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Original

Sleep-Wake Cycle of Elite Athletes Prior to the Rio 2016 Olympic Games

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ABSTRACT

Objective: To analyze chronotype, duration and quality of sleep among elite athletes, to compare differences in sleep variables between sex, and to compare differences between athletes of individual and team sports.
Method: The sample included 70 Brazilian elite athletes of both sex (male=37; female=33) with a mean age 23.0 ± 4.0 years old. To measure sleep-wake cycle, athletes wore an actigraph on the wrist for 10 days. Moreover, athletes answered the chronotype questionnaire of Horne and Östberg.
Results: The most athletes are intermediate-type (n=55, 78.6%), with a mean of 07h:18min of sleep per night. The athletes demonstrated higher sleep fragmentation (39.26 ± 23.66 minutes) and higher sleep latency (30.88 ± 16.19 minutes) during pre-competition training days. Additionally, the athletes of individual sports demonstrated more fragmentation ($p<0.001$) and less sleep efficiency ($p<0.001$) compared athletes of team sports. However, there was no significant difference in all sleep variables between the male and female sex.
Conclusion: The overall elite athletes presented poor sleep quality during the training periods prior to the Rio 2016 Olympic Games, and individual athletes showed higher fragmentation and poorer sleep efficiency compared to team athletes.
Keywords: Actigraphy, Sports, Sleep, Circadian Rhythm.

Ciclo de Vigilia-Sueño de Atletas de Élite Antes de los Juegos Olímpicos de Río 2016

RESUMEN

Objetivo: Analizar el cronotipo, la duración y la calidad del sueño entre los atletas de élite, comparar las diferencias en las variables de sueño entre los sexos y comparar las diferencias entre los atletas de los deportes individuales y de equipo.
Método: La muestra incluyó a 70 atletas de élite brasileños de ambos sexos (hombre = 37; mujer = 33) con una edad media de 23.0 ± 4.0 años. Para medir lo ciclo de vigilia-sueño, los atletas usaron un actígrafo en la muñeca durante 10 días. Además, los atletas respondieron el cuestionario cronotipo de Horne y Östberg.
Resultados: La mayoría de los atletas son de tipo intermedio (n = 55, 78.6%), con una media de 07h: 18min de sueño por noche. Los atletas demostraron una mayor fragmentación del sueño (39.26 ± 23.66 minutos) y una mayor latencia del sueño (30.88 ± 16.19 minutos) durante los días de entrenamiento previo a la competencia. Además, los atletas de deportes individuales demostraron más fragmentación ($p <0.001$) y menos eficiencia del sueño ($p <0.001$) en comparación con los atletas de deportes de equipo. Sin embargo, no hubo diferencias significativas en todas las variables de sueño entre el sexo masculino y el femenino.
Conclusión: Los atletas de élite en general presentaron mala calidad del sueño durante los períodos de entrenamiento previos a los Juegos Olímpicos de Río 2016, y los atletas individuales mostraron una mayor fragmentación y una menor eficiencia del sueño en comparación con los atletas del equipo.
Palabras clave: Actigrafía, Deporte, Sueño, Ritmo Circadiano.

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Ciclo de Vigília-Sono de Atletas de Elite antes dos Jogos Olímpicos Rio 2016

RESUMO

Objetivo: Analisar o cronotipo, a duração e a qualidade do sono de atletas de elite, comparar as diferenças nas variáveis do sono entre os sexos e as diferenças entre atletas de esportes individuais e coletivos.
Método: A amostra incluiu 70 atletas de elite brasileiros de ambos os sexos (masculino = 37; feminino = 33) com idade média de 23.0 ± 4.0 anos. Para mensurar o ciclo vigília-sono, os atletas usaram um actígrafo no punho por 10 dias. Além disso, os atletas responderam ao questionário de cronotipo de Horne e Östberg.
Resultados: A maioria dos atletas é do tipo intermediário (n = 55, 78.6%), com média de 07h:18min de sono por noite. Os atletas demonstraram maior fragmentação do sono (39.26 ± 23.66 minutos) e maior latência do sono (30.88 ± 16.19 minutos) durante os dias de treinamento pré-competição. Além disso, os atletas de esportes individuais demonstraram maior fragmentação (p <0.001) e menor eficiência do sono (p <0.001) em comparação aos atletas de esportes coletivos. No entanto, não houve diferença significativa em todas as variáveis de sono entre os sexos masculino e feminino.
Conclusão: Os atletas de elite em geral apresentaram baixa qualidade do sono durante os períodos de treinamento antes dos Jogos Olímpicos Rio 2016, e os atletas de esportes individuais apresentaram maior fragmentação e menor eficiência do sono em comparação aos atletas de esportivos coletivos.
Palavras-chave: Actigrafia, Esportes, Sono, Ritmo Circadiano.

