Sleep extension in athletes: What we know so far – a systematic review

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Abstract

Objective: This study reviewed systematically the effects of sleep extension on sports performance.

Design: systematic review

Method: The systematic review was conducted in November 2020. Articles published in English were searched in PubMed, Virtual Health Library, SPORTDiscus, and Web of Science and Scopus databases. The search terms used were "sleep extension" AND athlete. The measures of interest were sports performance. Studies were included if they were a) original articles, b) published in English and peer-reviewed article, c) had only athletes as participants, d) experimental protocol whose objective was to investigate the effects of sleep extension on sports performance, including randomized (RCT) and non-randomized controlled trial (nRCT), and e) at least a sports performance measure as a dependent variable.

Results: The primary search revealed that a total of 5 out of 74 articles were considered eligible and 2 studies were subsequently included. The studies used different strategies to extend time in bed or total sleep time (extending 26 to 106 min). From fifteen sports measures, six presented a large effect size, and the others ranged from trivial to medium. Overall, the risk of bias was high to RCT and low to nRCT and the quality of evidence ranged from very low quality to moderate quality in ten outcomes.

Conclusions: The limited evidence suggests that sleep extension interventions may be beneficial to improve sports performance in athletes where the magnitude is dependent on the variable assessed, although such conclusions are tentative because of the quality of the evidence and risk of bias.

Keywords: athlete, extra sleep, performance, and sport.

1. Introduction

Sleep is particularly important to athletes as sleep helps in the body restoration imposed by the fatigue of the waking period, with a restorative and repairing process in the energy of different physiological systems. Consequently, the athlete's body becomes prepared for both training and competition. In addition, sleep provides cognitive recovery and optimal decision-making capacity, contributing to an optimal mental state.[1] For an athlete to achieve the expected training results, recover for the next training session, and increase performance, sleep must be restorative, accomplished by getting adequate sleep per night.[2] The National Sleep Foundation (NSF) recommends different sleep durations according to the age group. For most healthy adults (18 – 64 years old), the NSF recommends between 7 and 9 h of sleep per night. Although some individuals might sleep longer or shorter than the recommended times without deleterious effects, getting sleep duration continually outside the normal range may harm his or her health and well-being. It is important to note that this recommendation referring to sleep duration instead of time in bed. Typically, actual sleep duration is lower than time in bed, which makes it important to know which term is related to in the studies with athletes.[3] Although there is no consensus on the ideal amount of sleep per night for athletes, especially during a competitive period,[4] higher amount of sleep per night than that recommended for non-athletes has been suggested.[5, 6]

Unlike sleep loss, sleep extension has ambiguous effects on sports performance. In one of the first studies to observe the effect of sleep extension on sports performance, Mah, Mah [7] extended the sleeping time of swimmers (from 6–8 h per night to 10 h per night) for 6–7 weeks. The authors observed an improvement in sprint time, reaction speed, and mood. The same group of researchers conducted a sleep extension program for college basketball players. They found that the players could achieve a minimum of 10 h of sleep for 5–7 weeks. In addition to improved sprinting, the authors observed an improvement in accuracy in free-throw or 3-point throws.[8] Likewise, Schwartz and Simon Jr [9] observed an improvement in the accuracy of service among college tennis players following sleep extension for 2 weeks. On the contrary, Fullagar, Skorski [10] did not observe the effect of sleep extension on physical performance (countermovement jump and intermittent yoyo recovery test), blood component measurements (creatine kinase, urea, and C-reactive protein), stress markers, or perceived recovery. These contradictory results can be attributed, at least in part, to the different research methods and designs used.

