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To Nap or Not to Nap? A Systematic Review Evaluating Napping Behavior in Athletes and the Impact on Various Measures of Athletic Performance

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Abstract

Purpose

The objective of this systematic review was to 1) determine how studies evaluated napping behavior in athletes (frequency, duration, timing and measurement); 2) explore how napping impacted physical performance, cognitive performance, perceptual measures (eg, fatigue, muscle soreness, sleepiness and alertness), psychological state and night-time sleep in athletes.

Methods

Five bibliographic databases were searched from database inception to 11 August 2020. Observational and experimental studies comprising able-bodied athletes (mean age  $\geq 12$  years), published in English, in peer-reviewed journal papers were included. The Downs and Black Quality Assessment Checklist was used for quality appraisal.

Results

Thirty-seven studies were identified of moderate quality. Most studies did not include consistent information regarding nap frequency, duration, and timing. Napping may be beneficial for a range of outcomes that benefit athletes (eg, physical and cognitive performance, perceptual measures, psychological state and night-time sleep). In addition, napping presents athletes with the opportunity to supplement their night-time sleep without compromising sleep quality.

Conclusion

Athletes may consider napping between 20 to 90 min in duration and between 13:00 and 16:00 hours. Finally, athletes should allow 30 min to reduce sleep inertia prior to training or competition to obtain better performance outcomes. Future studies should include comprehensive recordings of nap duration and quality, and consider using sleep over a 24 hour period (daytime naps and night-time sleep period), specifically using objective methods of sleep assessment (eg, polysomnography/actigraphy).

Keywords: athlete, health behavior, performance, physical health, psychological health, sleep, sports

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## Introduction

Napping is a ubiquitous behavior and an important public health tool to offset the adverse short- and long-term impacts of inadequate sleep.<sup>1</sup> By definition, a nap is any sleep period with a duration of less than 50% of the average major sleep period of an individual.<sup>2</sup> A nap is often referred to as a 'short sleep' which is distinct from, and considerably shorter than an individual's normal sleep episode.<sup>2,3</sup> Naps may be further categorized into three main types: a) the prophylactic nap: a nap taken in anticipation of sleep loss; b) the replacement nap: a nap taken in response to sleep loss; and c) the appetitive nap: a nap taken for convenience and/or enjoyment.<sup>4</sup> Another consideration absent within the sleep literature is the idea that athletes take naps as they are educated that napping may result in recovery and performance benefits. Napping during the day can increase the amount of sleep obtained in a 24-hour period and many athletes report including daytime napping in their training program.<sup>5,6</sup> For example, Sargent et al<sup>6</sup> demonstrated that more naps were taken on training days compared to rest days, and strategic napping during the day, as well as sleep hygiene practices (ie, healthy sleep practices) at night need to be considered. While several studies have investigated the impact of restricting or extending sleep on a number of outcomes of athletic performance (eg, sprint times, reaction time),<sup>7</sup> there has been comparatively less focus on the impact of napping.<sup>8,9</sup> It is possible that the lack of dedicated napping research in athletes may limit the ability of athletes, coaches and sports professionals to effectively implement strategic napping within their training programs.

Athletes are exposed to many stressors that impair sleep, including high training loads, competition demands, early morning training, travel and altitude exposure.<sup>9,10</sup> As a result, athletes are often unable to obtain the recommended adult night-time sleep duration of 7–9 h per night.<sup>11</sup> The majority of research examining athletes' sleep has focused on the impact of night-time sleep on performance and recovery.<sup>7,9</sup> Yet, napping represents an opportunity to supplement the night-time sleep period, which may assist athletes in obtaining recommended sleep. Previous research on non-athletes has shown that napping can improve daytime sleepiness, mood and cognitive performance,<sup>12–14</sup> with the magnitude of these effects comparable to other sleep restriction countermeasures (eg, caffeine, modafinil).<sup>3</sup> However, despite the recent interest in napping in athletes,<sup>7,15</sup> the impact of napping on athletes is yet to be systematically investigated. Therefore, the first aim of this study was to determine how studies evaluated napping behavior in athletes (frequency, duration, timing and measurement). The second aim of the study was to explore how napping impacted physical performance, cognitive performance, perceptual measures (eg, fatigue, muscle soreness, sleepiness and alertness), psychological state and night-time sleep in athletes. This review will provide key recommendations for practitioners and athletes, as well as directions for future research.

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Materials and Methods

Protocol Registration

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines.<sup>16</sup> The protocol for this review was registered in the PROSPERO database for systematic reviews (CRD42020208652).

## Search Strategy

Five bibliographic databases (PsychINFO, PubMed, Scopus, SportDiscus, and Web of Science) were searched for relevant peer-reviewed journal papers from database inception to 11 August 2020. Articles were published in English and the search strategy combined napping terms (“nap”, “daytime sleep”, “siesta”, “midday sleep”, “midday nap”, “afternoon nap”, “daytime sleepiness”) with athlete terms (“athlete/s”, “elite athletes”, “competitive athlete”, “sport”, “player”). In addition to the primary database searches, secondary searchers of reference lists of studies and citing articles meeting the inclusion criteria were carefully hand searched for potential inclusion of additional studies. The detailed search strategy is shown in Supplementary Material.

## Eligibility Criteria

Studies were included according to the PEOS (Population, Exposure, Outcomes, Study design) format. The PEOS format was preferred over other reporting frameworks (eg, PICO) as the included studies were a mix of observational and interventional designs, which align more closely with the PEOS format.<sup>17</sup>

**Population** Studies with able-bodied athletes, where the mean age of participants was  $\geq 12$  years were included. Athletes between 12 and 18 years were included as young athletes as the International Olympic Committee underlies that athletes, especially young athletes should obtain sufficient sleep quantity and quality.<sup>18</sup> Athlete was defined as someone who “engages in physical activity or sports with the primary goal of improving performance to bolster athletic excellence and/or achievement”.<sup>7,19,20</sup> This did not include non-athletes, such as habitual exercisers, industrial or occupational athletes (eg, military, firefighters, ski patrol) and healthy sedentary or recreationally active volunteers.

**Exposure** A nap was defined as “a short sleep” which is distinct from and substantially shorter than an individual’s normal sleep episode.<sup>2</sup> In more quantifiable terms, it was defined as “any sleep period with a duration of less than 50% of the average main sleep period of an individual”.<sup>21</sup> Subjective (eg, self-report) and/or objective (eg, polysomnography, actigraphy) measures of sleep within the nap period were considered for inclusion.

**Outcome** Outcomes included a) physical performance (eg, sprint times, time to exhaustion, grip strength, jump height), b) cognitive performance (eg, reaction time, levels of attention, levels of alertness), c) psychological state (eg, mood, well-being), and d) night-time sleep.

**Study Design** Studies that were observational (eg, cross-sectional, case-control, cohort) or experimental (eg, randomized, non-randomized trials, interventional trials) in nature were included.

**Other Criteria** Full-text articles published in a peer-reviewed journal and in English language were included. Narrative reviews, systematic reviews, commentaries, viewpoints, editorials and errata documents were excluded. In addition, studies investigating napping behavior of Muslim (fasting) athletes during Ramadan were excluded as fasting may impact athlete’s sleep.

## Study Selection

All search results were imported into EndNote X7 software (Thomson Reuters, San Francisco, CA, USA). After removing duplicates, articles were independently screened by two reviewers (ML and ARM), based on title and abstract to determine their eligibility for inclusion. The full-texts of all included articles were then sourced and independently screened by two reviewers (ML and ARM) to ensure they met eligibility criteria. At all stages, conflicts were resolved through consensus or by involvement of a third reviewer (GEV).