Introduction

Achievement of high-level sports performance is based on the ability to balance training and competition stress with recovery.[1] Sleep is recognized as an important component in recovery and is considered a fundamental physiological process for the maintenance of physical, cognitive and metabolic performance.[1] Additionally, the duration and quality of sleep vary widely across individuals and depend on several factors, such as chronotype, age, sex, lifestyle and biological rhythm.[1,2]

Some authors consider a nocturnal sleep duration of nine or 10h of sleep to the athletes for adequate recovery.[1,3] Ideal sleep quality can be defined as low sleep latency (< 30 min) and wake time after sleep onset (WASO) of less than 20 min[4] However, some athletes sleep less than the recommended amount.[5-10] In the specific case of elite athletes, studies have reported a shorter sleep duration (~ six hours) and poor sleep quality compared to the general population.[5,8-10]

Nevertheless, in recent years, elite athletes of several sports, such as swimming, cycling, sailing, dancing, judo, rugby, soccer and basketball, have been observed to show more sleep fragmentation, low sleep efficiency and sleep restriction during training and competition period.[7,8,10-13] Training and competing after sleeping poorly at night impair athletes´ performance due to inadequate physical and cognitive recovery.[1,6]

Additionally, in a study of Juliff et al.[12] it has been reported that there are no differences in sleep quality variables related to sex (male and female) among elite athletes[12] in contrast to studies on the population in general, except when unpleasant dreams have affected female's sleep prior to competition. However, differences in sleep variables between athletes of individual and team sports, independent of sex, have revealed poor sleep quality and reduced sleep duration.[11] There is a consensus in the literature that sleep restriction negatively influences the sporting performance of athletes in general, male or female, in any specific sporting modality.[6,9] Thereby, it is important to present the sleep-wake rhythm of athletes of different sporting modalities in periods of high-pressure as training period prior to the Olympic Games to implement future interventions to improve the athletes' sleep and performance. Therefore, the aims of the present study were: 1) to analyze chronotype, duration and quality of sleep among elite athletes, 2) to compare differences in sleep variables between sex, and 3) to compare differences in sleep variables between athletes of individual and team sports prior to the Olympic games.

Method

Sample

The sample included 70 Brazilian elite athletes of both sex (mean = 24.0 ± 1.4 years old), male: n = 37; 53% (mean = 23.0 ± 4.0 years old) and female: n = 33; 47%; (mean = 25.0 ± 3.0 years old) of four sporting modalities: 1. track and field (Individual sport – IND; n=21), 2. handball (Team sport – T; n=16), 3. swimming (IND; n=24 and T; n=8), 4. shooting (IND; n=1). In the present study, we included only the elite athletes were summoned to participate in the Rio 2016 Olympic Games. All participants were informed of the benefits and risks of the investigation and signed the informed consent form after being informed about the study's aims and procedures. The study was approved by Human Research Ethics Committee of the Federal University of São Paulo under protocol number 0294/11. Athletes who did not sign the consent form, reported a health problem, or did not complete the entire experimental protocol were excluded from the study (n = 8).

Experimental Design

On the first day of athletes´ assessments, they signed the consent form and completed the questionnaire of circadian preference (chronotype).[13] On the same day, all athletes received explanations about the use of the actigraph (rest-activity monitor) and sleep diaries. The actigraph was worn on the non-dominant wrist for 10 days and the sleep-wake cycle data from the athlete were collected from the home environment (own bed) during these 10 days. Additionally, during this period, it was recommended that the athletes not use electronic devices before sleeping with the aim of avoiding sleep fragmentation or high sleep latency. The athletes reported that complied with this request. The evaluation was performed at the training sites of the respective sports during the week of adaptation and preparation for the Rio 2016 Olympic Games (10 days before entering the Olympic Village). This week was proposed by the Brazilian Olympic Committee to prepare the athletes for the competition schedule and for the future interventions (sleep-wake rhythm) inside the Olympic Village.