Thus, interestingly, there are methodological issues that limit the application of the previous findings, and consequently, development of a standard for recommending sleep extension in athletes. For example, were the athletes with accumulated sleep debt or chronic sleep restriction? Would extending sleep only benefit individuals with sleep debt or sleep restriction? The length of sleep may have been an opportunity to achieve enough sleep, with no extension in the ideal amount of sleep. The literature reveals that individuals with sleep debt or reduced amount of sleep, benefit when provided with the opportunity to achieve adequate sleep. Another factor to be considered is the minimum intervention period necessary to experience the benefits of sleep extension. Moreover, there is a need to verify the effect of sleep extension programs on athletes and on what measures these interventions can be beneficial. This could contribute to the standardization of the sleep extension intervention recommendation for athletes.

To date, there are no systematic reviews on the use of sleep extension in athletes. Recently, sleep extension intervention has been recommended as beneficial for subsequent performance measures.[11] This article provides information from two articles that used intervention to extend sleep and its results in sports performance. However, it does not provide critical information about the quality of the studies that were used, the effect size of intervention, neither their risks of bias. In a recent narrative review on athlete's sleep,[12] the authors described sleep extension as a strategy that should be looked at carefully, with a brief introduction to the analyzes that should be done in sleep extension studies. Therefore, this study aimed to conduct a systematic review of the literature, perform a critical analysis of the sleep extension intervention designs used in athletes, and present the effects of sleep extension on sports performance of athletes when compared to habitual sleep patterns.

2. Methods

Two researchers screened the relevant published articles from PubMed, Web of Science, Scopus, SPORTDiscus, and Virtual Health Library. Moreover, we have researched on grey literature (OpenGrey, New York Academy of Medicine Grey Literature Report, ClinicalTrials, EThOS: UK E-

Theses Online Service) in February 2020 were searched and updated in November 2020. The search terms used were: "sleep extension" AND athlete and their Medical Subject Heading terms. Our review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[13] The search strategy and PRISMA checklist are available as supplementary material. Studies were eligible if they investigated the effect of sleep extension on athletes' sports performance. Sports performance was considered any activity whose outcome of interest required physical performance (e.g., strength, endurance, and speed), or specific sports skills (e.g., tennis serve and 3-point throw in basketball) in athletes. Following were the inclusion criteria: a) original article; b) published in English and peer-reviewed article; c) only athletes as participants, regardless of the modality practiced or age; d) experimental protocol (randomized and non-randomized controlled trials) whose objective was to investigate the effects of sleep extension on sports performance, without limit for the intervention time; and e) existence of a measure of sports performance as a dependent variable. For this review, sleep extension was defined as an increase in habitual total sleep time, either in nighttime sleep or addition of naps during the day. Studies were excluded if they did not meet at least one inclusion criterion. Reviews, systematic or critical, short-communication, and editorial articles were excluded. The screening and data extraction were performed by two researchers. Disagreements in any article or result were discussed among the authors and resolved by additional authors when necessary. We used the *k* statistic to describe the level of agreement between the reviewers in this phase.[14] After removing duplicate articles, the titles and abstracts were read by an author. The two authors then examined the articles in full to confirm the inclusion and eligibility criteria.

A total of 74 articles were found to be eligible. Of these articles, 16 were extracted from PubMed, 17 from Web of Science, 15 from Scopus, 13 from SPORTDiscus, 11 from Virtual Health Library and 2 from grey literature. After excluding the duplicate articles, 32 articles remained. After reading the titles and abstracts, 17 articles were excluded for not meeting the eligibility criteria (e.g., reviews and editorials), leaving 15 articles to be examined. A second reviewer also read the titles, abstracts and the full text. In case of discrepancy in any study, a third reviewer was invited to arrive at a final decision. After full reading of the selected articles, 10 were excluded such that articles that did not include athletes and articles whose outcome measure was not sports performance. Two articles were added from the reference lists of included studies. Therefore, a total of seven articles were included for the final review (Figure 1). Unpublished articles were not included for the analysis. There were good agreements between the reviewers during the screening after excluding duplicates (k= 0.86, 95% CI[0.66,1.05]; *p*= 0.00; agreement percentage= 97.2%) and during the screening of included articles in this review (k= 1.0, 95% CI[1.0,1.0]; *p*= 0.00; agreement percentage= 100%).

