sizes. *PLoS One* 2018;13:e0204056.

57   Girschik J, Fritschi L, Heyworth J, *et al*. Validation of self-reported sleep against actigraphy. *J Epidemiol* 2012;22:462–8.

58   Vlahoyiannis A, Sakkas GK, Manconi M, *et al*. A critical review on sleep assessment methodologies in athletic populations: factors to be considered. *Sleep Med* 2020;74:211–23.

59   Jackson CL, Patel SR, Jackson WB 2nd, *et al*. Agreement between self-reported and objectively measured sleep duration among white, black, Hispanic, and Chinese adults in the United States: multi-ethnic study of atherosclerosis. *Sleep* 2018;41:zsy057.

60   Lastella M, Roach GD, Miller DJ, *et al*. Athletes underestimate sleep quantity during daytime nap opportunities. *Chronobiol Int* 2018;35:869–71.

61   Gupta L, Morgan K, North C, *et al*. Napping in high-performance athletes: sleepiness or sleepability? *Eur J Sport Sci* 2021;21:321–30.