Accepted Manuscript online: 2023-12-19 Article published online: 2024-02-24

The Sleep Parameters of Olympic Athletes: Characteristics and Assessment Instruments

Authors

Marco Túlio de Mello[1], Eduardo Stieler[1], Isadora Grade[1], André Fernandes Chaves Filho[1], Gabriel Mendes[2], Natália Ituassu[2], Andressa Silva[1]

Affiliations

1 Sports, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

2 Physiotherapy, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

Key words

training, sports, recovery, chronotype, travel

accepted 19.12.2023

accepted manuscript online 19.12.2023

published online 24.02.2024

Bibliography

Int J Sports Med 2024; 45: 715–723

DOI 10.1055/a-2233-0323

ISSN 0172-4622

Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

Correspondence

Dr. Marco Túlio de Mello

Universidade Federal de Minas Gerais (UFMG)

Departamento de Esportes

Av. Presidente Carlos Luz

6627 - Pampulha

31310-250 Belo Horizonte - MG

Brazil

tmello@demello.net.br

Additional material is available at https://doi.org/10.1055/a-2233-0323

ABSTRACT

This systematic review aims to identify the sleep parameters of Olympic athletes and the instruments used to assess and monitor the sleep of these athletes. The search was conducted until February 2023 and was performed in PubMed, Web of Science, and Scopus databases. This systematic review has included studies that investigated at least one of the following sleep parameters: total sleep time (TST), sleep onset latency (SOL), sleep efficiency (SE), awakenings after sleep onset (WASO), quality of sleep, daytime sleepiness, and chronotype; the participants were Olympic athletes. The search returned a total of 280 studies. After screening based on exclusion and inclusion criteria, 11 studies were included. The main results demonstrate that Olympic athletes have TST of 06:10 h, SE of 84 %, SOL of 28 min, and WASO of 49 min. The most predominant chronotype is indifferent; over half of the athletes have poor sleep quality and complaints. Furthermore, actigraphy was the most used method to assess sleep. It is concluded that Olympic athletes have TST, SE, and WASO poor than the recommended values. In addition, sleep complaints and poor sleep quality were also observed. Among the objective sleep assessment methods, actigraphy was the method most frequently used in this population.

Introduction

Sleep is associated with different psychophysiological processes contributing to adequate recovery, improved performance, and training load adjustments [1]. During sleep, there is a peak of pulsatile secretion of growth hormone and testosterone, reduction of cortisol secretion, memory consolidation, and potentiation of immune system responses [1]. If there is sleep restriction or deprivation, these processes can be compromised, causing a decrease in the ability to recover and adapt to training [2]. On the other hand, sleep with ideal quantity and quality can favor better physical performance [3], while sleep extension can improve sports performance [4], as long as it is not a rebound and chronic effect of the sleep restriction period but rather an increase in total sleep time with rested athletes.

However, scientific evidence shows that regardless of modality, gender, team or individual sport, athletes have difficulty sleeping, especially elite athletes who have poor sleep quality [5, 6]. Among the factors that can negatively alter sleep, we highlight travel, competition, and training schedules [7]. Regarding competitors, in the Rio 2016 Olympic Games, for example, the semifinals and finals of swimming took place at night (from 10 pm until midnight) [7], which can impair the performance of athletes, as psychomotor vigilance is lower, there is a decrease in core temperature, and a greater propensity for sleep onset at this time [8]. In addition, the training schedule, competitions, and post-competition commitments can compromise regular sleep behaviors and reduce the quantity and quality of chronic sleep [9]. To mitigate athletes' sleep-related problems, some strategies can be adopted, including nutritional interventions, such as the intake of carbohydrates, tryptophan, valerian, and melatonin [10], as well as interventions aimed at sleep hygiene and exposure to light [11].

However, as far as is known, Olympic athletes have poorer sleep characteristics than non-athletes [12], reinforcing the concern of multidisciplinary teams with the sleep of high-performance athletes, mainly because this population is exposed to different stressors that can impair their sleep, such as travel and training schedules, in addition to pressure for results. Therefore, this systematic review aims to (1) systematize the evidence from research aimed at describing the patterns and quality of sleep of Olympic athletes and (2) identify which instruments are used to assess and monitor the sleep of Olympic athletes.

Materials and Methods

Search strategy

This systematic review was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA) [13]. ▶ **Fig. 1** shows the search strategy and the number of studies excluded and included at each stage. In addition, searches were performed in the following databases: Scopus, Web of Science, and Pubmed. The investigations were conducted in February 2023, and the keywords used were divided into two categories: Population ("Olympic" OR "Olympic Sport" OR "Olympic Sports" OR "Olympic Athlete") and Outcome: ("Sleep" OR " Sleep Deprivation" OR "Sleep Quality" OR "Sleep Efficiency" OR "Sleep Stages" OR "Sleep Hygiene" OR "Total sleep time" OR "Sleep Intervention").

Inclusion and exclusion criteria

A specific quality assessment tool could not be applied adequately to this review, nor were the studies assessed for risk of bias, as this was not a systematic literature review of randomized controlled trials [14]. However, a specific set of study inclusion/exclusion criteria was developed. This systematic review included studies that investigated at least one of the following sleep parameters, without restriction by year: TST, sleep latency (SOL), sleep efficiency, wake after sleep onset, quality of sleep, daytime sleepiness, and chronotype, obtained with instruments such as polysomnography, actigraphy, commercial devices, smartphone applications, questionnaires, sleep diaries, and scales.