Information regarding the population, intervention, comparisons, outcomes, study design (PICOS), was extracted from each study. This Data concerned characteristics of the participants (age, sex, level of athlete, and habitual sleep pattern), type of intervention (number of hours of sleep prescribed, duration of intervention), and outcome measures (sports performance). Sports performance measures were recorded using numerical information from the results of each study. The Cochrane Collaboration tools assessed the risk of bias in randomized trials (RoB 2.0) and non-randomized trials (ROBINS-I). The RoB 2.0 [15] assesses the risk of bias in five distinct domains and the judgments within each domain lead to overall risk-of-bias. The ROBINS-I [16] assesses the risk of bias in seven domains and shows an overall risk-of-bias. The items of this evaluation were classified as low, moderate, or high risk of bias. The plots obtained from these analyses [17] are available as supplementary material. All studies with matching eligibility were included in the review regardless of their risk of bias or quality. We used the *k* statistic to describe the level of agreement between the reviewers. The Grades of Recommendations, Assessment, Development, and Evaluation (GRADE) rated the overall quality of evidence for each outcome. This tool evaluates the level of confidence for each outcome and provides an overall summary of quality with 1 of 4 classifications: high, moderate, low, and very low.

Due to the large variation in intervention programs and the different measurement tools, it was not possible to perform a meta-analysis of the data. Hence, synthesis without meta-analysis guidelines was used to report the results.[18] The synthesis without meta-analysis guidelines (SWiM) checklist is available as supplementary material. The mean and standard deviation of the outcomes were collected from the three studies and were used to calculate the effect size and confidence interval of the intervention. The effect size was determined by Cohen's d ($d = \frac{M2-M1}{\sqrt{(SD2^2-SD1^2)/2}}$), with d > 0.2 and d < 0.5 considered as small effect; d > 0.5 and d < 0.8 as moderate effect; and d > 0.8 as large effect [19]. The following formula was used to calculate the percentage difference: (X2−X1)/X1 × 100, where X1 is pre-intervention, and X2 is post-intervention.

3. Results

The characteristics of the included studies are presented in Table 1. All the included articles were interventional studies published between 2011 and 2020 (randomized and non-randomized controlled trial). The study sample comprised 9–24 athletes aged 14–30 years playing eight different sports (tennis, basketball, cycling, handball, rugby, shooting, soccer and triathlon). Of the seven studies analyzed, five included only male athletes[8, 10, 20] and two included both male and female athletes.[9, 21] Two studies included university athletes,[8, 9] one included high-level student-athletes,[21] one included trained athletes,[20] one included highly trained athletes,[22] one included amateurs athletes,[23] and one included highly trained amateurs.[10]

To describe the sleep-wake cycle, five studies used actigraphy either in the pre-intervention period or during the intervention[8, 10, 20, 21, 23] and one used the polysomnography.[22] Two studies used actigraphy after the end of the intervention period, describing the sleep–wake cycle up to two days. Of the studies that used actigraphy to describe the sleep–wake cycle, two studies described the activity thresholds, considering the value of 40 and 60 for movement detection.[20, 23] This pre-interventional evaluation for sample characterization lasted from 1 day to 4 weeks. Roberts, Teo [20] observed the amount of sleep for 4 days before the intervention period, and there were other periods like 1 day,[10, 22, 23] 2 days,[21] 1 week,[9] and 2-4 weeks.[8] The total pre-interventional sleep time ranged from 06:54 to 08:45 h:min per night.

The duration of the sleep extension intervention in the studies ranged from 1 day to 7 weeks. The strategies for sleep extension intervention included a) extension in the habitual time in bed, b) provision of behavioral advice with sleep hygiene tips, and (c) a combination of both. There different recommendations like getting 9 to 10 h of sleep per night, an increase 30 % in habitual time in bed, and take 20, 40, or 90-min of nap. All studies reported an increase in the sleep parameter assessed with the intervention. The smallest difference observed between the control condition and the experimental condition was 00:26 h:min and the biggest difference observed was 01:48 h:min.