The chronotype of the athletes was measured by the *Morningness-Eveningness Questionnaire* translated and validated

for Brazil by Benedito-Silva et al.[13] The instrument included 19 self-assessment questions in which athletes filled out their circadian preference of daily life activities according to their usual hourly habits. The questionnaire was assessed by scores that classify individuals as *morning-type* (score > 58), *intermediate* or *neither-type* (score of 42 to 58) or *evening-type* (score < 42).[13]

The actigraph *Actiwatch 2* (*Philips Respironics®, Andover,* MA) was used to continuously to measure athletes' rest-activity or sleep-wake cycles (sleep/wake thresholds > 80 counts).[14] Recent studies have demonstrated a good agreement between actigraphy and polysomnography (sensitivity = 96%).[16] Therefore, this instrument reliably registers sleep parameters[14] and is a good tool to monitor the sleep of elite athletes.[8,10] The actigraph was worn on the non-dominant wrist of each athlete beginning on the first day of the assessment and remained there for 10 consecutive days. In addition, athletes completed sleep diaries that contained the following information to: sleep and wake-up times, time of naps and removal of the wrist instrument. Athletes were instructed to use the actigraph during periods of rest and activity (awake) except when they were in training exercises or taking a shower. The collected data at 60-second intervals were transferred to a computer and analyzed by the *Actiware* software (*Philips Respironics®, Andover,* MA). The analyzed variables were time awake, sleep duration at night (except naps), WASO, sleep efficiency and sleep latency.

Statistical Analysis

The results are expressed as descriptive statistics mean ± SD, confidence interval (CI 95%) and absolute frequency. We performed *Kolmogorov-Smirnov´s* normalcy test to verify the data distribution. The *t* independent test was performed to compare the circadian variables between sex (male and female) and between athletes of IND and T sports. The effect size was evaluated and the α-level for all analyses was set at 0.05 ($p < 0.05$).

Results

Athletes presented the following classifications in terms of chronotype (n=70): *intermediate or neither-type* (n = 55, 78.6%), *morning-type* (n = 12; 17.1%), and *evening-type* (n = 3; 4.2%). Analyzing the athlete's chronotype of each sport: 1. Handball (n=16) - the twelve handball athletes presented the *intermediate-type* (75%), three athletes were *morning-type* (19%) and one athlete was *evening-type* (6%); 2. Swimming (n=32) - Twenty-six swimming athletes were *intermediate-type* (81%), five were *morning-type* (16%) and one athlete was *evening-type* (3%); 3. Track & Field (n=21) - The 16 track & field athletes presented the *intermediate-type* (76%), four athletes *were morning-type* (19%) and one athlete was *evening-type* (5%); 4. Shooting (n=1) - The shooting athlete was *intermediate-type* (100%). Therefore, the most of athletes of IND and T sports presented the *intermediate-type* (n ≥ 75%).

Table 1 shows the variables of the sleep-wake cycle of athletes participating in the present study, such as time awake sleep duration, sleep efficiency, sleep latency and WASO.

Table 2 shows the comparative results between the sleep variables of the athletes by sex. There was no significant difference in all sleep variables between the male and female sex.

The comparison between individual and team sports is presented on table 3. The athletes of individual sports demonstrated more fragmentation and less sleep efficiency compared to athletes of team sports.

Table 1. Sleep-wake cycle variables of the athletes participating of the study.