The following eligibility criteria were followed: a) original and peer-reviewed article; b) samples comprising at least one group of Olympic athletes, regardless of age group and sport modality; c) articles that evaluated at least one sleep parameter; d) articles are written in English, Spanish, or Portuguese. Studies that did not meet the above criteria were considered ineligible for this systematic review, as well as review studies, short communications, editorials, reviews, opinion articles, books, journals, editorials, non-academic texts, animal studies, that mixed the sample among Olympic, Paralympic athletes or with other athlete profiles. Thus, all studies involving any sleep variable or jointly assessing other variables associated with sleep in Olympic athletes were included in this review.

Study selection and data extraction

Titles and abstracts of potentially relevant articles were selected, and duplicates were removed independently by two researchers (reviewer one and reviewer two), in consultation with reviewer three, if necessary. Reports that did not meet the eligibility criteria were blindly, randomly, and independently excluded by the aforementioned reviewers (▶ **Fig. 1**).

In addition, it is important to highlight that the studies included were evaluated using the STROBE tool (Strengthening the Reporting of Observational Studies in Epidemiology), which is used to assist in the elaboration and evaluation of cohort, case-control, and cross-sectional studies [16]. Nevertheless, it is worth noting that the STROBE tool was not developed to assess the methodological quality of scientific studies, but to guide the quality of reporting of these studies at the time of writing (Supplemental Digital Content) [14, 15].

Results

The search phrase used returned a total of 280 studies. Of these, 36 were excluded because they were duplicated and 233 studies were excluded by title analysis, abstract or were read in full. At the end of the process, 11 studies were considered eligible and were included in this systematic review.

Study characteristics

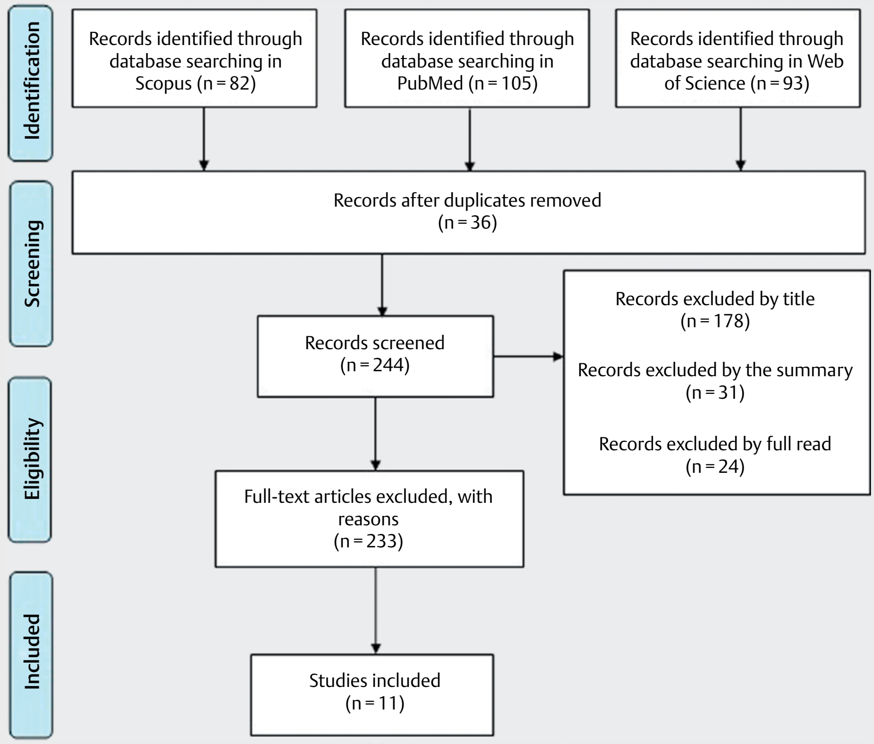
Of the 12 articles included, three articles are about the sleep characteristics of Olympic athletes [17, 18], one is about the differences between the sleep of Olympic athletes compared to the sleep of non-athletes [12], one article studies the relationship between sleep and psychological aspects [19], three articles examine the sleep of Olympic athletes during training periods [20–22], and four articles are on sleep interventions in Olympic athletes [23–26].

▶ **Table 1** summarizes the key findings from the studies included in this systematic review. The studies were published between 2012 and 2023, seven of which were developed with assessments carried out in preparation for the Rio 2016 Olympic Games [16–19, 24–26]. The number of participants in the studies ranged from 5 to 146, totaling 596 Olympic athletes, while the age ranged from 19 to 29 years.

The Olympic sports that the athletes were involved in were water polo, open water swimming, athletics, handball, swimming, shooting, wrestling, fencing, modern pentathlon, artistic gymnastics, canoeing, judo, beach volleyball, sailing, boxing, equestrian, football, gymnastics, hockey, rowing, rugby sevens, triathlon, diving, short track speed skating.

Sleep parameters

According to the reviewed studies, the main characteristics of the sleep parameters of the Olympic athletes demonstrated that, on average, the athletes have a TST of 6 h and 10 min, SE of 84 %, SOL of 28 min, and WASO of 49 min (▶ **Table 2**). These data were obtained by calculating the weighted average of data collected from studies that evaluated sleep using objective methods.