Performance measures varied between studies, from specific skills of the sports modality to measures of physical performance, totaling fifteen performance measures analyzed. The percentage difference in the measures evaluated in sleep extension intervention studies is provided in Table 2. Compared to baseline, Mah, Mah [8] reported improvements in free throw (11.4 %, d = 0.918), 3-point field goals (13.7 %, d = 0.757), and 282 feet sprint (-4.3 %, d = 1.215). Similarly, Schwartz and Simon Jr [9] reported improvements in tennis serving accuracy (17.7 %, d = 0.418) after sleep extension intervention compared to baseline. Roberts, Teo [20] reported significant decreases in time-trial performance after the sleep extension intervention on day 4 compared to normal sleep condition (−3.2 %, d = 0.583). Boukhris, Trabelsi [23] reported improvements in maximal voluntary isometric contraction and shuttle run test ranging from +5.7 to 12.6 % (d = 0.44 to 1.70). Two studies demonstrated no improvement in performance measures[10, 21, 22] despite the extension in total sleep time, and one study described an association between hours of sleep and sports performance.[21] Fullagar, Skorski [10] reported percentage changes from -4.6 to +2.8 % and Cohen'd from 0.10 to 0.25, and Petit, Mougin [22] reported percentage changes of +0.6 and 0.9 % (d = 0.050 and 0.049, respectively). Lastly, Suppiah, Low [21] did not report the values of central tendency and dispersion of sports performance variables in their results.

The three randomized controlled trial showed a high risk of bias. Of the four non-randomized studies, two were classified as being low risk of bias, one as being the moderate risk of bias, and one as a serious risk of bias. All non-randomized studies showed bias due to the selection of the participants. Overall RoB for non-randomized controlled trials was graded as 50 % showing a low risk of bias, 25 % showing a moderate risk of bias, and 25 % showing a serious risk of bias. The results of GRADE rating showed that one outcome provided evidence with very low quality (1/15, 6 %), five outcomes provided evidence with low quality (5/15, 33 %), four outcomes provided evidence with moderate quality (4/15, 27 %), and five outcomes provided evidence with high quality (5/15, 33 %). The risk of bias was found in all included articles. The RoB assessments and the quality of evidence are available as supplementary material.

4. Discussion

This study aimed to conduct a systematic review to present the effects of sleep extension on sports performance of athletes (9-10 h over 1-49 days who habitually sleep 6-9 h a day). To the best of our knowledge, this is the first study to review the effect of sleep extension in athletes. We present the initial results of a new strategy to improve sports performance and indicate that extending sleep in athletes without sleep disorders or sleep debt may be beneficial, although the quality of the research prevents firm conclusions. To apply a sleep extension intervention, it is important to consider two factors: sleep characteristics of the athletes and the sleep extension intervention.

The most important factor is the individual amount of sleep habitually taken by the athletes participating in the studies. Some factors must be considered while identifying the athlete's normal sleep pattern, such as the analysis period (number of observation days) and the amount of pre-intervention sleep. Concerning the analysis period, the wide range of the evaluation period (from 1 day to 4 weeks) observed in this review can cause diversity in the athlete's sleep pattern submitted to extension intervention. The Society of Behavioral Sleep Medicine recommends the use of actigraphy for a period of 7 to 14 days, including at least one weekend to estimate sleep-wake pattern.[24] In addition, the description of the activity count used to define the sleep–wake cycle should be considered, as there is a recommendation to use a higher threshold in studies involving athletes.[25]