Variables (n = 70)	Track & Field (n=21)	Handball (n=16)	Swimming (n=32)	Shooting (n=1)	Overall (n=70)
Time awake (h)	12.50±01.04 (12.24 – 13.18)	10.52±02.50 (09.31 – 12.24)	10.59±01.57 (10.15 – 11.38)	15.12	11.32±02.12 (11.01 – 12.04)
Sleep Duration (h)	07.42±01.00 (07.13 – 08.07)	07.05±00.23 (06.53 – 07.15)	07.09±01.14 (06.44 – 07.36)	07.12	07.18±01.02 (07.04 – 07.33)
Sleep Efficiency (%)	85.81±7.06 (82.18 – 88.52)	94.37±5.98 (91.27- 96.87)	84.03±12.57 (79.88 – 88.33)	95.00	87.08±10.54 (84.34 - 89.45)
Sleep Latency (min)	26.68±7.12 (23.76 – 29.75)	28.75±11.55 (24.00 – 35.07)	34.98±21.27 (28.60 – 42.47)	22.00	30.88±16.19 (27.46 - 35.10)
WASO (min)	50.52±19.49 (42.93 – 59.66)	21.00±17.75 (13.33 – 30.13)	41.62±23.91 (33.18 – 49.90)	19.00	39.26±23.66 (33.97 - 44.60)

Values presented as Mean ± Standard Deviation and (Confidence Interval – CI 95%). SD: Standard Deviation; CI: Confidence Interval; WASO: Wake after sleep onset.

Table 2. Comparison between sleep variables of the athletes by sex.

Variables (male: n=37; female: n=33)	Sex	Mean ± SD	($CI_{95\%}$)	*t*	p	ES
Time awake (h)	Female	11.00±02.14	(10.18-11.47)	1.942	0.056	0.47
	Male	12.01±02.05	(11.19-12.41)			
Sleep Duration (h)	Female	07.16±00.32	(07.05-07.28)	0.215	0.830	0.05
	Male	07.19±01.20	(06.54-07.45)			
Sleep Efficiency (%)	Female	87.58±9.20	(84.52-90.44)	0.377	0.708	0.09
	Male	86.64±11.72	(82.53-90.13)			
Sleep Latency (min)	Female	31.06±12.11	(27.26-35.75)	0.091	0.928	0.02
	Male	30.71±19.30	(25.53-36.67)			
WASO (min)	Female	39.48±25.54	(30.07-48.76)	0.073	0.942	0.02
	Male	39.06±22.21	(31.68-45.94)			

Values presented as Mean ± Standard Deviation and (Confidence Interval – CI 95%). SD: Standard Deviation; CI: Confidence Interval; WASO: Wake after sleep onset. ES: Effect size.

Table 3. Comparison between sleep variables of the athletes in individual *vs* team sports.

Variables	Sport	Mean ± SD	($CI_{95\%}$)	*t*	*p*	ES
Time awake (h)	IND (n=4)	11.47±01.55	(11.13-12.19)	1.210	0.241	0.40
	T (n=24)	10.52±02.40	(09.37-12.12)			
Sleep Duration (h)	IND(n=4)	07.21±01.09	(07.04-07.42)	0.929	0.356	0.36
	T (n=24)	07.05±00.23	(06.52-07.15)			
Sleep Efficiency (%)	IND (n=4)	84.93±10.67	(82.31-87.78)	4.535	<0.001	1.13
	T (n=24)	94.37±5.98	(90.94-96.87)			
Sleep Latency (min)	IND(n=4)	31.51±17.38	(27.43-35.84)	0.739	0.465	0.19
	T (n=24)	28.75±11.55	(24.14-35.92)			
WASO (min)	IND(n=4)	44.67±22.57	(38.08-50.33)	4.385	<0.001	1.17
	T (n=24)	21.00±17.75	(13.11-30.28)			

Values presented as Mean ± Standard Deviation and (Confidence Interval – CI 95%). SD: Standard Deviation; CI: Confidence Interval; WASO: Wake after sleep onset. IND: Individual sport. T: Team sport. ES: Effect size.

Discussion

The aims of this study were to analyze characteristics of sleep duration and sleep quality of elite athletes during training prior Rio 2016 Olympic Games. The results demonstrated that athletes (n=70) presented a mean sleep duration of 07h:18min per night (less than recommended for athletes),[3] and sleep latency (31 minutes) and fragmentation (39 minutes) higher than recommended for healthy adults.[4,15] Sleep latency and WASO times longer than 30 and 20 min, respectively, are considered to be high for healthy young adults.[4] Furthermore, athletes of individual sports showed lower sleep efficiency and higher sleep fragmentation compared with athletes of team sports.