#### Data Extraction

Using a standardized form, the following data were extracted independently by two reviewers (ML and ARM). Any discrepancies were identified and resolved through discussion or by involving a third reviewer (GEV). The extracted data included i) publication details (eg, authors surname, publication year, country); ii) study design (eg, cross-sectional); iii) sample characteristics (eg, age and sex); iv) type of sport; v) napping measurement (eg, actigraphy, self-report); and vi) napping outcomes (eg, duration, frequency and context).

#### Methodological Quality Assessment

The methodological quality of included studies was assessed using the Downs and Black Quality Assessment Checklist,<sup>22</sup> adjusted by the study design of included studies. Two reviewers (ARM and ML) conducted the assessment independently, with cases of uncertainty resolved by involving a third reviewer (GEV). For papers where one of the reviewers (ML) was a co-author, methodological quality assessment of studies was performed independently by two reviewers (ARM and GEV). Included studies were scored on 28 items for interventional, 20 for cohort and 16 for cross-sectional study designs. The overall quality scores were converted to a percentage value and rated as low (0–49%), moderate (50–89%) and high (≥90%).<sup>22,23</sup>

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Results

#### Study Identification and Selection

The database searches yielded 2730 studies (PsychINFO: 73; PubMed: 122; Scopus: 1029; SportDiscus: 974; and Web of Science: 532). Secondary searches identified an additional relevant study. Duplicate records were removed (n = 630) and the remaining 2101 records were assessed on the basis of title and abstract, with a further exclusion of 1992 studies. A total of 109 studies were eligible for full-text assessment. Of these, 72 studies were excluded because of the following reasons: participants were not athletes (n = 20), the study did not report napping data (n = 31), reviews (n = 7), no full-text (n = 9), non-scientific (n = 2), and Ramadan (n = 3). Thus, a total of 37 studies were included in the final review.<sup>5,6,8,24–57</sup> The search process and number of studies retrieved at each stage are shown in Figure 1.

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Figure 1

PRISMA flow diagram for the studies included in the review. Notes: Adapted from Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6(7):e1000097.16 Creative Commons Attribution License.

## Study Characteristics

Thirty-seven studies were included in the systematic review, with detailed characteristics in Tables 1 and 2. Due to the amount of diversity and heterogeneity across studies, conducting a meta-analysis was not appropriate. The studies were published between 2009 and 2020 and consisted of 3489 participants. 5,6,8,24–57 Both males and females were included in 35.1% (n = 13) of studies, 5,6,8,29,30,32,34–36,41,48,50,51 8.1% (n = 3) of studies included females exclusively, 37,38,57 and 48.6% (n = 18) studies included males only. 24–26,31,33,37,40,42,43,45–47,49,52–56 Three studies (8.1%) did not report sex. 27,28,44 The mean age of athletes was 23±4 years. Study designs were as follows: cross-sectional (n = 6), 25–30 longitudinal/cohort (n = 14), 5,6,31–39,41,57,58 randomized experimental (n = 14), 24,42–49,52–56 and non-randomized experimental (n = 3). 8,48,50 Athletes participated in 11 different sports (ie, karate, judo, netball, rowing, rugby, running, soccer, swimming, shooting marksmanship, track and field, and ultramarathon).

Table 1

Studies Reporting Nap Characteristics (Frequency, Duration, Timing and Measurement) in Athletes

Author, Year, Country, Study Design	N, Sex, Age	Sport, Nap Assessment	Nap Duration
Time of Nap (hh:mm)	Total Naps	Frequency of Naps	
Caia et al 2017 <sup>31</sup>			
Australia			
Longitudinal, observational	7		
M: 7			
24±2 years		Rugby League, professional	
Sleep diary, Actigraphy	Pre-season: 51±19 min		
Competition: 39±17 min	NR	Pre-season: 8 naps in 7 days	
Competition: 8 naps in 7 days	16 naps taken out of 14 days		
Carter et al 2020 <sup>32</sup>			
USA			
Longitudinal, observational	121		

M: 65, F: 56

M: 21±1 years

M: 20±1 years Multi-sport, individual, team sport

Sleep diary, Actigraphy (no naps included) M: 69±10 min

F: 72±7 min NR NR NR

Fullagar et al 201625

England

Longitudinal, observational 15

M:1526±5 years Soccer, professional

Sleep diary, Actigraphy Day of arrival: 65±15 min

Match day 1: 100±35 min

Match day 2: 91±38 min Day of arrival

Start: 14:27 ± 01:29

Wake up: 15:32 ± 01:19

Match day 1

Start: 14:54±01:28

Wake up: 16:34±01:06

Match day 2

Start: 14:53±0:14

Wake up: 16:30±0:32 Day of arrival: 6/15 participants napped

Match day 1: 7/15 participants napped

Match day 2: 11/15 participants napped NR

Fullagar et al 201624

Germany

Randomized cross-over 20

M: 20

NR Soccer, semi-professional

Sleep diary, Actigraphy Sleep hygiene condition: Baseline: 56±21 min

Match night +1: 66±19 min

Non-sleep hygiene condition:

Baseline: 42±34 min

Match night +1: 81±2 min      NR      Sleep hygiene condition: 5 naps

Non-sleep hygiene condition: 7 naps      NR

Fullagar et al 2016<sup>26</sup>

Germany, Netherlands

Longitudinal, observational      16

M: 1626±8 years      Soccer, professional

Self-report questionnaire      Training day: 57±36 min

Day game: 30±0 min

Night match: 67±29 min NR      NR      Training day: 10 participants (63%) napped at least once

Day game: 1 participant (1%) napped

Night match: 3 participants (20%) napped

Hurdiel et al 2018<sup>33</sup>

France

Longitudinal, observational      147

M: 92

>20 years      Ultramarathon

Self-report questionnaire      69.6% napped (64 out of 92)

14.5±9.5 min      NR      NR

Jones et al 2019<sup>34</sup>

Australia

Longitudinal, observational      70

M: 26, F: 4421±4 years      Multi-sport, elite

Sleep diary      73±48 min      NR      NR      15 participants reported napping (21%±4%)

Kolling et al 2016<sup>35</sup>

Germany

Longitudinal, observational      55

M: 30, F: 2518±1 years      Rowing, junior elite

Sleep diary      64±32 min      12:00–15:00: 80%

<12:00: 13%

15:00–18:00: 7%      NR      58–82% participants reported napping

Lastella et al 2015<sup>5</sup>

Australia Longitudinal, observational 124

M: 104, F: 2022±13 years Multi-sport, elite

Sleep diary, Actigraphy Individual sport: 45±41 min

Team sport: 59±62 min NR Individual sport: 114 naps

Team sport: 70 naps Individual Sport: 15% napped

Team Sport: 11% napped

Mah et al 201836

USA

Longitudinal, observational 628

M: 343, F: 28,520±1 years Multi-sport, college

Self-report questionnaire Habitual:

Did not nap: 9%

<10 min nap: 0%

10–30 min nap: 22%

30–60 min nap: 43%

60–120 min nap: 23%

>120 min nap: 2%

Pre-game:

Did not nap: 44%

<10 min nap: 3%

10–30 min nap; 26%

30–60 min nap: 19%

60–120 min nap: 8%

>120 min nap: 1% NR Habitual: 80% nap at least once per week

Pre-game: 11% napped

Martin et al 201830

Canada, USA, Italy

Cross-sectional 636

M: 541, F: 95

NR Ultramarathon

Self-report questionnaire Non-training days:



34% napped for 10–20 min

37% napped for 30–60 min

Training days:

20% napped for 10–20 min

40% napped for 30–60 min      NR      NR      Work days: 20% napped

Non-training days: 19% napped

Training days: 25% napped

Romyn et al 2016<sup>37</sup>

Australia Longitudinal, observational      8

F: 8

20±2 years      Netball, elite

Sleep diary, Actigraphy      Training: 46±28

Competition: 28±34      NR      Training: 10 naps across 4 days

Competition: 8 naps across 3 days

Sargent et al 2014<sup>6</sup>

Australia

Longitudinal, observational      70

M: 46, F: 24±3 years      Multi-sport, elite

Sleep diary, Actigraphy      49±46 min      NR      Total 139 naps recorded

Training days: 115 naps

Rest days: 24 naps      40 participants (57%) did not report napping

Training days: 15% napped

Rest days: 16% napped

Sargent et al 2014<sup>38</sup>

Australia Longitudinal, observational      7

F: 7

23±2 years      Swimming, elite

Sleep diary, Actigraphy      Training days: 12±30 min

Rest days: 0 naps      NR      Training days: 26 naps across 12 days      0 naps on rest days (rest day = 2)

Stevens et al 2018<sup>39</sup>

Australia

Prospective cohort 12

NR

48±14 years Triathlon, masters

Sleep-diary Baseline: 12±7 min

Pre-flight: 45±0 min

Flight: 0±0 min

Training: 72±31 min

Pre-race: 45±15 min

Post-race: 0±0 min NR 42% (5 out of 12) athletes napped Baseline: 67% napped

Pre-flight: 8% napped

Flight: 0% napped

Training: 67% napped

Pre-race: 17% napped

Post-race: 0% napped

Thornton et al 201740

Australia

Longitudinal, observational 31

M: 3125±4 years Rugby, professional

Sleep diary, Actigraphy Camp

Morning (<12:00):

30±15 min

Afternoon (>12:00):

32±18 min Morning nap (<12:00):

Bedtime: 07:05±00:35

Get up time: 07:52±00:39

Afternoon nap (>12:00):

Bedtime: 12:46±00:40

Get up time: 12:54±00:41 Morning: 71 naps recorded

Afternoon: 85 naps recorded in the

Home: 7 participants (23%) napped

Camp: 25 participants (83%) napped

Venter et al 2010<sup>29</sup>

South Africa

Cross-sectional 890

M: 507, F: 38,322±3 years Multi-sport, elite (team sports only)

Self-report questionnaire NR NR NR 32% never napped

47% sometimes napped

17% napped regularly

4% always napped

Walsh et al 2019<sup>41</sup>

Scotland

Longitudinal, observational 12

M: 9,

F: 3

21±2 years Swimming

Sleep diary, Actigraphy Rest: 6±10 min

Taper: 12±16 min

Training: 23±20 min

Competition: 25±24 min NR Rest: 4 (33%) participants napped

Taper: 9 (75%) participants napped

Training: 11 (92%) participants napped

Competition: 9 (75%) participants napped

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Abbreviations: F, female; M, male; NR, not reported.

## Table 2

The Effects of Naps on Physical and Cognitive Performance, Perceptual Measures of Fatigue and Muscle Soreness, Sleepiness and Alertness, Psychological State, and Night-Time Sleep

Author, Year Sleep Restriction, Nap Opportunity, Performance Measures Effects of Napping  
(Physical Performance; Cognitive Performance; Perceptual Measures of Fatigue and Muscle Soreness, Sleepiness and Alertness; Psychological State; and Night-Time Sleep)

Ajjimaporn et al 2020<sup>42</sup> Sleep restriction: Control 3 h sleep

Nap opportunity: N20

Performance measures: Running-based anaerobic sprint test (RAST), Isometric dynamometer

Physical performance: RAST in Control vs N20: ↓ Maximum power, ↔ Minimum power, ↑ Fatigue, ↑ Leg strength, ↑ RPE

RAST in 3 h vs 3 h ± N20: ↑ Maximum power, ↑ Minimum power, ↑ Mean power, ↔ Fatigue, ↑ Leg strength, ↔ RPE

Cognitive performance: ↔ Auditory

Blanchfield et al 2018<sup>43</sup> Sleep restriction: No

Nap opportunity: No nap vs N20

Performance measures: Motorized treadmill      Physical performance: ↑ RPE, ↑ Time to exhaustion (only for participants that slept <7 h)

Perceptual measures of fatigue and muscle soreness, sleepiness and alertness: (ESS) Sleepiness ↓ immediately but returned to ↔ 90 min post nap

Psychological state: ↔ BRUMS

Boukhris et al 2020<sup>44</sup> Sleep restriction: No

Nap opportunity: No nap vs N40 vs N90

Performance measures: Isometric dynamometer      Physical performance: ↑ RPE, ↑ 5MSRT, ↑ Muscle contraction, ↑ Higher distance, ↑ Total distance, ↑ Perceived recovery, ↑ Fatigue index, ↑ DOMS, ↑ DOMS after N90 compared to N40, ↑ all physical performances in N90 than N40

Cognitive performance: ↑ Attention, ↑ attention in N90 than N40

Perceptual measures of fatigue and muscle soreness, sleepiness and alertness: ↑ (SSS) Sleepiness, ↑ (SSS) Sleepiness in N90 compared to N40

Psychological state: ↑ POMS, ↑ tension, depression, fatigue, total mood score, ↔ confusion, ↑ perceived recovery, ↑ perceived recovery in N90 than N40

Brotherton et al 2019<sup>45</sup> Sleep restriction: Control 3 h for two nights

Nap opportunity: N60 ended 3 h before performance

Performance measures: Force velocity platform      Physical performance: Control vs Nap: ↔ Grip strength, ↔ Bench press average power, ↑ Bench press average force, ↑ Bench Press peak velocity, ↔ Time-to-peak velocity, ↔ Leg press average power, ↔ Leg press average force, ↔ Leg press peak velocity, ↔ Leg press distance

3 h vs 3 h ± N60: ↑ Grip strength, ↑ Bench press average power, ↑ Bench press average force, ↑ Bench press peak velocity, ↑ Time-to-peak velocity, ↑ Leg Press, ↑ Leg Press average power, ↔ Leg press average force, ↔ Leg press peak velocity, ↑ Leg press distance

Perceptual measures of fatigue and muscle soreness, sleepiness and alertness: ↑ (SSS) Sleepiness, ↑ (VAS) Alertness

Psychological state: Sleep Restricted vs Sleep Restricted with Nap: ↑ POMS, vigour, anger, calm, happiness, confusion, depression, fatigue, ↑ Tiredness, ↔ tension

Normal Sleep vs Sleep Restricted with Nap: ↑ POMS, vigour, calm, happiness, confusion, depression, fatigue, ↑ Tiredness, ↔ anger, tension, ↑ Tiredness

Daaloul et al 2019<sup>46</sup> Sleep restriction: Control vs 4 h sleep vs 4 h sleep with nap

Nap opportunity: No nap vs N30

Performance measures: Optojump optical jump system Physical performance: Control vs 4 h sleep ± N30: ↔ Karate-specific test, ↔ Squat jump, ↔ CMJ, ↑ Time to exhaustion

4 h sleep vs 4 h sleep ± N30: ↑ Karate-specific test, ↑ Squat jump, ↑ CMJ, ↑ Time to exhaustion, ↑ Fatigue

Cognitive performance: ↑ Reaction time, ↑ Mental rotation, ↑ Lower body reaction

Perceptual measures of fatigue and muscle soreness, sleepiness and alertness: ↑ (VAS) Alertness