▶ **Fig. 1** Flow chart of study search and selection process.

Regarding subjective parameters, two studies [17, 25] demonstrated that the most predominant chronotype is the indifferent one (78 % and 64 %, respectively), while one study [18] presented a 22 % prevalence of daytime sleepiness. Subjective poor sleep quality was 49 % in one of the studies [18] and 53 % in the other study [19], demonstrating that from a combined sample of 263 Olympic athletes, 51 % have poor sleep quality.

Concerning sleep complaints [16], it is noteworthy that 53 % of the athletes in a group of 146 Olympic athletes had sleep complaints, with 32 % reporting insufficient sleep and waking up tired, 21 % snoring, and 19 % insomnia.

Instruments used to assess sleep

It was possible to identify five instruments used to assess sleep: polysomnography, actigraphy, Pittsburgh Sleep Quality Index (PSQI), sleep diary, and the Likert sleep quality scale. In addition, three instruments are related to sleep: the Hörne and Ostberg Chronotype Questionnaire (HOQ), the Epworth Sleepiness Scale (ESS), and the Sleep Complaints Questionnaire (▶ **Table 3**).

Regarding objective methods to assess sleep, actigraphy was the most used instrument (n = 8) [12, 17, 21, 22, 24–26], followed by polysomnography (n = 1) [16]. Regarding subjective methods to assess sleep, two studies used the PSQI [18, 19], two studies used the sleep diary [21, 24] and one study used the Likert scale to assess sleep quality [21]. On the other hand, to evaluate aspects related to sleep, two studies used the HOQ [17, 25], one study used the ESS [18] and one study used the Sleep Complaints Questionnaire [16]. The following table presents methods for assessing sleep and was adapted from Driller et al. [27].

Discussion

According to the systematic review, Olympic athletes have a TST of approximately 06:10 h, SE of 84 %, SOL of 28 min, and WASO of 49 min. However, for restorative sleep, the recommended parameters [28] are > 7 h in healthy people and between 9 and 10 h for athletes (short or long sleepers are excluded), < 20 min for WASO, < 30 min for SOL, and > 85 % for SE, indicating that Olympic athletes are outside the recommended values for TST, SE, and WASO. On the other hand, when it comes to Paralympic athletes, although different types of disabilities are a factor that can generate sleep disorders, for example, people with spinal cord injuries have significantly more sleep problems than the population without disabilities [29], a recent systematic review [14] showed that Paralympic athletes have a subjectively assessed TST of 7 h and SOL of 28 min, demonstrating that the sleep of Olympic athletes who do not have disabilities that affect sleep may still be poorer than that of Paralympic athletes.

From this perspective, Narciso et al. [17] evaluated 70 athletes before the Rio 2016 Olympic Games with actigraphs. They observed that the athletes had on average 07:18 h of sleep per night and had a WASO of 39 min and SOL of 31 min during pre-Olympic training days. In terms of sleep complaints in this population [16], it is noteworthy that 53 % of athletes from a group of 146 Olympic

▶ **Table 1** Characteristics of the studies involving the sleep of the Olympic athlete.

Studies	Sample characteristics	Evaluation period	Instrument to assess sleep	Variables	Main results
Botonis et al. [20]	*Subjects:* 8 Olympic water polo athletes *Mean age:* 24 (2) y	Before, during and after a residential-based conditioning camp (CAMP)	▪ Actigraph	▪ TST ▪ SE ▪ WASO ▪ SOL	▪ During CAMP, athletes sleep and wake up earlier, in addition to greater WASO. In the post-CAMP period, SE increased, and WASO decreased
Vitale et al. [21]	*Subjects*: 5 Olympic open water swimmers *Mean age:* 25 (3) y	During 14 days of training at an altitude of 1500 m	▪ Actigraph ▪ Likert scale for sleep quality ▪ Sleep diary	▪ TST ▪ SE ▪ WASO ▪ SOL ▪ Subjective sleep quality	▪ Subjective and objective sleep was not negatively influenced by altitude training, even athletes reporting greater perceived exertion during training
Halson et al. [19]	*Subjects:* 131 Olympic athletes from ND sports *Mean age*: 25 (4) y	4 months before the 2016 Rio Olympic Games	▪ PSQI	▪ Subjective sleep quality	▪ 53 % with poor sleep quality ▪ Subjective sleep quality was associated with a higher state of perceived stress
Narciso et al. [17]	*Subjects*: 70 Olympic athletes from athletics, handball, swimming and shooting *Mean age*: 24 (1) y	10 days before entry to the Olympic Village for the Rio 2016 Olympic Games	▪ Actigraph ▪ HOQ	▪ TST ▪ SE ▪ WASO ▪ SOL ▪ Chronotype	▪ 78 % with indifferent chronotype ▪ 07 h:18 min on average of TST ▪ SOL (30.88 ± 16.19 min) and WASO (39.26 ± 23.66 min) higher during pre-competition training days ▪ Individual sports athletes demonstrated higher WASO and lower SE compared to team sports athletes
Hoshikawa et al. [26]	*Subjects*: 6 Olympic wrestling athletes (experimental group) and 5 fencing athletes (control group) *Mean age:* 20 (1) y	While traveling to the 2016 Rio Olympic Games	▪ Actigraph	▪ TST ▪ SE ▪ WASO ▪ SOL	▪ SOL decreases and SE increases in athletes who took 8 mg of ramelteon associated with light therapy intervention
Mello et al. [25]	*Subjects:* 14 Olympic swimmers *Mean age:* 27 (2) y	3 months before the 2016 Rio Olympic Games	▪ Actigraph ▪ HOQ	▪ TST ▪ SE ▪ WASO ▪ SOL ▪ Chronotype	▪ Decrease in total awake time (Δ = -13 %; ES = 1.0) and SOL (Δ = -33 %; ES = 0.7) and increase in TST (Δ = 13 %; ES = 1.1; $p = 0.04$) after an intervention with light therapy ▪ 64 % with indifferent chronotype
Silva et al. [16]	*Subjects:* 146 Olympic athletes from modern pentathlon, artistic gymnastics, canoeing, swimming, athletics, judo, beach volleyball and sailing *Mean age:* 24 (5) y	15 months before the 2016 Rio Olympic Games	▪ Polysomnography ▪ Sleep Complaints Questionnaire	▪ TST ▪ SE ▪ WASO ▪ SOL ▪ Stages of sleep ▪ Sleep disorders ▪ Sleep complaints	▪ 53 % of athletes had sleep complaints ▪ 32 % had insufficient sleep and woke up tired ▪ 21 % snored ▪ 19 % had insomnia ▪ Male athletes had higher SOL, lower SE and N3 than female athletes
Drew et al. [18]	*Subjects*: 132 Olympic athletes in boxing, equestrian, football, gymnastics, hockey, rowing, rugby sevens, sailing, triathlon and water polo *Mean age:* 25 (4) y	3 months before the 2016 Rio Olympic Games	▪ PSQI ▪ ESS	▪ Subjective sleep quality ▪ daytime sleepiness	▪ 49 % with poor sleep quality ▪ 22 % with excessive daytime sleepiness ▪ Poor sleep quality was associated with gastrointestinal tract symptoms in the previous month