Relative to sleep, in most studies, elite athletes demonstrate sleep durations of less than seven hours per night,[7,11] which is different from the athletes in our study, who showed a mean of 07h:18min of sleep. This result can be explained by the athletes have slept in their home environment (own bed). Substantially, sleeping at home environment (own bed) provides longer sleep duration than sleeping into the training camp. Sleeping into the training camp has other variables that influence in appropriate sleep duration, for example, the external noises; hotel phones, sleeping with roommate and the hotel or accommodation may not have blackout curtains to block outside light. Although, the athletes slept less than recommended for the population of athletes (09 to 10h).[3] A sleep duration of less than recommended per night or situations of chronic sleep restriction, independent of

chronotype, may generate psychomotor deficits, such as an increased number of lapses of attention and reduced reaction time to a stimulus,[3] compromising performance during competitions. Two studies found that sail and handball athletes who experienced sleep restriction and poor sleep quality demonstrated impairment in their reaction times during competition days.[6,16]

Although there is no consensus in the literature in terms of the ideal sleep duration for elite athletes.[8,10] A study showed that 10-hour sleep extension during six nights reduced rated perceived exertion (RPE) and improved motor performance.[17] Thereby, it is possible to suggest that seven hours of sleep per night, as observed in the present study, is not sufficient for the psychomotor recovery of athletes who face high training loads[3] and mental stress during training and competition periods that have greater recovery requirements.[7,10]

Relative to athletes' sleep variables, the present study verified that there was sleep fragmentation higher than recommended and difficulty falling asleep (high sleep latency) during the pre-game training days for Rio 2016. We believe that other psychobiological factors (fatigue, anxiety, worry, depression and stress) may have contributed to the poor sleep quality of our athletes prior this important competition. Elevated levels of anxiety[5], fatigue[7], tension[18] and stress[19] may affect an athlete's capacity to sleep, maintain restoring sleep and adequately recover, which may have occurred in the athletes in the present study. Nervousness, anxiety and mental fatigue, mainly during the days of competition[5,7,19], result in inadequate recovery (poor sleep quality).

Difficulty falling asleep and sleep fragmentation may also be related to the circadian preference (chronotype) for sleeping, to the emotional aspects, to the sleep disorders, and to the endogenous circadian rhythm. Regarding the circadian rhythm (approximately 24 hours), individuals show variability related to physiological markers that facilitate sleep (for example, the nadir of central temperature between 3 - 5:00 h in the morning and the acrophasis of melatonin between 2 - 4:00 h in the morning).[20,21] In terms of chronotypes, some individuals demonstrate a circadian preference for going to sleep early and waking up early (*morning-type*), and others prefer to go to sleep late and wake up late (*evening-type*).[22] The sample in our study (IND and T) demonstrated a circadian profile of the *intermediate-* or *neither-type*, similar to the study of Lastella et al.[22] Therefore, the sample presented more flexible chronotype relative to sleep-wake cycles, which facilitates the understanding that difficulty the falling asleep that could have occurred because of other reasons.

On the other hand, studies have demonstrated that athletes who are worry and anxious during a competitive period tend to show symptoms similar to insomnia, such as sleep fragmentation, high sleep latency, non-restorative sleep, fatigue and diurnal sleepiness.[12,23] These symptoms compromise the adherence and disposition of athletes as well as the quality of training and performance in highly competitive sporting events.[8,23]

It is important to note that restorative sleep is fundamental for cognition, energy restoration and brain energetic metabolism[1,2] and involves not only psychobiological or behavioral aspects (i.e. sleep hygiene, mood, anxiety) but also environment (i.e. quiet and comfortable bedroom) and social aspects (i.e. working time; family leisure time).[2] Increased sleep latency may also be related to the use of electronic devices that emit light. Actually, the use of these technologies is very common for communicating with friends and family during training and competition periods. However, Dunican et al.[24] demonstrated that removing these devices 48 hours pre-competition did not affect sleep, cognition or sporting performance. Hence, longitudinal studies must be conducted to investigate the true effects of these devices on sleep.