Davies et al 2010<sup>47</sup> Sleep restriction: No

Nap opportunity: N90 60 min after endurance training vs N90 120 min after endurance training

Performance measures: Rowing ergometer, Motorized treadmill Physical performance: ↑ Readiness to perform for exercise 2 h post compared to 1 h post

Perceptual measures of fatigue and muscle soreness, sleepiness and alertness: ↔ (VAS) Alertness

Driller et al 2016<sup>48</sup> Sleep restriction: No

Nap opportunity: 45 min in floatation device Physical performance: ↔ Muscle soreness

Psychological state: Multidimensional mood-state questionnaire = ↑ Worn-out, ↑ At-ease, ↑ Tense, ↑ Fresh, ↑ Exhausted

Hammouda et al 2018<sup>49</sup> Sleep restriction: 4.5 h sleep

Nap opportunity: No nap vs N20 vs N90

Performance measures: Running-based anaerobic sprint test (RAST) Physical performance: Both Napping Conditions: ↑ RAST, ↑ Maximum power, ↑ Minimum power, ↑ Mean power, ↑ Fatigue, ↑ N90 than N20

Knechtle et al 2012<sup>27</sup> Sleep restriction: Ultramarathon

Nap opportunity: Nap vs no nap

Performance measures: Race finish time Physical performance: Nap ↓ race finish time

O'Donnell et al 2018<sup>57</sup> Sleep restriction: No

Nap opportunity: Short nap (<20 min) vs Long nap (>20 min)

Performance measures: Linear transducer device Physical performance: Short nap ↑ CMJ, ↑ Coach performance, ↔ Subjective energy, ↔ Subjective player performance, ↔ Jump height

Pelka et al 2017<sup>50</sup> Sleep restriction: No

Nap opportunity: N20 vs Systematic breathing

Performance measures: Non-motorized treadmill, Contact platform Sprint, ↔ CMJ      Physical performance: ↔

Psychological state: ↔ Subjective rating

Pelka et al 2017<sup>51</sup>      Sleep restriction: No

Nap opportunity: N20 vs Yoga vs Systematic breathing

Performance measures: Non-motorized treadmill      Physical performance: ↑ Speed, ↔  
Maximum power output

Psychological state: ↔ Subjective recovery and stress

Petit et al 2014<sup>53</sup>      Sleep restriction: Control 9 h TIB 5 h phase advance

Nap opportunity: N20

Performance measures: Cycle      Physical performance: ↔ Wingate, ↔ Peak Power

Night-time sleep: Control condition and 5 h phase advance: ↓ Sleep onset latency, ↔ other sleep variables (eg, TST, SE, sleep stages)

Petit et al 2018<sup>52</sup>      Sleep restriction: Control 9 h TIB 5 h phase advance

Nap opportunity: N21      Cognitive performance: Control condition: ↑ Vigilance, ↑ Attentional performance

5 h phase advance ± nap: ↑ Vigilance, ↑ Attentional performance

Perceptual measures of fatigue and muscle soreness, sleepiness and alertness: Control condition: ↑ (VAS) Alertness

5 h phase advance: ↔ (VAS) Alertness

Poussel et al 2015<sup>28</sup>      Sleep restriction: Ultramarathon

Nap opportunity: Nap vs no nap

Performance measures: Race finish time      Physical performance: Napping = ↓ race finish time

Romdhani et al 2020<sup>54</sup>      Sleep restriction: 4.5 h sleep

Nap opportunity: No nap vs N20 vs N90

Performance measures: Running-based anaerobic sprint test (RAST)      Physical performance: N20 condition: RAST ↑ Maximum power, ↔ Minimum power, ↔ Mean power, ↑ Fatigue

N90 condition: ↑ Maximum power, ↑ Minimum power, ↑ Mean power, ↑ Fatigue, ↑ RPE

Overall ↑ N90 than N20

Cognitive performance: ↑ N20 Reaction time

Perceptual measures of fatigue and muscle soreness, sleepiness and alertness: ↑ (ESS) Sleepiness

Psychological state: ↑ Wellness, ↑ POMS

N90 vs N20: ↑ Wellness, ↑ POMS

Romyn et al 2018<sup>55</sup> Sleep restriction: 9 h vs 8 h + 1 h nap vs 7 h + 2 h nap

Nap opportunity: N60 vs N120

Performance measures: Race finish time Night-time sleep: ↔ Sleep

Suppiah et al 2019<sup>56</sup> Sleep restriction: No

Performance measures: Timing gates Physical performance: ↔ Shooting performance, ↓ Sprint performance

Perceptual measures of fatigue and muscle soreness, sleepiness and alertness: In shooting athletes = ↑ Sleepiness (in shooting athletes), ↓ Alertness: In track and field athletes = ↔ Sleepiness, ↔ Alertness

Thornton et al 2017<sup>40</sup> Sleep restriction: No Night-time sleep: ↑ Sleep, ↑ TIB, ↑ SE

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Abbreviations: ↑, positive effect of napping; ↓, negative effect of napping; ↔, no effect of napping; 5MSRT, 5 Metre Shuttle Run Test; BRUMS, Brunel Mood State Questionnaire; CMJ, counter movement jump; ESS, Epworth Sleepiness Scale; N before any number indicates mins of nap (eg, N20 = 20 min nap); POMS, Profile of Mood State Questionnaire; RAST, Running-based Anaerobic Sprint Test; RPE, rating of perceived exertion; SE, sleep efficacy; SSS, Stanford Sleepiness Scale; TIB, time in bed; TST, total sleep time; VAS, Visual Analogue Scale.

## Study Quality

Overall, the risk of bias score ranged from 43.8% to 92.9%, with 2.7% (n = 1)<sup>50</sup> considered high quality, 91.9% (n = 34)<sup>5,6,8,24–27,29–47,49,51–57</sup> considered moderate quality, and 5.4% (n = 2)<sup>28,59</sup> considered low quality. The overall risk of bias for each study is presented in Figure 2A–C) and results for each item of the Downs and Black Checklist are provided in Supplementary material.

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## Figure 2

The overall risk of bias for each study (A) cross-sectional design (B) longitudinal design and (C) experimental design.

## Measuring Naps

Overall, four main types of sleep assessments (eg, questionnaires, sleep diaries, actigraphy, and polysomnography) were used in the included studies. The most common form of sleep assessment was subjective, with ten (27%) studies employing self-report questionnaires<sup>26–30,33,36,48,50,51</sup> and seven (18.9%) studies employing self-report sleep diaries.<sup>32,34,35,39,49,54,57</sup> Thirteen (35.1%) studies utilized wrist actigraphy as an objective form of sleep assessment,<sup>5,6,24,25,31,37,38,40–</sup>

44,46 whereas six studies (16.2%) used polysomnography, the gold standard in sleep assessment.<sup>8,47,52,53,55,56</sup> One study (2.7%) did not report any form of sleep assessment, however, sleep duration was controlled in a laboratory environment.<sup>45</sup>

### Napping Characteristics

In total, 16 (43.2%) studies reported napping characteristics of either frequency, duration and/or timing of naps taken by athletes.<sup>5,6,24–26,29,31,32,34–41</sup> There was no consistency across studies for napping frequency (Table 1). Ten (27%) studies reported the percentage of athletes who napped at least once throughout the data collection period.<sup>5,6,25,26,29,34,36,39,41,60</sup> For example, Walsh et al<sup>41</sup> showed that 33% of the participants (national and international level swimmers) reported napping at least once during a rest period, 75% napped during a taper period, 92% napped during a training period, and 75% napped during the competition period. Five (13.5%) studies reported the total amount of naps taken during the data collection period.<sup>6,24,31,37,40</sup> For example, Caia et al<sup>31</sup> reported a total of 16 naps were taken during 14 days of data collection with 8 naps taken during a 7-day pre-season period and 8 naps taken during a 7-day competition period in professional Rugby League players. Overall, the percentage of participants that napped across studies ranged between 11% and 100% (Table 1).