The amount of sleep can vary between nights. A previous study reported that nightly variability was greater than yearly variability. Thus, the analysis of only 1 or 2 days of sleep may not represent the individual's sleep characteristics.[26] For a reliable measure of total sleep time, the minimum recommended period is 7 days.[27] Interestingly, only 2 studies observed an amount of sleep for least 7 days. Thus, other studies may fail to estimate the volunteers' habitual sleep time. Another important point is the amount of sleep in the pre-intervention moment. To show that athletes did not return from a period of sleep loss, three studies presented the amount of sleep referring to 2-3 days before the beginning of the study.[10, 20, 21] Although two days are sufficient to restore the daytime sleepiness, fatigue, cortisol level, and IL-6 level, after a period of sleep loss, evidence shows that cognitive performance may need a longer period to restore pre-debt sleep values.[28, 29] Consequently, athletes may have started the study period with a cognitive pattern different from a normal period of sleep, compromising the results of the research.

Thus, standardization in the observation of the total sleep time before the intervention can help describe whether the athlete has sleep debt or restriction or a period with an ideal amount of sleep. Long-term sleep restriction can have deleterious cognitive and performance effects.[30] After a period of chronic restraint or sleep deprivation, as long as there is a free amount of sleep, there is a rebound effect in the period of sleep recovery (period after the end of the intervention to reduce the amount of sleep) with an increase in the total sleep time. Thus, if the athlete has sleep debt, the sleep extension intervention will only offer the ideal amount of sleep for recovery.

Knowledge of the athlete's sleep pattern in terms of quantity helps estimate whether or not the athlete is a short, intermediate, or long sleeper. Although most of the population get a satisfactory amount of 7.5 h of sleep a night, there are individuals with a lower ideal amount of sleep.[31] Short sleepers can achieve satisfactory sleep with only 3 h of sleep per night. Long sleepers may require >10 h of sleep per night.[32] Thus, sleepers are categorized into three classes: short sleepers, with <6 h of sleep per night; intermediate sleepers, with 7–8 h of sleep per night, and long sleepers, with >9 h of sleep per night.[31, 33]

An important aspect is that the ability to extend the amount of sleep beyond normal appears to be a psychophysiological feature.[34] Normal sleepers sleep for 7–9 h per night and can extend the amount of sleep to 10–11 h even without a previous period of sleep deprivation or restriction. Individuals with this ability are called sleep extenders.[35, 36] On the other hand, 5 consecutive nights with an approximately 25 % reduction in total sleep time affects short and long sleepers than intermediate sleepers.[37] In general, sleep extension intervention studies in athletes use an index on PSQI less than 5 (good sleeper), and a sleep amount greater than 6 and less than 9 hours as the inclusion criteria for participants. Thus, there is a margin of approximately 2 h in the usual sleep of these athletes, which can affect the results of the studies. There are reports that individuals were able to achieve 10 h of sleep per night after an acute recommendation for the length of sleep, although this ability may be characteristic of some individuals.[36] On comparing the ability of single twins to extend the sleep, Gagnon, De Koninck [38] reported that 8 out of 10 normal sleepers were able to extend sleep between 12 and 15 h a night.

A critical question to describe whether the subject is short or long sleeper is to define the sleep pattern and this question has been addressed for several decades.[32] As noted earlier, there is an intra-individual variation in sleep nights. besides the variation that occurs between the weekdays, there is a difference of approximately 30 minutes in sleep time on weekdays compared to weekends.[32] Several kinds of researches have been used the subjective description of the sleep time duration and then, the volunteer is observed for a certain time to describe the sleep pattern. This period for describing the sleep pattern can vary from two weeks to one year of follow-up.[31, 39] Thus, research shows that volunteers have a sleep pattern and classifies them according to the typology.

Only Mah, Mah [8] and Schwartz and Simon Jr [9] monitored the athletes' sleep at least 7 days before the intervention period. The other studies did not monitor sleep for long enough to describe the sleep patterns. Thus, it is not certain whether these articles used athletes coming from a chronic period of sleep restriction or whether the athletes were short or long sleepers, or that they would impact the sleep extension intervention; another important fact is that most studies did not describe the usual schedule for training sessions for athletes. Training sessions started before 07:00 h are known to negatively affect athletes' sleep. Thus, the authors may have monitored and described the opportunity that athletes have to sleep more than the amount of sleep that athletes usually need.

