ABSTRACT

Introduction: Circadian rhythms can impact athletes’ sports performance, where the plateau occurs between 15 and 21 hours. Swimming is a peculiar case, as athletes perform training and final sessions in competitions at different times, as in the Rio2016 Olympic Games for example, where the semifinal and final competitions took place from ten o’clock at night. Objectives: (1) to present the protocol of an intervention performed with elite athletes of the Brazilian swimming team during the 2016 Olympic Games in Rio; (2) to find out whether the time at which the competitions were held affected the swimming performances of these athletes during the competition. Materials and Methods: Fourteen athletes of the Brazilian swimming team (males: n= 10; 71% and females: n= 4; 29%) participated in the study. They were followed up during two preparation periods (baseline and intervention) for the 2016 Olympic Games in Rio during June and July 2016. During the competition, we recorded the Reaction Time (RT) and Competition Time (CT) of each athlete in different modalities. The intervention strategies used were light therapy and sleep hygiene. The values of RT at the starting block and CT were registered and conferred with the official results. Results: The athletes showed a decrease in the total time awake (Δ = -13%; Effect size [ES] = 1.0) and sleep latency (Δ = -33%; ES = 0.7), and an increase in total sleep time (Δ = 13%; ES = 1.1; p = 0.04) between the baseline and the period of the intervention, pre-competition. We identified an improvement in the RT (Δ = -2.2% to -1.0%; ES = 0.2 to 0.5) during the competition only for the athletes who participated in the competition finals. Conclusion: We conclude that the intervention carried out was effective in mitigating any negative influence of competition time on the RT and CT of elite athletes of the Brazilian swimming team. Level of evidence II; Prospective comparative study.

Keywords: Sports performance; Athletes; Actigraphy; Chronobiology.
INTRODUCTION

In human beings, the biological rhythms are observed in different physiological, mental, physical and behavioral processes. In the physiological process, these rhythms modulate the entire metabolism, influencing the development of strength, hormonal secretions, autonomous nervous system’s activity, among others. Considering that circadian changes implicate in adjustments of the biological clock and the meaning of the circadian rhythms or its diurnal variations of approximately 24 hours, would also have an impact upon the sporting performance of athletes, amateurs or high performance athletes.1,2

The circadian variation on the sporting performance has been researched since the end of the 60’s, with major emphasis from the 90’s.1 The consensus is that the majority of the physical performance rhythms reaches a plateau between 3:00 - 9:00 p.m. At the end of afternoon or beginning of night, the body temperature, the strength and flexibility are in acrophase (major peaks), contributing to a better performance at this time.4 Additionally, the circadian rhythms may be influenced by external factors, called zeitgebers, such as light and dark phases of the day, application of exogenous light, time of food ingestion and physical exercise, as well as the regular physical training in specific time.5,11

Among the sporting modalities, swimming is considered a peculiar case when one observes the influence of time to train and performance. Swimmers perform their first training session in the morning (for example, 6:00-8:00 a.m.) and another session at the end of the afternoon, between 4:00 - 6:00 p.m. Results from different studies have indicated improvement on the times of sprint during the day, with a peak at the beginning of the night. These daily variations oscillate from 3 to 21.2%, depending on the population.4,5,7-11 However, the circadian variation upon the psychomotor performance can also suffer the influence of other factors, such as sleep deprivation of restriction, duration of the warming up, working time or time for familiar commitments.4,5