The nap durations across all studies inclusive of training, rest, and competition phases ranged from 6 to 120 min. Nap durations were similar between training ( $43 \pm 28$  min) and competition ( $44 \pm 24$  min) days. However, nap durations were considerably shorter on rest days ( $6 \pm 10$  min).<sup>41</sup>

Only three (8.1%) studies reported nap timing,<sup>25,40,60</sup> however reporting was inconsistent. For instance, Fullagar et al<sup>25</sup> reported the exact nap start and end times (see Table 1), whereas Kolling et al<sup>35</sup> reported the percentage of naps taken before 12:00, between 12:00 and 15:00 and between 15:00 and 18:00. Specifically, soccer players in the Fullagar et al<sup>25</sup> study initiated naps at  $14:44 \pm 01:03$  and ended naps at  $16:12 \pm 00:59$ . Rugby League players in the Thornton et al<sup>40</sup> study were allocated specific times within the training schedule for napping such that naps were taken in the early morning (number of naps  $<12:00 = 71$ ; start  $07:05 \pm 00:35$ , end  $07:52 \pm 00:18$ ) or afternoon (number of naps  $<12:00 = 85$ ; start  $12:46 \pm 00:40$ , end  $13:40 \pm 00:47$ ).

In summary, the percentage of participants that napped across studies ranged between 11% and 100%, with highest percentage of naps reported during training compared to rest days. While there was a large variability in the duration of naps (6–120 min), nap durations on training and competition days were similar (43–44 min). Studies reporting data on the timing of naps were scarce with minimal consistency.

### Impact of Napping

In total, 17 (45.9%) studies examined at least one element of performance (eg, physical, cognitive), perceptual measures of fatigue or muscle soreness, perceived exertion and/or psychological state (eg, mood, stress). The following results section is divided into a) physical performance, b) cognitive



performance, c) perceptual measures of fatigue, muscle soreness, sleepiness and alertness; d) psychological state; and e) night-time sleep.

**Physical Performance** The impact of napping behavior on physical performance was assessed using various sport-specific measurement tests (see Table 2). Nine (24.7%) studies found positive effects of napping on measures of physical performance,<sup>42–46,49,51,54,57</sup> five (13.5%) studies revealed no impact of napping<sup>50,51,53,56,57</sup> and only two (5.4%) studies revealed napping had a negative impact on performance.<sup>27,56</sup> In the nine studies reporting positive effects of napping on measures of physical performance, participants were either a) well-rested or b) sleep restricted.

In well-rested athletes from both individual and team sports, Pelka et al<sup>50,51</sup> examined the impact of napping (20 min nap) on maximum power using counter-movement jumps (ie, using a force platform) and maximum speed (ie, non-motorized treadmill) using two 6×4 second sprint sessions with 20 seconds breaks. While Pelka et al<sup>50</sup> observed no differences in physical performance (speed or maximal power) between the napping and the control condition, improvements in average maximum speed, but not maximum power output were noted. In well-rested elite netballers, O'Donnell et al<sup>57</sup> observed improvements in peak jump velocity (via counter-movement jumps) following short naps (<20 min) compared to longer naps (>20 min) and the no nap condition. The authors found that the mean jump velocity was increased following longer naps compared to the no nap condition. However, no differences were observed between conditions for jump height. Further, Boukhris et al<sup>44</sup> conducted a comprehensive study examining three different napping conditions (no nap, 40 min nap, 90 min nap) in amateur team sport athletes (soccer, rugby, handball). The findings revealed that maximal voluntary isometric contraction and total distance improved following both the 40 min and 90 min napping conditions compared to no nap. When exploring the differences between nap duration, the 90 min nap condition had greater benefits for maximal voluntary isometric contraction and total distance compared to the 40 min nap condition.

In sleep restricted athletes (range: 3.0–4.5 h), findings revealed consistent positive effects of napping on physical performance.<sup>42,45,46,49,54</sup> Ajijmaporn et al<sup>42</sup> and Brotherton et al<sup>45</sup> both restricted sleep to 3 h of sleep per night in amateur soccer players and weightlifters, respectively. Ajijmaporn et al<sup>42</sup> observed improvements in maximum isometric leg strength (via leg dynamometry) and mean power output following a 20 min nap. Although maximal power improved following a nap, this finding did not reach statistical significance.<sup>42</sup> Brotherton et al<sup>45</sup> examined weightlifting performance using grip strength, bench and leg press between three conditions (control 7.5 h sleep, 3.0 h sleep, 3.0 h sleep plus 60 min nap). Comparisons between the control condition and the 3 h sleep restriction accompanied with a 60-min nap revealed no differences between the control and napping condition. However, the comparisons between 3 h sleep restriction and 3 h sleep restriction plus the 60 min nap condition revealed significant benefits for weightlifting performance, with grip strength, bench press (ie, power, peak velocity, force) and leg press (ie, power, distance) all higher following the 60 min nap compared to the no nap condition. Daaloul et al<sup>46</sup> examined the impact of a 30 min nap after 4 h of sleep compared to 7 h of sleep on squat jumps, counter-movement jumps and a karate-specific test. While there was no initial impact of napping on squat jump and counter-movement jumps, following the fatigue induced by the karate-specific tests, the 30 min nap improved squat jump, counter movement jump performance and time to exhaustion compared to the no nap conditions. Further, Hammouda et al<sup>49</sup> and Romdhani et al<sup>54</sup> used the same napping conditions (no nap, 20 min nap, 90 min nap) following 4.5

h of sleep restriction to examine anaerobic capacity and power using the running anaerobic sprint test.<sup>61</sup> Both studies reported significant improvements in power output and fatigue indices. It was also observed that the 90 min nap had greater effects on performance compared to the 20 min nap (Table 2). Blanchfield et al<sup>43</sup> examined runners' time to exhaustion with and without a 90 min afternoon nap. While runners improved their time to exhaustion, previous night-time sleep duration predicted change in time to exhaustion such that naps had a greater influence on runners' time to exhaustion when they slept less than 7 h the previous night.

Four (10.8%) studies reported napping during an ultramarathon.<sup>27,28,30,33</sup> While Martin et al<sup>30</sup> explored the sleep habits of ultramarathon runners during training, the authors did not examine the impact of napping during an ultramarathon (Table 1). In addition, Hurdie et al<sup>33</sup> reported that 70% of runners reported napping during the ultramarathon obtaining an average of 23±22 min of sleep. The authors found that the race finish time was positively related to the amount of sleep obtained during the ultramarathon. In contrast, Knechtle et al<sup>27</sup> and Poussel et al<sup>28</sup> observed that runners that napped during an ultramarathon finished the race significantly slower than those who did not nap. Knechtle et al<sup>27</sup> found that a total of 57% runners napped during the ultramarathon with nap durations ranging from 30 to 175 min, while Poussel et al<sup>28</sup> revealed that 28% took at least one nap with the majority of participants napping between 15 and 30 min.