We emphasize that few studies considered the chronotype of the athletes and the time of day to start the activities. Chronotype is an individual characteristic that determines the propensity to be more alert and more active at a certain time of the day, establishing a preference to be more active or to sleep at a certain time. [40] In the studies used in this review, only 3 articles analyzed the chronotype. [10, 20, 22] Of these 3 studies, only Roberts, Teo [20] considered the chronotype for the prescription of the sleep extension program and the usual training schedule for performing the performance analysis. Individuals who practice sports for their chronotype (example: evening type training at night), train and compete better than at times opposite to their chronotype [41]. Regarding the time of day, five studies applied the tests between 12:00-18:00 h, one study applied the tests between 06:00-09:00 h, and one study applied tests at 10:00 and 16:00 h. In a recent systematic review, Vitale and Weydahl [42] observed that the chronotype influences the perceived exertion and fatigue scores, with morning types feeling less fatigued in the early hours of the day than intermediate types and night types. Thus, it is essential that future studies regarding sleep extension describe the athlete's chronotype, establishing relationships between the chronotype and the time when the performance test is performed.

The magnitude of the sleep extension effects varies between the studies. The current review shows that using sleep extension programs leads to trivial to larger effects on sports performance. Regarding the percentage difference, Mah, Mah [8] observed an 11 % increase in pitch, and Schwartz and Simon Jr [9] observed an increase of approximately 20 % in the accuracy of service, with moderate and small effects, respectively. Roberts, Teo [20] have observed a better aerobic performance (~3 %) on day 3 in the sleep extension group, compared to the normal group. It is important to note that even small effects can be decisive in sports performance. Boukhris, Trabelsi [23] described improvement ranging from +5.6 to +9.6 % in maximal voluntary isometric contraction and improvements ranging +7.8 to 12.6 % in shuttle run test with large effect size. On the contrary, Petit, Mougin [22] reported no improvement in Wingate test, Suppiah, Low [21] did not observe an increase in shooting performance, after a period of unrestricted sleep, with at least 9 h of sleep, and Fullagar, Skorski [10] describe that there was no change in performance in the countermovement jump or in the yoyo test after an acute sleep hygiene protocol that increased the total sleep time.

However, the results favorable to the extension of sleep in these studies should be viewed with caution. As mentioned earlier, Boukhris, Trabelsi [23] assessed the total sleep time for only one night and Roberts, Teo [20] assessed the total sleep time just 4 days before starting the intervention. This period is not enough to describe the habitual sleep and the 2 days of free sleep before starting the study may be insufficient to restore cognitive performance. Mah, Mah [8] and Schwartz and Simon Jr [9] studies are non-randomized quasi-experimental trials. In both studies, the subjects served as their control, a pre-post intervention design. Thus, the positive results of the intervention period may be due to the previous trial, also known as serial order carryover effects.[43] That is, the improvement in performance may be due to a dependence on previous testing.[44] This dependence may be because of learning from the test performed or training adjustments. One way to try to mitigate the effect of dependence on the previous testing would be to try to counterbalance the testing order of different groups. Another fact to highlight is the lack of information regarding sports training developed during the study. Thus, the increase in performance may have been due to a peak period of performance previously established by the athletes' staff, more than an increase due to the period of sleep extension. It is important to note that almost 50 % of the studies used in this review had a moderate or serious risk of bias and almost 70 % of the studies were between very low and moderate quality. All six outcomes that showed a large effect size showed methodological bias that may have affected the results. Therefore, it is understood that the positive results of sleep extension on athletes' performance are overestimated, considering the methodological flaws presented in the articles cited.