▸ **Table 1** Continued.

Studies	Sample characteristics	Evaluation period	Instrument to assess sleep	Variables	Main results
Rosa et al. [24]	*Subjects*: 22 Olympic swimmers *Mean age*: 25 (3) y	10 days before entering the Olympic Village for the Rio 2016 Olympic Games	▪ Actigraph ▪ Sleep diary	▪ TST ▪ SE ▪ WASO ▪ SOL	▪ Through intervention with light therapy athletes slept later and reaction time improved
Sargent et al. [22]	*Subjects:* 7 Olympic swimmers *Mean age:* 22 (2) y	During a training period 9 months before the 2008 Beijing Olympics	▪ Actigraph	▪ TST ▪ SE ▪ WASO ▪ SOL	▪ When athletes trained in the morning, they slept and woke up earlier, spent less time in bed, and TST was lower when compared to days without training
Leeder et al. [12]	*Subjects:* 47 Olympic athletes from Canoeing, Diving, Rowing, Short track speed skating and 20 non-athletes (control group) *Mean age*: ND	ND	▪ Actigraph	▪ TST ▪ SE ▪ WASO ▪ SOL	▪ Olympic athletes have higher SOL and WASO, as well as lower SE, when compared to non-athletes

ESS = Epworth Sleepiness Scale; PSQI = Pittsburgh Sleep Quality Index; HOQ = Horne and Ostberg's Questionnaire; ND = Non Declared; WASO = Wake After Sleep Onset; TST = Total Sleep Time; SE = Sleep Efficiency; SOL = Sleep Onset Latency; CAMP = Residential-Based Conditioning Camp.

▶ **Table 2** Information on sleep parameters of Olympic athletes.

Studies	TST (min)	SE (%)	SOL (min)	WASO (min)
Actigraph				
Vitale et al. [21]	06:36 ± 00:24	88 ± 07	21 ± 17	22 ± 08
Narciso et al. [17]	07:18 ± 01:02	87 ± 10	31 ± 16	39 ± 24
Hoshikawa et al. [26]	06:31 ± 00:36	82 ± 03	16 ± 04	92 ± 32
Mello et al. [25]	06:30 ± 00:49	82 ± 09	35 ± 13	42 ± 16
Rosa et al. [24]	07:33 ± 00:34	85 ± 01	21 ± 06	49 ± 05
Sargent et al. [22]	05:40 ± 01:30	71 ± 15	41 ± 43	ND
Leeder et al. [12]	06:55 + 00:43	81 + 06	18 + 16	77 + 31
Polysomnography				
Silva et al. [16]	05:31 ± 00:49	86 ± 10	31 ± 35	23 ± 21
Pondered mean ± SD	06:10 ± 00:37	84 ± 09	28 ± 24	49 ± 22

WASO = Wake After Sleep Onset; TST = Total Sleep Time; SE = Sleep Efficiency; SOL = Sleep Onset Latency; ND = Non Declared; SD = Standard deviation.

athletes had sleep complaints, with 32 % having an insufficient sleep (average of 05:31 h of TST) and woke up tired, 21 % snored, 19 % had insomnia, and 36 % of athletes had sleep disturbances before the Rio 2016 Olympic Games. Overall, these results indicate that Olympic athletes during training before the Olympic Games Rio 2016 had poor sleep quality [16, 17], which may be a concern for the health area and the technical committee of the teams, considering that the low quality of sleep or insufficient sleep can be related to injuries in soccer athletes, for example [30, 31].

