

The impact of sleep during the tapering period on young swimmers: A scientific investigation

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Abstract:

During adolescence, sleep is essential for physical and cognitive development. However, modern lifestyles often disrupt sleep patterns in young people, potentially impacting athletic performance. Swimming, with its demanding training schedules, presents unique challenges to sleep patterns and may influence performance. This study investigates the role of sleep in the performance of young swimmers during the tapering period. Nineteen athletes participated in this study, but only 15 completed it. The data were collected 21 days before the target competition, when the athletes were already engaged in training. Based on sonography, divided into good sleep group (GSG; n=8) and poor sleep group (PSG; n=7). Athletes used an actigraph daily (for 21 days, during tapering phase) to identify sleep quality and had their performance results obtained by the International Point Score (IPS). We observed that 46.67% of the athletes had poor sleep, with no difference between genders. We identified a significant difference ($p=0.001$; $ES=1.52$; 18.65%) between week 1 and week 3 of total sleep time (TST), without showing changes in sleep efficiency (SE). Sleep latency (SL) in both groups improved, with a reduction in the difference between the groups (9.73%), and wake after sleep onset (WASO) decreased ($p=0.001$; $ES=-1.79$; 20.91%). The increase in TST, maintenance of SE, reduction of WASO, and the difference in SL between the groups, associated with the equal performance of the groups obtained by IPS, suggest better sleep quality during the period, with tapering reducing any performance differences that PSG could have compared to GSG.

Key Words: Sleep Quality, tapering, performance, swimmer, athlete

Introduction

Sleep is a vital physiological necessity that, during adolescence, emerges as a significant modulator of various transformations and functions at hormonal, physical, psychosocial, and cerebral levels, which will have repercussions throughout life in all domains (Hrozanova *et al.*, 2023). However, in contemporary times, young people have exhibited patterns that directly affect the timing and quality of sleep, such as the use of electronic devices close to bedtime (Viner *et al.*, 2019).

Insomnia, characterized by difficulty initiating and maintaining sleep, is the most common sleep disorder among adolescents. It is generally associated with a range of biological and environmental factors, such as physical inactivity, depression, anxiety, trauma, and physical and mental stress (Tartar *et al.*, 2023). In this context, the practice of physical activity, such as exercise and sports, emerges as an important environmental factor that can be a positive strategy to improve sleep quality, as well as contribute to the control of other factors that favor insomnia, such as depression, anxiety, and stress (De Pano-Rodriguez *et al.*, 2023).

The relationship between physical activity and sleep quality has been widely explored. Studies such as that of De Pano-Rodriguez *et al.* (2023) observed a directly proportional relationship between sleep quality and level of physical activity (LPA), with higher LPA correlating with better sleep quality. However, male youth expressed better sleep quality regardless of LPA. According to Tatar *et al.* (2023), this gender disparity may be explained by the fact that the female body undergoes more sensitive hormonal changes, which can lead to physiological disturbances affecting sleep.

Specifically among young people, Rosa *et al.* (2021) found that children and adolescents engaged in various sports modalities (in participatory and educational dimensions) exhibit better sleep patterns compared to sedentary youth. However, variations exist related to factors such as gender, activity intensity, and sports

modality. Regarding the intensity of practice, Zhao, Lu, and Yi (2023) did not observe differences in sleep quality when comparing high and moderate-intensity activities.

Regarding the competitive sports dimension, the physical and mental demands of competitions, training, travel, and pressure for results become important points of concern, as such conditions can directly affect the physiological aspects of the body, such as sleep, potentially influencing athletic performance. Hence, there is a need for appropriate monitoring to ensure better recovery and rest for athletes (Vitale *et al.*, 2019). During the final phase of preparation for a competition, known as the tapering period (2-3 weeks before the competition), it is common to hear reports of athletes experiencing insomnia or other sleep disturbances, which impairs recovery and often has a negative impact on athletic performance (Da Costa *et al.*, 2023).