Only two (5.4%) studies reported that napping negatively affected physical performance.<sup>27,56</sup> While Suppiah et al<sup>56</sup> demonstrated that 20 m sprint times were slower following a nap compared to no nap, other measures of performance in this study (other sprint distance times and shooting performance) were not different between the nap and no nap condition. Further, the study by Knechtle et al<sup>27</sup> was conducted during a continuous ultra-cycling race (~24 hours in duration) which examined the finish time and found that stopping to nap during the race logically delays the finish time of competitors who napped.

In summary, the physical performance benefits of napping are greater in sleep restricted athletes compared to well-rested athletes. While shorter naps (~20 min) show physical performance benefits, longer naps (~90 min) were likely to yield more benefits to physical performance.

**Cognitive Performance** Five (13.5%) studies examined the impact of cognitive performance following napping. Four of the five studies demonstrated a positive influence of napping on cognitive performance.<sup>44,46,52,54</sup> Boukhris et al<sup>44</sup> examined three conditions (no nap, 40 min nap, 90 min nap) without sleep restriction. While the authors observed that both nap conditions improved attention using the digit cancellation test,<sup>62</sup> the 90 min nap condition resulted in greater improvements in attention compared to the 40 min nap condition.

Daaloul et al<sup>46</sup> and Romdhani et al<sup>54</sup> examined cognitive performance under sleep restricted conditions of 4.0 h and 4.5 h of sleep, respectively. Daaloul et al<sup>46</sup> observed improvements in both simple visual reaction time and lower leg reaction time tasks as well as a mental rotation task following a 30 min nap in karate athletes. However, Romdhani et al<sup>54</sup> observed improvements in simple reaction time and multiple-choice reaction times following the 20 min nap condition only and not the 90 min nap condition. In comparison to the aforementioned studies, Ajijmaporn et al<sup>42</sup>

examined reaction time using an auditory reaction time task to examine the impact of a 20 min nap following 3 h of sleep restriction. The authors observed no differences between the control, sleep restricted and napping conditions.<sup>42</sup> Finally, Petit et al<sup>52</sup> examined the impact on vigilance and attention following a 21 min nap in a 9 h time in bed condition versus a 5 h phase advance condition to simulate jet lag. Regardless of the condition, the 21 min nap improved vigilance and attention performance (Table 2).

In summary, napping improves cognitive performance in the form of visual reaction time, attention and mental rotation tasks. However, no differences were found when reaction time was examined using an auditory reaction time task.

**Perceptual Measures of Fatigue and Muscle Soreness, Sleepiness and Alertness** The positive impact of napping on perceived exertion, subjective fatigue and/or vigour was evident in four of the five studies examining the effects of napping on various perceptual measures.<sup>42–44,47,54</sup> O'Donnell et al<sup>57</sup> demonstrated energy levels remained unchanged in netballers who napped versus those who did not nap. However, it is important to note that O'Donnell et al<sup>57</sup> employed a 5-point Likert scale which may have minimized the variability in responses.<sup>63</sup> Consistent with the notion of sleep inertia and readiness to perform, Davies et al<sup>47</sup> observed that athletes reported greater readiness to perform 2 h post nap versus 1 h post-nap. However, there was no comparison between athletes' preparedness or readiness to perform compared to a no nap condition.

Two (5.4%) studies examined muscle soreness following napping.<sup>44,48</sup> Driller and Argus<sup>48</sup> examined the impact of floating in an enclosed, warm, saline-dense water tank for 45 min as a form of recovery in 60 international level athletes. While a single 45 min floatation session improved perceived muscle soreness, 27 athletes who napped during the floatation session did not report any differences in their perceived recovery (Table 2). It is possible that in this study, laying in an enclosed, warm, saline-dense water tank had benefits on muscle soreness itself independent of napping. Boukhris et al<sup>44</sup> conducted a comprehensive study examining three different napping conditions (no nap, 40 min nap, 90 min nap). The findings related to recovery revealed that napping had a favourable effect on delayed onset muscle soreness<sup>64</sup> and perceived recovery status.<sup>65</sup> Further, Boukhris et al<sup>44</sup> revealed that the longer nap (90 min) resulted in decreased delayed onset muscle soreness and increased perceived recovery, indicating that longer naps may have a greater impact on recovery than shorter naps (Table 2).

Four (10.8%) studies examined the impact of napping on perceived exertion<sup>42,43,54,66</sup> using the original Borg scale<sup>67</sup> or the validated French version<sup>68</sup> of the Borg scale. All studies revealed napping had a positive impact on perceived exertion such that athletes' rating of perceived exertion was lower following a nap, particularly under sleep restricted conditions.<sup>42,43,54,66</sup>

In summary, evidence supports the role of napping in improving perceptual measures of fatigue and muscle soreness, however not perceived energy levels. Naps have the potential to improve athletes' rating of perceived exertion.

Seven (18.9%) studies employed a measure of sleepiness and/or alertness (Table 2). The three main scales employed to assess sleepiness were the Epworth Sleepiness Scale (n = 1),<sup>69</sup> the Karolinska Sleepiness Scale (n = 1)<sup>70</sup> and the Stanford Sleepiness Scale (n = 2).<sup>71</sup> In addition, three studies examined alertness using a 100-mm visual analogue scale.<sup>45–47</sup> All four studies examining sleepiness demonstrated that napping (nap duration range: 20–90 min) improved sleepiness (Table 2).<sup>43–45,54</sup> Although Blanchfield et al<sup>43</sup> reported sleep inertia with an initial increase in sleepiness immediately following a 20 min nap, runners' sleepiness scores returned to baseline levels after 90 min.

Similar to sleepiness, two out of three studies reported improved alertness following naps (Table 2).<sup>45,46</sup> There was variability in the timing of administration of alertness scales with Daaloul et al<sup>46</sup> and Davies et al<sup>47</sup> administering the scales either immediately or within 15 min upon waking, whereas Brotherton et al<sup>45</sup> administered the scales 3 h post-nap. Interestingly, out of the three studies examining alertness, Davies et al<sup>47</sup> was the only study that did not deprive prior sleep such that participants were not in a sleep-deprived state before napping and subsequently no differences in alertness between the nap and no nap condition were observed.

In summary, napping was found to improve sleepiness and alertness. There was some evidence to indicate sleep inertia; however, this dissipated 90 min post-nap. In circumstances where athletes were well rested, there were no differences for alertness between nap and no nap conditions.

Psychological State Eight (20.6%) studies examined the psychological impact of napping (Table 2). In these studies, participants were either a) well-rested or b) sleep restricted. In well-rested athletes, Boukhris et al<sup>66</sup> revealed that tension, depression, vigour, fatigue and total mood disturbance scores, assessed via the French version of the Profile of Mood State questionnaire,<sup>72</sup> improved following both a 40 min and 90 min nap compared to no nap. However, no differences were observed for confusion. Likewise, Driller and Argus<sup>48</sup> revealed positive changes in 5 mood-state variables (ie, worn-out, at-ease, tense, fresh, and exhausted), assessed via the multidimensional mood-state questionnaire,<sup>59</sup> following a 45 min nap opportunity (mean nap duration: 26±13 min). In contrast, three studies found no differences between napping and no napping conditions on measures of psychological state (eg, Brunel Mood State questionnaire, Profile of Mood State questionnaire and the Short Recovery and Stress Scale) in well-rested athletes.<sup>43,45,51</sup>

Perhaps unsurprisingly, in circumstances where athletes were sleep restricted, napping had a consistent positive impact on mood.<sup>45,54</sup> In studies where sleep was restricted (3.0–4.5 h per night),<sup>45,54</sup> napping significantly improved mood as assessed by the Profile of Mood States questionnaire.<sup>73</sup> Further, Romdhani et al<sup>54</sup> showed that longer naps (90 min vs 20 min nap) resulted in greater positive effects on mood. These data are consistent with data in non-athletic populations indicating that in sleep-deprived individuals, napping showed positive effects on mood.<sup>74–76</sup>

In summary, data consistently show that napping results in improved mood states. The improvements in mood following napping were more pronounced following both sleep restriction and longer naps.