On the other hand, regarding subjective sleep parameters, poor subjective sleep quality was reported by 49 % of respondents in one study [18] and 53 % in the other study [19], demonstrating that in a pooled sample of 263 Olympic athletes, more than half of the athletes have poor sleep quality. This poor quality of sleep, associated with significant competitions such as the Olympic Games, can have consequences for the health of athletes. Halson et al. [19] investigated 130 athletes four months before competing in the Rio 2016 Olympic Games. They observed that a state of more significant stress perceived by athletes was associated with poor sleep quality and increased sleep disturbances. Furthermore, they indicated that relatively high levels of psychological stress are associated with poor sleep quality in Olympic athletes. In the same perspective, the study by Drew et al. [18] observed a high prevalence of daytime sleepiness and poor sleep quality. Furthermore, poor sleep quality was associated with greater chances of having gastrointestinal disorders, reinforcing the need for interdisciplinary programs for health prevention and management in high-performance sports.

In the same perspective, however, when dealing with Paralympic athletes before the Beijing 2008 Paralympic Games [32], of the 27 athletes evaluated, 83 % of them had poor sleep quality and excessive daytime sleepiness, while 72 % of the athletes who had an average level of anxiety also had poor sleep quality. In another study, Silva et al. [33] observed that increased symptoms of insomnia, night awakenings, movements during sleep, and poor sleep quality were associated with the occurrence and/or severity of health problems. In addition, in futsal athletes, for example, athletes who had a better subjective sleep quality the night before also felt more recovered the next day [34], thus demonstrating that sleep quality is a factor that is related to the perception of recovery [34], the occurrence and/or severity of health problems [33], and level of daytime sleepiness [32].

Another important aspect of the sleep of Olympic athletes is related to chronobiology, which refers to the individual preference of wakefulness and sleep hours. The human population is divided into three basic chronotypes: morning, evening, and indifferent [35]. According to the evidence systematically reviewed in this study [17, 25], the majority of Olympic athletes (78 % and 64 %, respectively) are classified as having an indifferent chronotype, which is characterized by a lack of preference for sleep and wakefulness, and the phases of their endogenous rhythms are intermediate to those of the afternoon and morning chronotypes [35]. This finding is important since obtaining information about the athletes' chronotype can help the technical committees plan the best times for training, competitions, social activities, and leisure [36]. Furthermore, the type of sport must be considered since soccer players [37] and swimmers [25] have an indifferent chronotype, and marathon runners [38] have a morning chronotype.

Thus, Olympic athletes generally have an indifferent chronotype, sleep complaints, poor sleep quality, daytime sleepiness, and TST, SE, and WASO outside the recommended parameters. In this sense, Leeder et al. [12] have already shown that Olympic athletes, compared to non-athletes, have poor sleep parameters (SOL, WASO, and SE) and that this difference could be due to the habits and behaviors arising from the sports practices contributing to these poor sleep characteristics.

Among the aspects that influence the sleep of Olympic athletes, travel, competition time, and training stand out. From this perspective, Sargent et al. [22] investigated the impact of training performed in the morning (06:00–08:00 h) on the amount of sleep of Olympic swimmers during 14 days of intensified training in preparation for the Beijing 2008 Olympic Games. The results showed that on the nights before the training days, the sleep onset and offset were earlier, and the amount of sleep was also less than on the nights before the rest days (7.1 h > 5.4 h of TST), indicating that morning workouts drastically restrict the amount of sleep Olympic athletes get. However, chronic sleep restriction, as in this case, can compromise psychophysiological functioning, limiting the effectiveness of sports training and compromising performance and recovery [22].

In the case of intensified water polo training in a preparation camp for the Tokyo 2020 Olympics [20], interruptions during nighttime sleep and in salivary cortisol were observed while simultaneously worsening the athletes' subjective well-being. The increased workload during the preparation camp, associated with a change in environment, may explain the negative differences. However, after this training period, the reduction in workload, along with the return to their homes, decreased sleep interruptions and salivary cortisol, but subjective well-being remained unchanged. These results suggest that the increase in workload, along with inadequate recovery, can increase the athletes' risk of infection and that for effective monitoring, subjective and objective parameters of psychophysiological variables must be taken into account [20].

▶ **Table 3** Information about the instruments used to assess the sleep of Olympic athletes.

Instrument	Strong points	Negative points	Measured variables
Objective instruments			
Actigraph	Long-term monitoring in a realistic environment;Non-intrusive and less expensive than polysomnography;Validated with polysomnography.	It does not assess sleep stages;Some devices do not disclose the algorithms;Not suitable for diagnosing most sleep disorders (eg, apnoea).	TST, SE, WASO, SOL, time awake, time in bed, the time you woke up and slept, heart rate, body movements, luminosity, and body temperature.
Polysomnography	The gold standard for sleep assessment;Diagnosis of sleep disorders;Sleep stage assessment.	Expensive and intrusive assessment;Usually in laboratory;One day assessment.	TST, SE, WASO, SOL, sleep disorders, REM sleep latency (min), REM sleep (%), Stages N1, N2, and N3 of NREM sleep (%), heart rate, body temperature, and breathing.
Subjective instruments			
Sleep diary	Long term monitoring;Non-intrusive, low cost, and time.	It may be influenced by memory and response bias;Overestimates sleep duration and efficiency compared to polysomnography;It depends a lot on the responsibility and effort of the athlete.	TST, SE, SOL, bedtime, wake and sleep time, wake time.
Questionnaires	Short and long-term assessments;Non-intrusive, low cost, and time.	It may be influenced by memory and response bias;May overestimate sleep parameters.	TST, SE, SOL, time in bed, the time you woke up and slept, time awake, subjective sleep quality, sleepiness, sleep complaints, sleep-related behaviors, chronotype, and insomnia.