Regarding the variation in sleep patterns among athletes, Nedelec *et al.* (2028) assert that the specificity of training and competition schedules is possibly the most influential factor, resulting in inconsistencies in sleep among these athletes. Therefore, it is crucial to consider the sports calendar and competition schedules during planning so that athletes can express their best athletic performance and are not adversely affected by circadian rhythms (Mello *et al.*, (2020)

Among the most popular sports in the world, swimming presents peculiarities that intensify these challenges, which can be significantly explained by its schedules, affecting both training and athletic performance. Typically, training sessions occur in the early morning (05:00-07:00, with prior warm-up) and late afternoon (16:00-19:00), resulting in sleep restriction for swimmers (Mello *et al.*, 2020).

During the tapering phase, coaches and swimmers concentrate their efforts on refining and "polishing" tactical, technical, and physical abilities while monitoring stress and anxiety, maintaining self-efficacy, and promoting adequate periods of rest. These measures are fundamental to preserve the athlete's energy reserves, essential for performance during competition (Costa *et al.*, 2022).

Due to the scarcity of studies that investigate the relationship between sleep patterns and athletic performance in young swimmers during critical periods, such as the pre-competitive tapering phase, this research is necessary. Although the literature has already highlighted the influence of sleep on physical recovery and sports performance, there is a significant gap in understanding the specific demands of swimming, a sport characterized by strict schedules that include sleep restriction. Moreover, adolescence is a phase of physiological and psychological vulnerability, with a higher propensity for sleep disorders such as insomnia. In this context, understanding how sleep can be optimized to minimize negative impacts on performance and promote evidence-based strategies is essential to help coaches and physical trainers make informed decisions and design programs that balance health and athletic performance.

However, the relationship between sleep and pre-competitive periods, and consequently, the performance of young athletes, especially in swimming, still requires a more robust scientific scope to support coaches' and physical trainers' planning and decision-making. In this context, the present study aimed to analyze the role of sleep in the performance of young swimmers during the tapering period: a perspective to understand the influence of sleep patterns on optimizing athletic performance.

Material & methods

Study type and population

It is a cross-sectional study with an exploratory-descriptive design (Nelson & Thomas, 2002), conducted with athletes from the youth category of Swimming of the Pernambuco Swimming Federation, Brazil, all of whom are affiliated with the Brazilian Aquatic Sports Confederation (CBDA).

To participate in the study, athletes were required to have a minimum of 12 months of uninterrupted training, with a minimum weekly training load of 12 hours, and to sign the Informed Assent Form (IAF), with consent from their legal guardians, who would sign the Informed Consent Form (ICF). Those who presented any type of injury, medical restriction, or contraindication to participate in any phase of the study were excluded.

All procedures in this study adhered to ethical standards stipulated in accordance with Resolution 466/12, which regulates research involving human subjects. The study was approved by the Research Ethics Committee on Human Beings of the Federal University of Pernambuco, under opinion number 2,938,180.

Study design

A juvenile swimming team consists of 19 athletes, all of whom met the aforementioned inclusion and exclusion criteria. Thus, the study proposal was presented to the athletes, coaches, and legal guardians, who were informed about the procedures and risks they would be subjected to. Everyone was invited to participate in the study, receiving the IAF, and legal guardians were directed to sign the ICF, agreeing to the participation.

After the instructions, all athletes agreed to participate in the study, which was conducted over 21 days (three weeks) before a national competition (target competition). This period (21 days; three weeks before the competition) falls within the macrocycle of the athletes, understood as the tapering phase (Maglischo *et al.*, 1999; Walsh *et al.*, 2019).

Inicialmente, the athletes underwent polysomnography to identify sleep quality (Oliveira *et al.*, 2012) and had their anthropometric variables (height and weight) collected to characterize the sample. Based on the

polysomnography results, they were divided into two groups: the good sleep group (GSG) and the poor sleep group (PSG). Then, they received an actigraph device to measure the sleep-wake cycle (Leeder *et al.*, 2012) for three weeks, evaluating sleep efficiency (SE), total sleep time (TST), sleep latency (SL), and number of awakenings after sleep onset (WASO). Additionally, to complement and corroborate the data obtained by the actigraph, the athletes filled out a "sleep diary" (Walsh *et al.*, 2019), in which they reported bedtime, wake time, and the number of nocturnal awakenings. The Karolinska Sleepiness Scale (KSS) (Åkerstedt *et al.*, 1990; Teixeira *et al.*, 2007), was also applied to assess daytime sleepiness levels among the athletes.