The effect of sleep restriction on physical performance is not the scope of this review, however, we would like to emphasize that research related to banking sleep is scarce in sports sciences. In one of the first studies on banking sleep, Rupp, Wesensten [45] found that the effect of sleep restriction on cognitive performance is dependent on the amount of sleep prior to the restriction period. In a randomized crossover study, Arnal, Sauvet [46] confirmed this hypothesis and observed that the sleep extension for one week attenuated the effects of sleep deprivation on psychomotor performance. It is important to highlight that studies on this theme did not use athletes and performance measures as dependent variables. Considering that athletes may have their sleep impacted by competition, using banking sleep prior to competition may be an area of interest in future studies. Moreover, all outcomes were evaluated in-laboratory settings, with control exerted on several parameters. Considering that sports performance can be affected by the environment that it is performed,[47, 48] it would be prudent that future research evaluate the effects of sleep extension on the real-life condition, especially, during a real sports competition.

The results observed in this review cannot be extrapolated to all athletes. In this review, most studies included only men and few sports, introducing a risk of bias in generalizing all information. Moreover, the included studies differed widely with respect to the instrument used to describe sleep, sample size and outcome measures. It is likely that indirect measures may have values that are not in accordance with direct measures. Finally, there is a risk of bias in the interpretation of the results when considering whether the athletes submitted to the intervention were short or long sleepers or were sleep restricted. Moreover, there is a risk of language bias because we only included studies written in English. Research, however, reveals that language bias does not necessarily influence the results of a systematic review.[49]

5. Conclusion

Before starting a sleep extension program, athletic trainers and medical staff should analyze the chronotype and sleep pattern, and if the athlete is getting adequate sleep for their needs. The current review highlights that coaches and staff should be careful to use sleep extension as a measure to improve sports performance. Rather, establishing good sleeping habits and meeting the required sleep length and duration should be a priority. Evidence from this systematic review indicates that sleep extension interventions may be beneficial for athletes in different sports but should be viewed with caution due to the risks of bias and the quality of the studies. Future research should consider training status of athletes, order of testing and methodological flaws to validate the current results observed.

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Table 1. Characteristics of the included studies.

Study	Study design	Sample			Pre-intervention			At-intervention		Post-intervention
		Gender	Age (years old) (M±SD)	Modality	Period	Sleep parameter (h:min) (M±SD)	Instrument	Period	Strategy	Sleep parameter (h:min) (M±SD)
Mah et al. (2011)	nRCT	11 males	19.4 ± 1.4	Basketball	2-4 weeks	TST: 06:40 ± 01:01	Actigraphy	5-7 weeks	> 10 hours in bed per night Including naps	TST: 08:27 ± 01:18
Petit et al. (2014)	RCT	16 males	22.2 ± 1.7	-	30 days	TST: 08:11 ± 00:41	Sleep diary	1 day	20 min of nap	-

Table 1. Continued

Study	Study design	Sample			Pre-intervention			At-intervention		Post-intervention
		Gender	Age (years old) (M±SD)	Modality	Period	Sleep parameter (h:min) (M±SD)	Instrument	Period	Strategy	Sleep parameter (h:min) (M±SD)
Schwartz and Simon (2015)	nRCT	5 males 7 females	20.2	Tennis	1 week	Sleep per night: 07:08 ± 00:48	Sleep diary	1 week	> 9 hours of sleep per night Including naps	sleep per night: 08:51 ± 00:36
Fullagar et al. (2016)	RCT	20 males	-	Soccer	3 days	Sleep duration: Control: 06:38 ± 01:01 SHS: 06:54 ± 01:06	Actigraphy	1 day	Without specific target of hours No naps	Sleep duration: Control: 04:30 ± 0:27 SHS: 06:09 ± 0:43

Table 1. Continued.