WASO = Wake After Sleep Onset; TST = Total Sleep Time; SE = Sleep Efficiency; SOL = Sleep Onset Latency; REM = Rapid Eye Movement; NREM = Non Rapid Eye Movement.

In addition to training issues, competition is also a factor that can influence athletes' sleep and performance [7]. In the Rio 2016 Olympic Games, for example, some preliminary and final disputes were held at night/dawn, which could negatively affect sleep and consequently compromise the decision-making, attention, and physiological aspects of athletes [7]. In this way, interdisciplinary teams can intervene in the circadian rhythm to minimize the impact on sports performance.

Rosa et al. [24] carried out interventions during the Olympic Games acclimatization period (8 days), through intervention with artificial light therapy lasting 30 and 45 min per day, in addition to recommendations on sleep hygiene for 22 athletes in swimming. The results showed that light therapy, along with sleep hygiene, delayed sleep/wake cycles and improved reaction times in swimmers. Thus, this type of intervention proved to be effective in modulating the sleep/wake cycles and improving reaction time performance, and it can be used with athletes who have competitions that occur late at night [24].

In the same perspective, Mello et al. [25] performed an intervention where the athletes stayed for a certain period in a room with adequate lighting and also used specific glasses for light therapy aimed at phase-shifting the sleep phase of swimming athletes in preparation for the 2016 Olympic Games in Rio. With the phase drag, it was observed that the athletes decreased the total time in wakefulness and SOL and increased TST between pre and post-intervention. In addition, the athletes' block reaction time improved throughout the competition, demonstrating that the light therapy intervention effectively minimized the effects on sports performance and improved sleep [25]. Therefore, sports calendar and competition schedules must be considered when planning for the team.

In this sense, in the case of long trips such as, for example, the transition of 12 time zones from Japan to Brazil to compete in the Rio 2016 Olympic Games, Hoshikawa et al. [26] intervened with exposure to bright light at night to perform gradual delays in the wakefulness/sleep cycle, associated with the use of 8 mg of Ramelteon to treat insomnia in athletes. The experimental group that underwent this intervention had a lower SOL and higher SE compared to the control group, indicating an improvement in sleep parameters with this type of intervention and suggesting that this method may be an option for teams planning a transition from time zones due to travel [26]. Despite this, a meta-analysis [39] demonstrated that this short-term drug was associated with improving some sleep parameters in patients with insomnia but with a small clinical impact and a negative effect on daytime sleepiness. Therefore, using these drugs must be done with caution and planning not to compromise the athlete during the day.

In the context of Olympic sports, we can observe that the most used methods to assess athletes' sleep are objective, such as actigraphy [12, 17, 21, 22, 24–26], followed by polysomnography [16]. Among these instruments, actigraphy stands out, a device similar to a watch that records the movement of the limbs using an accelerometer [40]. This method allows the monitoring of sleep over several days, reporting data on the athlete's behavior and sleep routine, which is very important in the sports context due to the variation in the quality and quantity of sleep depending on the periods of training and competition seasons [41], in addition to being non-invasive and less expensive than polysomnography [42, 43].

In addition to objective methods, there are also subjective instruments to assess athletes' sleep. Subjective and objective instruments are antagonistic, particularly in data collection, but both complement each other. However, one of the main differences between them is that subjective instruments are influenced by personal, interpretation, or memory factors. On the other hand, an objective method is based impartially, and personal biases do not affect the data presented, but they may contain systematic errors, algorithms, and technical bias [14, 44].

Subjective instruments used to assess the sleep of Olympic athletes include the PSQI [18, 19], HOQ [17, 25], ESS [18], Sleep Complaints Questionnaire [16], Likert scale to assess sleep quality [21] and sleep diary [21, 24]. These tools are mainly for self-assessment and aim to assess various sleep-related parameters. They are used widely for screening, identifying athletes with more severe sleep problems, and facilitating referral to a sleep specialist when needed [43]. Nevertheless, these instruments have not been validated specifically for the athletic population. Yet they have a high level of popularity in research focused on sports. Regarding validation in the athletic population, there are already specific instruments for athletes, such as the Athlete Sleep Screening Questionnaire [45] and the Athlete Sleep Behavior Questionnaire [46].

Regarding limitations and future perspectives, although most studies have used objective methods to assess sleep, the study by Silva et al. [16], which was the only one to evaluate with polysomnography, demonstrated that from a sample of 146 Olympic athletes, the average TST was 05:31 h, indicating a TST well below the other studies [17, 24]. This difference may have occurred due to the evaluation method; however, to have greater clarity regarding the sleep characteristics of these athletes, more studies investigating sleep with polysomnography would be necessary.