To evaluate the performance of athletes in the GSG and PSG groups, taking into account variations in swimmers' specialties in terms of distance and strokes, the International Point Score (IPS) system was adopted in the target competition, as described by Nogueira *et al.* (2015). The IPS is widely recognized by the Fédération Internationale Natation Amateur (FINA), the CBDA, and state federations as a reliable metric for assessing athlete performance. In this system, the evaluation score ranges from 0 to 1100 points, based on world records, thus reflecting the athlete's performance. The higher the score, the better the athlete's performance, considering different events, distances, genders, and age groups.

Polishing phase

At the onset of this study, athletes were in the midst of their training process and, as part of their regimen, were to undergo the tapering phase 21 days before the target competition. To ensure the specificity of the training programs, which varied according to the individual characteristics required by each athlete's events, coaches retained autonomy without interference from researchers. Individualized intensity zones were established by the responsible coach, aligned with the planned tapering microcycle leading up to the target competition, as described by Maglischo (Maglischo, 2010).

Collection instrument

To determine height, a stadiometer (Sanny®, São Paulo, Brazil) with an accuracy of 0.1 cm was used, recording it in centimeters. Body mass was measured using a digital scale (Filizola®, São Paulo, Brazil) with an accuracy of 100 grams. Thus, it was possible to calculate the Body Mass Index (BMI) using the formula: body mass (kg) divided by height squared (m).

For the grouping division (GSG and PSG), polysomnography (Oliveira *et al.*, 2012), was utilized, a technique considered non-invasive, which graphically records multiple biophysiological variables occurring during sleep, including variables derived from the electroencephalogram (brain electrical activity), electrooculogram (eye movements), and electromyogram (muscle activity). For this analysis, the athlete was observed overnight during their sleep period, being monitored by electrodes that recorded the movements of at least 22 parameters (Alice PDX® model). The examination was conducted in the athlete's own residence using portable equipment. For this purpose, a partnership was established with Interne – Home Care Ltda., which provided the equipment to the athlete's residence, installing it and monitoring its overnight use. The company responsible for conducting polysomnography (mentioned above) was tasked with determining the diagnosis based on the examination variables and thus defining the athletes who comprised GSG and PSG.

The sleep-wake cycle was assessed using an actigraph (ActiGraph GT3X model), which was worn on the non-dominant wrist of each athlete. Through motion sensors such as accelerometers, the device continuously recorded the user's movement data during sleep. The recorded data were stored in the device's internal memory and later transferred for analysis on a computer, providing information such as SE, TST, SL, and WASO (Leeder *et al.*, 2012). The equipment was provided so that each athlete could monitor the 21 days (polishing phase) preceding the target competition. Sleep diaries were used as a complementary method to correct data in actigraphy analyses (Walsh *et al.*, 2019), where each morning the athlete recorded in a notebook provided by the researchers the bedtime, wake time, and number of nocturnal awakenings.

The assessment of sleepiness was conducted using the KSS (Åkerstedt & Gillberg, 1990), validated for the Brazilian population (Teixeira *et al.*, 2007). This is a subjective scale that evaluates sleepiness at the time of application. Comprised of 9 points, it starts with the value 1 ("Very alert") and ends with the value 9 ("Very sleepy, fighting sleep, extreme effort to stay awake"). The scale asks the question: "How do you feel right now?". It was used daily to assess the sleepiness level of the athletes before the first training session.

The athletes' performance was assessed using the IPS, a system developed by Swimnews and recognized by the FINA and CBDA. This system assigns a score to the athlete based on their gender, age, event type, distance, and the time achieved in the race (Nogueira *et al.*, 2015).

Statistical analysis

The statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS version 20.0) by IBM, in Chicago, United States. Normality and homogeneity of variance of the data were assessed, and the assumptions of data normality were confirmed using the Shapiro-Wilk and Levene tests. Results are presented as mean and standard deviation for the total sample and by sleep group (GSG and PSG). For the comparison analysis between weeks for sleep variables (TST, SE, SL, WASO, and daytime sleepiness), repeated measures ANOVA was used, followed by post-hoc tests and Tukey's multiple comparison test to identify differences between weeks, for the total sample and stratified by group (GSG and PSG). Pearson

correlation was used to examine the relationship between performance and sleep variables (TST, SL, SE, WASO, and sleepiness). Additionally, the independent samples t-test was used to compare the two groups (GSG and PSG) with sleep and performance variables. Effect size was determined by Cohen's d in all analyses. Cohen's d effect size was classified as follows: 0.1 as very small; 0.2 as small; 0.5 as medium; 0.8 as large; 1.2 as very large; and 2 as huge (Sawilowsky, 2009). The significance level was set at 5% ($p < 0.05$).