Night-Time Sleep Two (5.4%) studies reported the impact of daytime naps on night-time sleep.<sup>40,53</sup> Thornton et al<sup>40</sup> reported that rugby league athletes in their study were encouraged to nap between 15 and 45 min to avoid any disruptions to their night-time sleep, with nap durations ranging from 30 to 32 min. Athletes that napped during the day went to bed earlier, increased their night-time sleep duration by 30 min and improved their sleep efficiency by 1% compared to those who did not nap. In contrast, Petit et al<sup>53</sup> examined the effects of a 20 min nap scheduled following a normal sleep condition and a 5 h phase advance condition. The main findings indicated that a 20 min nap between 13:00 and 14:00 h (normal condition) and between 08:00–09:00 h (5 h phase advance condition) increased sleep onset latency but did not alter any other sleep variables, including sleep staging. In the normal sleep condition, sleep onset latency increased from  $13 \pm 6$  min to  $24 \pm 12$  min. In the 5 h phase advance condition, sleep onset latency increased from  $7 \pm 4$  to  $12 \pm 13$  min. It is important to acknowledge that these recommendations apply to those athletes with regular circadian timing and may not be appropriate for those with extreme chronotypes.

In summary, there are inconsistent findings regarding the effects of daytime naps on night-time sleep onset latency. Daytime nap durations of up to 45 min may increase the time taken to fall asleep at night in athletes.

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## Discussion

This systematic review is the first to explore a) how studies evaluated napping behavior in athletes (frequency, duration, timing and measurement) and b) how napping impacted physical performance, cognitive performance, perceptual measures (eg, fatigue, muscle soreness, sleepiness and fatigue), psychological state and night-time sleep in athletes. This information is important for athletes and practitioners who provide advice and education to athletes regarding napping.

## Why and When Athletes Nap?

Sleep is essential for optimising recovery and athletic performance.<sup>7,77</sup> It is well established that athletes' sleep and wake behaviors are dictated by rest days as well as training and competition schedules such that early morning training, multiple training sessions per day<sup>5,38</sup> and night-time competition.<sup>24</sup> Sleep disturbances in response to sport-specific conditions show high inter- and intra-individual variability and athletes may experience insomnia symptoms associated with greater sleep fragmentation indices, longer sleep latencies and excessive daytime sleepiness. In this context, daytime napping represents a common compensatory strategy used by athletes to increase sleep duration over a 24 hour period and potentially counteract daytime sleepiness associated with sleep restriction.<sup>78</sup> Rest days in athletes may present athletes with opportunities to extend their main night-time sleep duration such that they are less likely to nap on rest days.<sup>38</sup>

This review showed evidence of athletes engaging in two main types of naps a) the prophylactic nap: a nap taken in anticipation of sleep loss<sup>4</sup> and b) the replacement nap: a nap taken in response to sleep loss.<sup>4</sup> No studies specifically identified athletes as engaging in the appetitive nap. Although there is no evidence that athletes take naps for convenience or enjoyment, Gupta et al<sup>8</sup> applied

Harrison and Horne's<sup>79</sup> idea of "sleepability" such that athletes may have a greater ability to nap on demand without prior sleep debt. Gupta et al<sup>8</sup> utilized polysomnography to assess sleep latency associated with a 20 min nap opportunity taken at 15:00 h and observed that high-performance athletes showed significantly shorter daytime sleep latencies than non-athletes controls. Further, this difference was maintained even when data were adjusted for pre-trial sleepiness scores and total sleep time. These results suggest that napping may actually reflect the athletes' "sleepability", and that the opportunity to take a nap is not necessarily associated with sleep restriction and daytime sleepiness. Field-based studies in athletes' habitual environment are needed to provide further insight into napping behaviors.

The recuperative value of a nap is dependent on when the nap is taken in regard to the 24 hour circadian rhythm.<sup>3</sup> For example, the maximum period of daytime circadian sleepiness occurs in the mid-afternoon (13:00–16:00 h) and is often referred to as the post-lunch dip.<sup>80</sup> Experimental studies conducted in non-athlete populations have indicated that naps taken during this time have a greater recuperative value than naps taken at other times of the day.<sup>81–83</sup> Despite the established recuperative benefits of napping between 13:00 and 16:00 h, only three studies recorded the timing of naps taken by athletes.<sup>25,40,60</sup> Interestingly, these studies generally reported athletes napped between 13:00 and 16:00 h and, similarly, Thornton et al<sup>40</sup> observed that only 7% of naps were taken after 15:00. As noted by Sargent et al<sup>38</sup> and Lastella et al<sup>84</sup> where sleep and wake behaviors were dictated by the timing of training and competition schedules, it is possible that naps were taken between 13:00 and 16:00 h as a result of the opportunity provided between daily training/competition schedules.

Importantly, no study has investigated the association between athletes' chronotype (the expression of circadian rhythmicity in an individual) and the timing of napping. Chronotype may largely influence sleep behavior, training schedules and the physical or cognitive performance in athletes, with evening-types having delayed sleep onset and offset times and showing peak times for performance later in the day than morning-types.<sup>85–87</sup> Therefore, the impact of chronotype on napping behavior in athletes warrants further investigation. Regardless of the reasoning for the timing of naps recorded in this review, the optimal time to nap was identified as the maximum period of circadian sleepiness occurring in the mid-afternoon (13:00–16:00 h).

### The Impact of Napping

Overall, the percentage of participants that napped across studies ranged between 11% and 100%.<sup>6,24,31,37,40</sup> In the current review, naps not only consistently reduced sleepiness and increased alertness,<sup>44–47,54</sup> but also produced favourable outcomes on physical and cognitive performance as well perceptual and measures of psychological state (eg, mood) (Table 2). While the evidence to support the benefits of napping in well-rested athletes was clear,<sup>42,45,46,49,54</sup> the physical, cognitive and mood state benefits of napping were greater in sleep restricted athletes.

Cognitive performance is particularly sensitive to sleep restriction such that cognitive functions are the first level of functioning to become compromised.<sup>88,89</sup> Upon investigating the studies that examined cognitive performance following napping, it was evident that regardless of participants

prior sleep debt, all studies demonstrated a positive influence of napping on cognitive performance.<sup>42,44,46,52,54</sup> The duration of naps in studies that investigated cognitive performance outcomes ranged from 20 to 90 min, and several domains of cognition were explored (eg, reaction time, mental rotation, psychomotor vigilance, and attention tasks). Of interest the length of the nap likely influences the strength of cognitive performance improvements. For example, Boukhris et al<sup>44</sup> observed greater cognitive effects on a digit-cancellation task designed to examine attention with a longer nap (90 min) compared to a shorter nap (20 min).

Overall, napping between 20 and 90 min improved sleepiness as observed in four studies.<sup>43–45,54</sup> Blanchfield et al<sup>43</sup> did demonstrate initial signs of sleep inertia with a slight increase in sleepiness immediately following a 20 min nap; however, sleepiness returned to baseline levels after 90 min. Similar findings were observed for alertness with two of the three studies demonstrating positive effects for alertness following naps which was thought to be related to the dissipation of sleep homeostatic pressure.<sup>45,46</sup> In non-athletes, studies have shown that short naps provide a wide range of benefits from increasing alertness to improving cognitive outcomes.<sup>76,90</sup> Conversely, Davies et al<sup>47</sup> did not observe any difference in alertness following a 90 min daytime nap and a potential explanation for this result was that they did not deprive sleep in runners a priori.