Furthermore, despite the fact that the present review has a total of 596 athletes from 26 different sports, there are still 20 Olympic modalities that have not been explored, opening a margin for new research. Additionally, depending on the sport modality, circadian preferences may vary; for example, athletes in individual sports sleep less (individual vs. team; 6.5 vs. 7.0 h) than athletes in team sports [47]; however, they have better sleep regularity [48]. Therefore, studies with other Olympic sports and different manipulations of external and internal training load may also be interesting, in order to better understand sleep during training.

In conclusion, Olympic athletes have TST (06:10 h), SE (84 %), and WASO (49 min) poorer than the values recommended for the general population. In addition, sleep complaints, poor sleep quality, and daytime sleepiness were also observed in these athletes, while the most predominant chronotype was indifferent. Regarding the methods to assess sleep, among the objective methods, the most used was actigraphy (n = 8 studies), and among the subjective methods was the PSQI (n = 2 studies).

Funding

This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior under Grant number 0001; and Ministério do Esporte (Governo Federal, Brazil) under Grant number 58000.008978/2018–37 and 71000.056251/2020–49; Pró-Reitoria de Pesquisa - Universidade Federal de Minas Gerais.

Acknowledgement

The authors thank the support given by Pro-Reitoria de Pesquisa - Universidade Federal de Minas Gerais - UFMG, Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq, Fundação de Amparo à Pesquisa do Estado de Minas Gerais - FAPEMIG, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES, Ministério do Esporte (Governo Federal, Brazil - N° 58000.008978/2018–37 and N° 71000.056251/2020–49), Centro de Treinamento Esportivo – CTE/UFMG, Fundação de Apoio ao Ensino, Pesquisa e Extensão - FEPE, Centro de Estudos em Psicobiologia e Exercício - CEPE, and Centro Multidisciplinar em Sonolência e Acidentes – CEMSA.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Kryger M, Roth T, Dement W. Principles and Practise of Sleep Medicine. Elsevier Saunders; Canada: 2011

[2] Fullagar HH, Skorski S, Duffield R et al. Sleep and athletic performance: The effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. Sports Med 2015; 45: 161–186

[3] Watson A, Brickson S. Impaired sleep mediates the negative effects of training load on subjective well-being in female youth athletes. Sports Health 2018; 10: 244–249

[4] Silva AC, Silva A, Edwards BJ et al. Sleep extension in athletes: What we know so far–a systematic review. Sleep Med 2021; 77: 128–135

[5] Gupta L, Morgan K, Gilchrist S. Does elite sport degrade sleep quality? A systematic review. Sports Med 2017; 47: 1317–1333

[6] Estivill-Domènech C, Galilea B, Rodríguez-Morilla B et al. Do elite athletes sleep well? Apunts Medicina de l'Esport 2018; 53: 47–54

[7] Rosa JPP, Rodrigues DF, Silva A et al. 2016 Rio Olympic Games: Can the schedule of events compromise athletes' performance? Chronobiol Int 2016; 33: 435–440

[8] Bea Drust. Circadian rhythms in sports performance – An update. Chronobiol Int 2005; 22: 21–44

[9] Nédélec M, Dawson B, Dupont G. Influence of night soccer matches on sleep in elite players. J Strength Cond Res 2019; 33: 174–179

[10] Halson SL. Sleep in elite athletes and nutritional interventions to enhance sleep. Sports Med 2014; 44: 13–23

[11] Fowler PM, Knez W, Thornton HR et al. Sleep hygiene and light exposure can improve performance following long-haul air travel. Int J Sports Physiol Perform 2020; 16: 517–526

[12] Leeder J, Glaister M, Pizzoferro K et al. Sleep duration and quality in elite athletes measured using wristwatch actigraphy. J Sports Sci 2012; 30: 541–545

[13] Moher D, Weeks L, Ocampo M et al. Describing reporting guidelines for health research: A systematic review. J Clin Epidemiol 2011; 64: 718–742

[14] Grade I, Andrade H, Guerreiro R et al. The Sleep Parameters of Paralympic Athletes: Characteristics and Assessment Instruments. J Sport Rehabil 2022; 1: 1–12

[15] Vandenbroucke JP, Ev Elm, Altman DG et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): Explanation and elaboration. Ann Intern Med 2007; 147: 163–194

[16] Silva A, Narciso FV, Rosa JP et al. Gender differences in sleep patterns and sleep complaints of elite athletes. Sleep Sci 2019; 12: 242

[17] Narciso F, Silva A, Rodrigues D et al. Sleep-Wake Cycle of Elite Athletes Prior to the Rio 2016 Olympic Games. Rev Andal Med 2020; 13: 76–80

[18] Drew M, Vlahovich N, Hughes D et al. Prevalence of illness, poor mental health and sleep quality and low energy availability prior to the 2016 Summer Olympic Games. Br J Sports Med 2018; 52: 47–53

[19] Halson SL, Appaneal RN, Welvaert M et al. Stressed and not sleeping: Poor sleep and psychological stress in elite athletes prior to the Rio 2016 Olympic Games. Int J Sports Physiol Perform 2021; 17: 195–202

[20] Botonis PG, Toubekis AG. Intensified Olympic Preparation: Sleep and Training-Related Hormonal and Immune Responses in Water Polo. Int J Sports Physiol Perform 2023; 1: 1–8

[21] Vitale JA, Ieno C, Baldassarre R et al. The Impact of a 14-Day Altitude Training Camp on Olympic-Level Open-Water Swimmers' Sleep. Int J Environ Res Public Health 2022; 19: 42–53