Results

Of the 19 swimmers initially included in the study, four did not complete the sleep-wake cycle phase due to difficulty adapting to the actigraph, resulting in a final sample size of 15 athletes, with eight composing the GSG and seven the PSG. Among the total sample, the majority ($n=10$) were female, with five in each group (GSG and PSG). Table 1 presents the description of the total sample and the comparison by group, including the descriptive characteristics of the athletes and the average results of the sleep-wake cycle during the polishing phase (21 days before the target competition).

Table 1. Descriptive characteristics of the total sample and by group (GSG and PSG) of anthropometric variables (age, body mass, height, and BMI) and sleep-wake cycle during the polishing phase.

	Variables Mean $\pm$ SD (n=15)	Variables Mean $\pm$ SD	
		GSG (n=8)	PSG (n=7)
Age (years)	13.50 $\pm$ 0.51	13.40 $\pm$ 0.51	13.6 $\pm$ 0.53
Body mass (kg)	53.80 $\pm$ 7.83	52.60 $\pm$ 6.54	55.2 $\pm$ 9.42
Height (cm)	1.63 $\pm$ 7.14	164.00 $\pm$ 8.37	161.0 $\pm$ 5.70
BMI (kg/m ²)	20.30 $\pm$ 2.18	19.50 $\pm$ 1.55	21.2 $\pm$ 2.59
TST (hs)	8.27 $\pm$ 1.00	8.33 $\pm$ 0.52	8.21 $\pm$ 1.42
SL (min)	28.60 $\pm$ 18.9	21.70 $\pm$ 11.90	36.40 $\pm$ 23.00
SE (score)	91.80 $\pm$ 13.70	95.30 $\pm$ 3.59	87.80 $\pm$ 19.60
WASO (number)	18.50 $\pm$ 2.08	19.40 $\pm$ 1.00	17.40 $\pm$ 2.52
Somnolence (score)	3.70 $\pm$ 0.94	3.61 $\pm$ 0.84	3.80 $\pm$ 1.10

GSG= Good sleep group; PSG= Poor sleep group

Table 2 presents the parameters of the sleep-wake cycle during the polishing phase (21 days before the target competition) and the distribution of values for the total sample per week, revealing significant differences in TST in week 3 of polishing ($p=0.001$), with a longer time for PSG (16.75%); as well as in SL, where PSG showed higher values in week 1 ($p=0.030$; 77.20%) with a large effect size ($ES=1.08$) and in week 2 ($p=0.020$; 129.89%), with a very large effect size ($ES=1.30$). Regarding the cumulative three weeks, SL was 67.74% higher in PSG, representing a large effect size ($ES=0.83$); while in WASO, GSG showed higher values in week 2 ($p=0.001$; 17.16%) with huge effect size ($ES=2.17$), as well as in the cumulative weeks, which had a large effect size ($ES=1.11$), being 10.31% higher than PSG. Another relevant point is daytime sleepiness, which can directly affect competitive performance; although no significant differences were found, it was observed that in week 1, PSG had daytime sleepiness 6.86% higher than GSG, while in week 3 the values were equal, making the effect null ($ES=0.00$). Furthermore, when comparing gender differences, no significant differences were found between and within groups.

Table 2. Comparative analysis of mean values for GSG and PSG, regarding parameters of the sleep-wake cycle (TST, SL, SE, WASO, and daytime sleepiness).