Study	Study design	Sample			Pre-intervention			At-intervention		Post-intervention
		Gender	Age (years old) (M±SD)	Modality	Period	Sleep parameter (h:min) (M±SD)	Instrument	Period	Strategy	Sleep parameter (h:min) (M±SD)
Suppiah et al (2016)	nRCT	12 males 12 females	14.1 ± 1.4	Pistol shooters Rifle shooters	2 days	TST: RC: 07:05 ± 01:05 URC: 06:54 ± 01:09	Actigraphy	5 days	> 9 hours of actual sleep No naps	TST: RC: 05:42 ± 00:44 URC: 06:08 ± 00:47
Roberts et al. (2016)	nRCT	9 males	30 ± 6	Cycling Triathlon	4 days	TIB: D1: 07:06 ± 00:48 D2: 06:30 ± 01:00 D3: 06:54 ± 00:42	Actigraphy	4 days	+ 30% of hTIB No naps	TIB: D1: 08:36 ± 01:00 D2: 08:18 ± 00:36 D3: 08:12 ± 00:36

Table 1. Continued.

Study	Study design	Sample				Pre-intervention		At-intervention		Post-intervention
		Gender	Age (years old) (M±SD)	Modality	Period	Sleep parameter (h:min) (M±SD)	Instrument	Period	Strategy	Sleep parameter (h:min) (M±SD)
Boukhris et al. (2020)	RCT	14 males	20.3 ± 3.0	Football, rugby, and handball	1 day	TST N40: 08:35 ± 01:19 N90: 08:45 ± 01:51	Actigraphy	1 day	40-min of nap 90-min of nap	-

Abbrevetiations: D1, day 1; D2, day 2; D3, day 3; hTIB, habitual time in bed; M, mean; min, minutes; nRCT, non-randomized controlled trial; RC, restricted condition; RCT, Randomized Controlled Trial; SD, standard deviation; SHS, sleep hygiene strategy; TIB, time in bed; TST, total sleep time, URC, unrestricted condition.

Table 2**.** Percentage of change, effect size and confidence interval of the included studies.

Study	Performance parameters	Percentage of change (%)	Effect size	
			Cohen’s d (95% Confidence Interval)	Classification
Mah et al. (2011)	282 feet sprint	-4.3	1.215 (-2.07/-0.26)	Large
	Free throws	+11.4	0.918 (0.01/1.76)	Large
	Three-point field goals	+13.7	0.757 (-0.13/1.59)	Medium
Petit et al. (2014)	Wingate – peak power	+0.9	0.050 (-0.65/0.74)	Trivial
	Wingate – mean power	+0.6	0.049 (-0.65/0.74)	Trivial
Scwartz and Simon (2015)	Serving accuracy	+17.3	-0.421 (-0.40/1.21)	Small
Suppiah et al. (2016)	Shooting performance	Not described	Not described	Not described

Continued

Table 1. (continued). Percentage of change, effect size and confidence interval of the included studies.

Study	Performance parameters	Percentage of change (%)	Effect size	
			Cohen's d (95% Confidence Interval)	Classification
Fullagar et al. (2016)	Countermovement jump height	+2.8	0.25 (-0.38/0.86)	Small
	Countermovement jump force	+1.3	0.10 (-0.52/0.72)	Trivial
	Yoyo intermittent recovery test distance	-4.6	-0.20 (-0.82/0.42)	Small
	Yoyo intermittent recovery test MHR	-0.5	-0.13 (-0.75/0.49)	Trivial
Roberts et al. (2019)	Time trial	Normal sleep s vs sleep extension:		
		-3.2	0.583 (-1.80/0.73)	Medium
Boukhris et al. (2020)	Maximal voluntary isometric contraction	40-min: +5.6	0.44 (-0.32/1.18)	Small
		90-min: +9.6	0.75 (-0.03/1.50)	Moderate
	Shuttle run test- higher distance	40-min: +7.8	1.13 (0.3/1.89)	Large
		90-min: +10.1	1.28 (0.44/2.06)	Large
	Shuttle run test- total distance	40-min: +7.8	0.97 (0.16/1.72)	Large
		90-min: +12.6	1.70 (0.79/2.51)	Large