[22] Sargent C, Halson S, Roach GD. Sleep or swim? Early-morning training severely restricts the amount of sleep obtained by elite swimmers. Eur J Sport Sci 2014; 14: 310–315

[23] Li Q, Steward CJ, Cullen T et al. Presleep Heart-Rate Variability Biofeedback Improves Mood and Sleep Quality in Chinese Winter Olympic Bobsleigh Athletes. Int J Sports Physiol Perform 2022; 17: 1516–1526

[24] Rosa JPP, Silva A, Rodrigues DF et al. Effect of bright light therapy on delayed sleep/wake cycle and reaction time of athletes participating in the Rio 2016 Olympic Games. Chronobiol Int 2018; 35: 1095–1103

[25] Mello MT, Simim MAM, Narciso FV et al. Duration and quality of sleep in sprint and recovery performances among elite swimmers. Rev Bras Med Esporte 2020; 26: 126–129

[26] Hoshikawa M, Uchida S, Dohi M. Intervention for Reducing Sleep Disturbances After a 12-Time Zone Transition. J Strength Cond Res 2020; 34: 1803–1807

[27] Driller MW, Dunican IC, Omond SET et al. Pyjamas, Polysomnography and Professional Athletes: The Role of Sleep Tracking Technology in Sport. Sports 2023; 11: 14

[28] Ohayon M, Wickwire EM, Hirshkowitz M et al. National Sleep Foundation's sleep quality recommendations: First report. Sleep Health 2017; 3: 6–19

[29] Biering-Sørensen F, Biering-Sørensen M. Sleep disturbances in the spinal cord injured: An epidemiological questionnaire investigation, including a normal population. Spinal Cord 2001; 39: 505–513

[30] Silva A, Narciso FV, Soalheiro I et al. Poor sleep quality's association with soccer injuries: preliminary data. Int J Sports Physiol Perform 2019; 15: 671–676

[31] Freitas LSN, Silva FR, Araújo Andrade H et al. Sleep debt induces skeletal muscle injuries in athletes: A promising hypothesis. Med Hypotheses 2020; 142: 109836

[32] Silva A, Queiroz SS, Winckler C et al. Sleep quality evaluation, chronotype, sleepiness and anxiety of Paralympic Brazilian athletes: Beijing 2008 Paralympic Games. Br J Sports Med 2012; 46: 150–154

[33] Silva A, Pinheiro LSP, Silva S et al. Sleep in Paralympic athletes and its relationship with injuries and illnesses. Phys Ther Sport 2022; 56: 24–31

[34] Wilke CF, Wanner SP, Santos WH et al. Influence of faster and slower recovery-profile classifications, self-reported sleep, acute training load, and phase of the microcycle on perceived recovery in futsal players. Int J Sports Physiol Perform 2020; 15: 648–653

[35] Horne JA, Östberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. Int J Chronobiol 1976; 4: 97–110

[36] Vitale JA, Weydahl A. Chronotype, physical activity, and sport performance: A systematic review. Sports Med 2017; 47: 1859–1868

[37] Pivovarnicek P, Kondratova D, Kentiba E. Does the chronotype distribution vary between different level football leagues? Insights gained from Czech elite football players. Chronobiol Int 2021; 38: 1162–1169

[38] Henst RH, Jaspers RT, Roden LC et al. A chronotype comparison of South African and Dutch marathon runners: The role of scheduled race start times and effects on performance. Chronobiol Int 2015; 32: 858–868

[39] Kuriyama A, Honda M, Hayashino Y. Ramelteon for the treatment of insomnia in adults: A systematic review and meta-analysis. Sleep Med 2014; 15: 385–392

[40] Bonuck KA, Schwartz B, Schechter C. Sleep health literacy in head start families and staff: exploratory study of knowledge, motivation, and competencies to promote healthy sleep. Sleep Health 2016; 2: 19–24

[41] Sanz-Milone V, Narciso FV, Silva A et al. Sleep of wheelchair rugby athletes: Training, rest and competition. Int J Sports Med 2021; 42: 169–174

[42] Quante M, Kaplan ER, Rueschman M. Practical considerations in using accelerometers to assess physical activity, sedentary behavior, and sleep. Sleep Health 2015; 1: 275–284

[43] Walsh NP, Halson SL, Sargent C et al. Sleep and the athlete: Narrative review and 2021 expert consensus recommendations. Br J Sports Med 2021; 55: 356–368

[44] Ibáñez V, Silva J, Cauli O. A survey on sleep questionnaires and diaries. Sleep Med 2018; 42: 90–96

[45] Bender AM, Lawson D, Werthner P et al. The clinical validation of the athlete sleep screening questionnaire: An instrument to identify athletes that need further sleep assessment. Sports Med Open 2018; 4: 23

[46] Driller MW, Mah CD, Halson SL. Development of the athlete sleep behavior questionnaire: A tool for identifying maladaptive sleep practices in elite athletes. Sleep Sci 2018; 11: 37

[47] Lastella M, Roach GD, Halson SL et al. Sleep/wake behaviours of elite athletes from individual and team sports. Eur J Sport Sci 2015; 15: 94–100

[48] Facundo L, Brant VM, Guerreiro R. Sleep regularity in athletes: Comparing sex, competitive level and sport type. Chronobiol Int 2022; 39: 1381–1388