Weeks	Mean $\pm$ SD (n=15)	GSG (n=8)	PSG (n=7)	Δ (%) sig	Effect Size
Total sleep time – TST (hours)					
Week 1	8.31 $\pm$ 1.09	8.28 $\pm$ 0.41	8.34 $\pm$ 1.60	0.06 (0.72%) 0.480	0.15 Very small
Week 2	7.48 $\pm$ 0.51	7.59 $\pm$ 0.56	7.35 $\pm$ 0.44	0.24 (3.16%) 0.190	0.21 Small
Week 3	6.76 $\pm$ 0.94	6.27 $\pm$ 0.55	7.32 $\pm$ 1.01	1.05 (16.75%) 0.001***	0.61 Medium
Accumulated over the weeks	8.27 $\pm$ 1.00	8.30 $\pm$ 0.52	8.21 $\pm$ 1.42	0.09 (1.08%) 0.829	0.11 Very small

Sleep latency – SL (minutes)					
Week 1	21.87±12.91	16.10±9.98	28.50±13.30	12.40 (77.20%) 0.030*	1.08 Large
Week 2	27.96±20.95	17.40±8.36	40.0±25.00	22.60 (129.89%) 0.020*	1.30 Very large
Week 3	35.83±32.36	31.40±33.67	40.80±32.70	9.40 (29.94%) 0.310	0.55 Medium
Accumulated over the weeks	28.55±18.86	21.70±11.90	36.40±23.00	14.70 (67.74%) 0.135	0.84 Large
Sleep efficiency – SE (score)					
Week 1	80.02±1.42	80.00±1.68	80.00±1.20	0.00 (0.00%) 1.00	0.00 Very small
Week 2	76.70±4.37	76.60±4.21	76.80±4.90	(0.26%) 0.490	0.04 Very small
Week 3	77.37±6.36	78.10±2.82	76.60±9.16	1.50 (1.92%) 0.350	0.24 Small
Accumulated over the weeks	78.03±2.74	78.20±2.09	77.80±3.52	0.40 (0.51%) 0.7874	0.14 Very small
Number of awakenings after sleep onset – WASO (number)					
Week 1	20.52±2.48	21.40±1.09	19.50±3.31	1.90 (8.88%) 0.080	0.83 Large
Week 2	18.77±2.42	20.40±0.76	16.90±2.33	3.50 (17.16%) 0.001 ***	2.17 Huge
Week 3	16.23±1.96	16.60±1.88	15.80±2.13	0.80 (4.82%) 0.400	0.40 Small
Accumulated over the weeks	18.50±2.08	19.40±1.00	17.40±2.52	2.00 (10.31%) 0.056	1.11 Large
Daytime drowsiness – DD (escore)					
Week 1	3.61±1.13	3.50±0.88	3.74±1.43	0.24 (6.86%) 0.360	0.21 Small
Week 2	3.81±1.13	3.76±1.15	3.87±1.19	0.11 (2.93%) 0.290	0.09 Very small
Week 3	3.69±0.91	3.59±0.76	3.59±1.12	0.00 (0.00%) 1.00	0.00 Very small
Accumulated over the weeks	3.70±0.94	3.61±0.84	3.80±1.10	0.19 (5.26%) 0.711	0.20 Small

GSG= Good sleep group; PSG= Poor sleep group; * p < .05; ** p < .01; ***; p < .001.

When comparing sleep-wake cycle parameters between weeks, significant differences were observed in TST. We found differences between week 1 and week 2 (p=0.009; 9.99%) and between week 1 and week 3 (p=0.001; 18.65%), with higher values in week 1. These results are supported by effect sizes between weeks, which were respectively large (ES=0.98) and very large (ES=1.52). Additionally, a large effect size (ES=0.96) was observed between week 2 and week 3. Regarding ES, a significant reduction was observed between week 1 and week 2 (p=0.039; 4.15%) with a large effect size (ES=-1.10). No differences were observed between week 2 and week 3, suggesting maintenance of ES in the two weeks preceding the competition. When analyzing WASO, a reduction was observed from the beginning to the end of the polishing phase (week 1 and week 3) of 20.91% (p=0.001), with a very large effect size (ES=-1.79). This reduction was observed between week 1 and week 2 (p=0.001; 8.53%) and was accentuated between week 2 and week 3 (p=0.001; 13.53%), representing a large effect size (ES=-1.16) (Table 3).

Table 3. Comparative analysis of weeks for sleep-wake cycle parameters (TST, SL, SE, WASO, and daytime sleepiness).