Regardless of whether athletes were well rested<sup>22,66</sup> or sleep restricted,<sup>45,54</sup> napping had a consistent positive impact on measures of psychological state. However, in circumstances where athletes were sleep restricted, napping had a marked positive impact on psychological state.<sup>45,54</sup> For example, in studies where sleep was restricted (3.0–4.5 h per night), napping significantly improved mood.<sup>45,54</sup> Further, Romdhani et al<sup>54</sup> showed that longer naps (90 min vs 20 min nap) had greater psychological benefits to mood. These data are consistent with the data on non-athlete populations indicating that napping showed promising effects on psychological state in sleep-deprived individuals.<sup>90</sup>

Based on the findings of the present review, there is minimal evidence to indicate that napping is detrimental for athlete's physical performance. While two studies revealed napping had a negative impact on measures of physical performance,<sup>27,56</sup> it is important to acknowledge that Knechtle et al<sup>27</sup> examined race finish times during a ~24 hour ultramarathon such that participants napped during the race itself. Suppiah et al<sup>56</sup> on the other hand, examined the influence of napping in youth athletes sprint performance under well-rested conditions (ie, 7.8 h time in bed). While there was a decline in the fastest 20 m sprint time between nap and no nap conditions, no differences were observed for any other reaction time or sprint performance measures.<sup>56</sup> Although Suppiah et al<sup>56</sup> discuss sleep inertia as a plausible explanation for the decline in sprint times, athletes in this study were woken up immediately prior to the onset of Stage 3 sleep (ie, slow wave sleep) to minimize the effects of sleep inertia. Given this was the only negative finding related to physical performance within the study as well as across all studies examined within this review, it is reasonable to conclude that napping does not have a negative impact on physical performance.

## Considerations When Implementing Napping for Athletes

**Sleep Inertia** Sleep inertia is a transitional state of impaired cognitive performance and reduced alertness upon waking.<sup>91</sup> Often colloquially described as a feeling of “grogginess”, the level of sleep inertia impairment is greatest upon waking and usually takes 15–30 min to fully dissipate. However, some studies in non-athletes have observed performance impairments for up to 2 h post-wake.<sup>92</sup> Data derived from non-athlete populations indicate that the duration and/or severity of sleep inertia following a nap can be influenced by a number of factors, including a) prior sleep loss/sleep debt; b) being woken up from slow wave sleep;<sup>93</sup> c) the amount or percentage of slow-wave sleep in a nap<sup>94</sup> and d) time of day.<sup>95</sup> While many studies in the current review suggest that sleep inertia may explain their findings (eg, reductions in physical performance<sup>56</sup> and alertness<sup>43</sup> following a nap), no studies to date have specifically investigated the impact of sleep inertia following napping opportunities on measures of performance in athletes.

Given the known impacts of sleep inertia on measures of performance and alertness in non-athletes, athletes should ensure that there is adequate time (at least 30 min in most cases) for sleep inertia to dissipate following a nap before commencing training or competition. In some cases, it may be possible to accelerate this dissipation by employing known sleep inertia countermeasures, which can be employed proactively (ie, before the nap) or reactively (ie, after a nap). Examples of these countermeasures include caffeine, bright light, sound, temperature and physical activity, and these countermeasures have been reviewed extensively elsewhere.<sup>96,97</sup> However, it should be noted that none of these strategies can reliably dissipate sleep inertia within the first 15 min upon waking.<sup>96,97</sup> Further, if the goal of the napping opportunity is to benefit performance and/or recovery, and there is no immediate need to perform within 30 min of waking, then the impact of sleep inertia is negligible.

A recent study by our team investigated the possibility whether athletes exercising prior to their night-time sleep periods would exhibit greater amounts of slow-wave sleep in their night-time sleep period, which could subsequently impact the severity and/or duration of sleep inertia.<sup>98</sup> This hypothesis could potentially mean that athletes may be more susceptible to the impacts of sleep inertia given (in most cases) that their level of exercise is greater than the general population.<sup>98</sup> However, this study concluded that exercise of a moderate-intensity performed 90 min before bed did not negatively impact sleep inertia and there was no relationship between the amount of slow wave sleep in the preceding sleep period and sleep inertia.<sup>98</sup> Therefore, it seems unlikely that athletes have a greater likelihood of experiencing enhanced duration and/or severity of sleep inertia compared to non-athletes.

**Ensuring a Nap Does Not Impact Night-Time Sleep** Napping has the potential to disrupt night-time sleep. This is dependent on several factors including the duration of the nap, the timing of the nap and prior sleep debt. In general, the longer the nap, the greater the reduction in sleep propensity; thus, if a nap is taken for a longer period later in the day, and the athlete still attempts to sleep at their habitual time of day, the main night-time sleep period, particularly sleep onset latency, may be disrupted. However, only one study by Petit et al<sup>53</sup> showed that sleep onset latency increased the night following a 20 min nap opportunity. As stated previously, the optimal time to nap is when the maximum period of circadian sleepiness occurs in the mid-afternoon (13:00–16:00 h), this timing should also protect delays in sleep onset latency and any intrusion into the night-time sleep period.

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## Limitations

The current systematic review has limitations which should be acknowledged. First, articles were only considered for inclusion if they were published in peer-review journals and written in English, resulting in potential language bias. Second, some studies may have reported napping conditions yet failed to indicate if participants had initiated sleep. For example, Brotherton et al<sup>45</sup> stated that participants were required to sleep/rest in a quiet room for 60 min yet, did not provide any data on the number of participants that initiated sleep. Third, articles on napping behavior of Muslim (fasting) athletes during Ramadan and athletes with a disability (eg, Paralympic athletes) were not included in the review. Finally, there is a lack of data reporting nap quality, specifically examining sleep efficiency and/or fragmentation indices (eg, the amount of movement during naps). This is predominantly a reflection of the rapid growth pertaining to sleep in athletes such that main night-time sleep periods have been at the forefront of sleep in athlete research. It is imperative for future studies to provide data examining the napping behaviors of athletes to ensure that sports practitioners and researchers are able to comprehensively examine both quantity and quality of naps in athletes.

Although the overall evidence included in this review was of moderate quality with the majority of experimental or longitudinal studies, it was observed that most of the studies: a) did not include detailed information for nap timing and duration, b) had inconsistencies in reporting of nap frequency, c) focused specifically on the night-time sleep period, and d) relied on self-report data (ie, sleep diaries or questionnaires) to explore napping behavior. Future studies should, therefore, include comprehensive recordings of nap duration and quality, and consider using sleep over a 24 hour period (daytime naps and night-time sleep period), specifically using objective methods of sleep assessment (eg, polysomnography and actigraphy).

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## Conclusion

Research investigating napping behaviors indicates that napping is common practice among athletic populations. While napping presents athletes with the opportunity to supplement their night-time sleep, evidence also indicates that napping may be beneficial for a range of measures (eg, physical performance, cognitive performance and mood) in athletes (Figure 3). Data from the present review suggest that athletes should aim to nap for between 20 and 90 min between 13:00 and 16:00 hours. Finally, athletes should allow 30 min to reduce sleep inertia prior to training or competition to obtain better performance outcomes. Future studies should utilize objective measurement tools to comprehensively evaluate the frequency, duration, timing of naps in athletes and the resulting impact on athletic performance.

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Figure 3

Overview of the evidence examining the impact of napping on various measures of athletic performance.

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