When we compared the sleep-wake cycle variables between sex, we did not find any difference between athletes' sleep, in contrast to the study of Leeder et al.[10] These authors confirmed a better sleep efficiency in women and more time awake in male athletes. On the other hand, Juliff et al.[12] found similar results to the present study, although the reports indicate that sleep among female athletes was more affected by unpleasant dreams compared with male athletes. These findings were also observed by Erlacher et al.[5], who showed that unpleasant dreams disturbed sleep among female athletes more frequently compared to male athletes. It is evident in the literature that age, individual features and sex influence sleep.[2,19] In general, sleep quality among women is impaired by factors such as difficulty in initiating sleep, frequent WASO and the symptoms of insomnia.[23] However, our results seem to be related to other factors (external environment, social factors, symptoms of tension, stress and anxiety) or personal routines of sleep-wake developed by athletes in preparation for competitions, independent of sex. Although, inadequate recovery results in reduced performance in training and competitions, there is no evidence for changes in athletes´ behavior to sleep-wake rhythms relative to the sex in this study. In general, non-restorative sleep represented by sleep fragmentation and higher sleep latency negatively affect the psychomotor and neurobehavioral functions of athletes.[1,6]

Finally, differences were found between the sleep of athletes of individual sports compared to athletes of team sports. These results observed in our athletes of team sports demonstrated poor sleep efficiency (< 85%; ES=1.13) and higher sleep fragmentation (WASO > 20 min; ES=1.17)[4], even sleeping at home environment. Poor sleep quality among athletes of individual sports during pre-competitive periods was also reported by Lastella et al.[11] The authors observed that athletes of the individual group demonstrated poor sleep efficiency, reduced total sleep time, higher sleep latency and sleep fragmentation compared to the athletes of the team group.

High pressure and responsibility to produce positive results and the symptoms of anxiety[5,25] have been proposed as possible explanations for the poor sleep quality among athletes of the individual group, before and after important competitions.[7,25] Increased fatigue and tension were associated with poor sleep quality (total sleep time and waking-up during the night) of the 103 marathon runners prior to competition in the study of Lastella, Lovell[18] Another factor is that IND athletes tend to have differential routines of training[8,10] and they are solely responsible for their own results. For example, track & field, sailing, swimming, gymnastics, and shooting sports require higher attention, precision and less time reaction. On the other hand, habitually, swimming athletes perform their first training session during the morning (06:00 - 08:00 h) and another session at the end of the afternoon, between 16:00 - 18:00 h.[15] These athletes are sleep restricted, wake up very early to train, and maintain an intense training routine[8], similar to the swimming athletes of our study. Other studies indicate that sleep restriction/deprivation reduce endurance performance[3] and increase fatigue[7] and reaction time[6,16] in addition to impairing the sleep-wake rhythm as well as athletes' performance during training and competitions.[1] Although our study did not show the methodological characteristics of the above-mentioned studies, which impact some of the conclusions, our study was conducted during athletes' training for Olympic Games (field study). This fact has made it impossible to control for the ingestion of coffee and/or alcohol as well as participation in social events during the period of training for the Rio 2016 Olympic Games. Furthermore, the non-use of polysomnography in the present study may be considered as a limitation. In future studies, it would be interesting to use polysomnography (gold standard) to quantify sleep disorders and to analyze athletes' sleep architecture. Nevertheless, we believe

that this type of study better represents the daily routine of athletes in periods of high-pressure events, which may have contributed to the findings of our study. Poor sleep quality during training periods for important competitions are common among elite athletes[5,10] and should be monitored and minimized with specific and individualized actions. Recently, a six-week program for sleep education and the optimization of sleep resulted in significant improvements in sleep duration, sleep efficiency, and vigor among members of the Australian Football League.[9]

A practical recommendation of this study could be implement sleep strategies that improve sleep duration and sleep quality at night, especially in individual athletes' sports. The elite athletes should be made aware to maintain the regularity of the sleep-wake rhythms, and the training time-of-day and chronotype may also have an influence on sleep. Therefore, the sleep time and training schedule should occur in according with athletes' chronotype. According to our findings, it was possible to observe that a shorter sleep duration and poor sleep quality are present among elite athletes during pre-competition training periods. Individual athletes (IND sports) showed higher fragmentation and poorer sleep efficiency compared to team athletes (T sports). These conclusions suggest that to prevent inadequate physical and cognitive recovery in elite athletes in general, it is necessary to implement strategies that increase sleep duration and sleep quality at night and to maintain the regularity of the sleep-wake rhythms among this population.

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