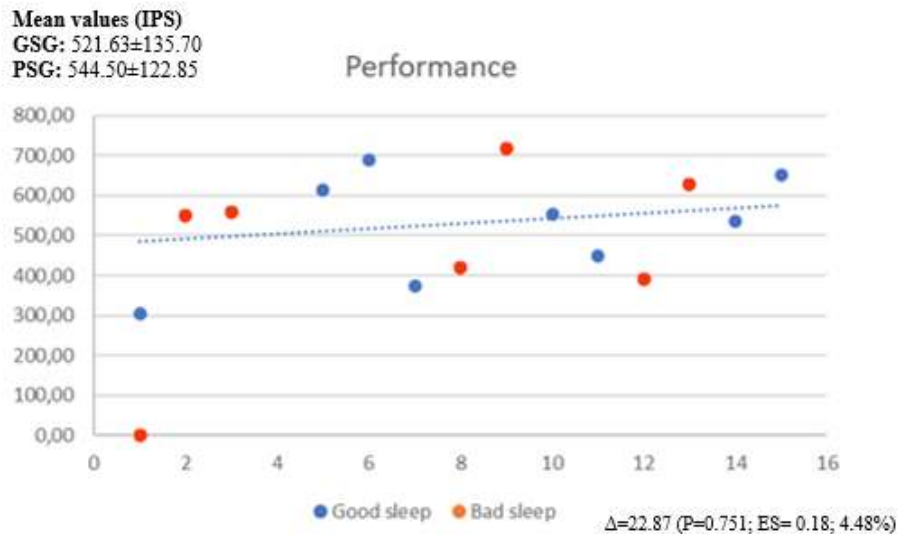
Comparison (mean ± SD)		Δ (%)	SE	Effect Size	Sig	
Total sleep time – TST (hours)						
Week 1 (8.31±1.09)	Week 2 (7.48±0.51)	0.83 (9.99%)	0.230	0.98 Large	0.009	**
Week 1 (8.31±1.09)	Week 3 (6.76±0.94)	1.54 (18.65%)	0.290	1.52 Very large	0.001	***
Week 2 (7.48±0.51)	Week 3 (6.76±0.94)	0.72 (9.63%)	0.269	0.96 Large	0.055	
Sleep latency – SL (minutes)						
Week 1 (21.87±12.91)	Week 2 (27.96±20.95)	6.12 (27.85%)	2.844	0.35 Small	0.148	

Week 1 (21.87±12.91)	Week 3 (35.83±32.36)	13.98 (68.63%)	7.423	0.57 Medium	0.242	
Week 2 (27.96±20.95)	Week 3 (35.83±32.36)	7.86 (28.15%)	7.341	0.29 Very small	0.906	
Sleep efficiency – SE (score)						
Week 1 (80.02±1.42)	Week 2 (76.70±4.37)	3.32 (4.15%)	1.166	-1.10 Large	0.039	*
Week 1 (80.02±1.42)	Week 3 (77.37±6.36)	2.64 (3.31%)	1.629	-0.62 Medium	0.381	
Week 2 (76.70±4.37)	Week 3 (77.37±6.36)	0.68 (0.87%)	1.953	0.14 Very small	1.000	
Number of awakenings after sleep onset – WASO (number)						
Week 1 (20.52±2.48)	Week 2 (18.77±2.42)	1.75 (8.53%)	0.312	-0.58 Medium	0.001	***
Week 1 (20.52±2.48)	Week 3 (16.23±1.96)	4.29 (20.91%)	0.452	-1.79 Very large	0.001	***
Week 2 (18.77±2.42)	Week 3 (16.23±1.96)	2.54 (13.53%)	0.533	-1.16 Large	0.001	***
Daytime drowsiness – DD (escore)						
Week 1 (3.61±1.13)	Week 2 (3.81±1.13)	0.20 (5.54%)	0.201	0.18 Very small	1.000	
Week 1 (3.61±1.13)	Week 3 (3.69±0.91)	0.08 (2.22%)	0.232	0.08 Small	1.000	
Week 2 (3.81±1.13)	Week 3 (3.69±0.91)	0.12 (3.15%)	0.232	-0.12 Very small	1.000	

SE= Standard error; * p < .05; ** p < .01; ***, p < .001.

In relation to the athletes' performance in the target competition, no significant difference was observed between the GSG and PSG groups after the polishing period (Figure 1).

Figure 1. Athletes' performance by Sleep Group (GSG and PSG) based on the IPS of the target competition



GSG= Good sleep group; PSG= Poor sleep group

Dicussion

During adolescence, the biological adjustments of development lead to significant hormonal fluctuations, which, along with behavioral patterns, can result in psychophysiological changes, leading to alterations such as sleep quality (Viner *et al.*, 2019; Hrozanova *et al.*, 2023). Sports practice in educational and participatory dimensions seems to be an important ally in controlling sleep in adolescents, contributing to improvements in psychobiological conditions (De Mello *et al.*, 2004; Rosa *et al.*, 2021). However, the demands required by competitive sports suggest that it may exacerbate conditions that affect sleep quality (Vitale *et al.*, 2019).

When evaluating the sleep quality of adolescents practicing swimming from the perspective of competitive sports, the present study observed that 46.67% of the subjects had poor sleep when assessed close to a competition (21 days before), without finding differences between men and women. These data corroborate the study by Halson & Juliff (2017), which observed that 52% of elite athletes (across various sports) had poor sleep, with no significant differences between genders, which was attributed to the stressful conditions of competitive sports.

According to Fullagar *et al.* (2015), the psychophysiological conditions of stress caused by training are responsible for altering athletes' sleep patterns. Among the stressful factors, sleep can have a negative influence on sports performance. Excessive demands for results and the deprivation of necessary social interaction due to sports demands are psychosocial conditions directly related to changes in sleep. This is compounded by physiological issues, especially the pro-inflammatory responses to the strenuous effort of competitive practice.

To minimize the stress caused by training, the polishing phase (a period of 3 to 4 weeks preceding a target competition) aims to reduce the psychobiological impact of training load on the athlete (De Mello *et al.*, 2004). This is done by reducing the workload in order to enhance the physical, technical, tactical, and psychological capacities of the athlete, adequately preparing them for the target competition (Maglischo, 2010).

Upon observing differences in the evolution of sleep quality through daily monitoring of sleep-wake parameters during the polishing phase between groups, we identified a significant difference ($p=0.001$) in TST in week 3, with 16.75% more in the PSG group compared to the GSG. These values contrast with those found in week 1, where, although with a small difference of 0.72%, the GSG had a higher TST. When comparing athletes from both groups, we found a significant difference ($p=0.001$; $ES=1.52$; 18.65%) between week 1 and week 3, highlighting an evolution over the polishing period. These findings suggest that adjustments in the psychobiological demands of the polishing phase may contribute to a better condition for athletes with poor sleep, allowing for relaxation and increased TST during this training period.

Resources that promote relaxation contribute to better quality of restorative sleep (Morin *et al.*, 2012), enabling athletes with sleep problems to improve their performance by achieving more effective recovery. This is because during sleep, metabolic recovery processes occur that optimize the efficiency of physiological systems, allowing them to meet the athlete's hypermetabolic demands more effectively, which in turn contributes to better performance (Fullagar *et al.*, 2015).

Associated with TST, SE is an important marker for determining the subject's sleep quality as it represents the total time spent sleeping while lying down. The tension of approaching competition can directly influence SE, affecting athletes' performance (Smithies *et al.*, 2021). When comparing SE between the weeks of the study athletes, we identified a small reduction between week 1 and week 2 ($p=0.039$; $ES=-1.10$; 4.15%). However, there were no differences between week 2 and 3, nor between week 1 (baseline) and week 3. Therefore, we suggest that the polishing phase was able to maintain athletes' SE even as the competition approached.

SL is an important precursor of sleep quality. As reference values, Albqoor and Shaheen (2021) recommend an SL of up to 30 minutes for significant and restorative sleep. When comparing the study groups, we observed that PSG presented higher SL values in week 1 ($p=0.030$; $ES=1.08$; 77.20%), in week 2 ($p=0.020$; $ES=1.30$; 129.89%), and in the cumulative of the weeks ($ES=0.84$; 67.74%). When quantitatively stratifying the SL values at baseline, both groups were within the indicated reference values, with GSG averaging 16.10 ± 9.98 minutes and PSG 28.50 ± 13.30 minutes, with a difference of 77.20%; a difference that reduced to 67.74% in the cumulative of the three weeks (reduction of 9.73%), although both groups increased the SL time.

The increase in SL in both groups as the target competition approached is an expected component, attributed to pre-competitive stress and anxiety (Albqoor *et al.*, 2021). However, the reduction in the difference between the groups (GSG and PSG) when comparing the baseline with the cumulative suggests that the adaptations promoted by the polishing period contribute to improvements in sleep quality for athletes who initially had poor sleep.

Another significant difference found in the present study was regarding WASO, with the GSG group showing higher values in week 2 ($p=0.001$; $ES=2.17$; 17.16%) and in the cumulative of the weeks ($ES=1.11$; 10.31%). Both groups showed a reduction in WASO values when comparing the baseline ($GSG=21.40 \pm 1.09$; $PSG=19.50 \pm 3.31$) with the cumulative of the weeks ($GSG=19.40 \pm 1.00$; $PSG=17.40 \pm 2.52$), evidenced by comparing the difference in WASO between the beginning and end of the polishing phase ($p=0.001$; $ES=-1.79$; 20.91%).

Such differences can be justified by the fact that intense physical effort can trigger a pro-inflammatory and oxidative response, as well as an increase in lactate production, which are determining factors in reducing the amount of REM sleep and increasing WASO (Fullagar *et al.*, 2015). The reduction in WASO due to psychophysiological adjustments made during the polishing period may contribute to the decrease in inflammatory, oxidative response, and lactate production, favoring an increase in REM sleep. This, in turn, can contribute to athletes' performance by improving cognitive function and emotional control (Weinberg, 2023),

fundamental aspects for competitive performance. These factors may have a direct influence on individual sports modalities, such as swimming, which require greater emotional control (Chandrasekaran *et al.*, 2020).

Although no significant difference was demonstrated, the evolution of daytime sleepiness during the polishing phase showed a positive trend. In week 1, PSG had daytime sleepiness 6.86% higher than GSG, while in week 3 the values equalized, resulting in a null effect size ($ES=0.00$; 0.00%). According to Gwyther *et al.* (2022) poor sleep leads to increased daytime sleepiness, which exacerbates feelings of fatigue and, consequently, impairs athletic performance. The fact that athletes with poor sleep matched the levels of daytime sleepiness to those with good sleep suggests that the polishing phase contributes to an improvement in the sleep pattern of athletes who initially had poor sleep, which can directly favor athletes' performance. In terms of athletes' performance in the target competition, based solely on the IPS, no difference in outcome was observed between athletes from GSG and PSG. This suggests that any performance differences that athletes might have had due to differences in sleep quality were minimized during the polishing phase, aligning the psychobiological conditions of both groups.

Conclusions

The results highlight that a significant portion of the young swimmers experienced sleep problems close to the competition, and no significant performance differences were observed between the GSG and PSG groups. There was a notable improvement in sleep quality throughout the tapering period, with significant increases in TST and SL among athletes with poor sleep. Additionally, there was a maintenance of SE and a reduction in WASO as the competition approached. These findings emphasize the importance of interventions that prioritize sleep quality as a strategy to reduce potential performance disparities.

The results underscore the relevance of monitoring and optimizing sleep patterns, especially during critical periods such as tapering, to minimize the impact of external factors that affect recovery and performance. Furthermore, the maintenance of sleep efficiency (SE) and the reduction of WASO during tapering highlight the possibility that adjustments in the sleep-wake cycle can contribute to improving athletes' overall recovery status.

The study also points to the need for more comprehensive investigations into the impact of individual and environmental variables, such as psychological aspects and training conditions, on athletes' sleep quality. Future research could explore practical interventions that integrate sleep monitoring, behavioral strategies, and psychological support to maximize athletic potential. These efforts are crucial for enhancing the understanding of the relationship between sleep and sports performance, as well as providing practical tools for coaches and support teams in promoting both well-being and athletic performance.

The study's limitations primarily focus on the sample, which consisted exclusively of young swimmers, limiting the generalizability of the results to other sports or age groups. Additionally, individual variables, such as psychological or environmental characteristics, were not considered, despite their potential impact on the athletes' sleep quality.

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