From the point of view of sporting competition, for the swimmers who competed in the modalities of 50, 100 and 200m, to participate in the finals of these modalities, they must swim in the elimination session during the morning and the semifinals during the period of afternoon/night, of the same day. The swimmers classify for the finals, will have to compete during the afternoon/night of the following day. This fact made trainers and physical assistants to prescribe trainings that would coincide with the same time as the competitions were to take place. We must also point out that the competition timetable is, sometimes, defined to conform to the typical activities of spectators and TV audiences, in detriment of the athletes. An example of this happened during the last Olympic Games in Rio 2016, where the swimming semifinals and finals took place from 10:00 p.m. Concerning this, Rosa et al.7 pointed out the potential negative effects of the night competitions upon the sporting performance of the athletes during the Games. These authors recommended the development of specific activities for this competition, once these events during the night time have never occurred in the history of the Olympic Games. Therefore, the present study has two main objectives: (1) to present the protocol of the conducted intervention with the elite athletes of the Brazilian swimming team during the Olympic Games in Rio 2016; (2) to compare whether the time of the games interfered on the sporting performance of the athletes during the Olympic Games Rio 2016.
Light therapy (or phototherapy) involves the exposition to light wavelengths for a determined period of time in a specific time of the day, allowing for a change of phase in the individual’s circadian rhythms.\textsuperscript{18} We used in the present study, glasses model Re-Timer\textsuperscript{19} with light 100% free of UV rays and 2,500 lux, at a distance of 5 cm from the eye. Additionally, a room of the Olympic District was adapted to receive the athletes for their light therapy. This room was characterized by: Light, 100% free of UV rays with LED lamps (9,500 lumens) and environment with 10,000 lux. The time of exposition was of 30 continuous minutes, between 6:00 and 7:00 p.m., during the period of intervention and during the Olympic Games.

The strategy of sleep hygiene is a method utilized for the re-education of necessary habits for a good sleep night.\textsuperscript{20,21} It refers to behavioral aspects, environment conditions and other factors that are related to sleep and that might promote better quantity and quality of sleep.\textsuperscript{21} The sleep hygiene strategies utilized in the present study were based on previous work with elite athletes\textsuperscript{20,21} and performed during 10 consecutive days. Therefore, the athletes followed the recommendations, such as: air-conditioned room, dark and silent; use of masks for eyes and ear plugs; strategic naps during the afternoon; avoid watching TV before sleeping, use of computer or cell phones in bed; create sleep routine, sleep and waking up always at the same time; avoid caffeine approximately 4-5 hours before sleeping; do not consume any liquid before going to bed; use of dark glasses after the training conducted during the light phase of the day.

The results of the swimming events of the selected athletes were organized taking into consideration the days and times of the competition. The values of RT on the starting block and CT, were registered and confirmed with the official results, displayed in the Rio2016’s Swimming Results Book.

Statistical analysis

The results are shown by means of descriptive statistics (average ± standard deviation, confidence interval [CI 95%] and frequency distribution). We used the normality test (D’Agostino & Pearson omnibus normality test) to verify the data distribution. The effect size (ES) was calculated based on the baseline results, as well as the percentage difference (Δ%). For comparison between RT and CT among the elimination phases versus semifinals, we used the paired t-test. The Anova test (repeated measures) was used to compare the results of RT and CT between the elimination phases versus semifinals versus finals. We considered 5% the probability of an error type I.

RESULTS

In relation to the athletes’ chronotype, they were classified as indifferent (n = 9; 64%), moderate morning (n = 3; 21%), morning (n = 1; 7%) and moderate afternoon (n = 1; 7%). From the point of view of the evaluated periods of quantity and quality of sleep (Table 1), the athletes demonstrated a decrease in the total time awake (Δ = -13%; ES = 1.0) and sleep latency (Δ = -33%; ES = 0.7) and increase in total sleep time (Δ = 13%; ES = 1.1; p = 0.04) between the baseline and the pre-competition period of intervention.

Table 2 shows the comparative results between the elimination phase versus semifinals for RT and CT.

There were no differences between the results of RT and CT when we compared the three phases of the competition. (Table 3)

| Table 1. Results of the variables of quality and quantity of sleep in swimming athletes (n = 14). |
|---------------------------------------------------------------|
| **Baseline** | **Pre-competition** | **P** | **Δ** | **ES** |
| Total time awake (hours) | 12.09 ± 1.31 | 10.31 ± 1.18 | 0.07 | -13% | 1.0 |
| TTS (hours) | 6.30 ± 0.49 | 7.21 ± 0.47 | 0.04* | 13% | 1.1 |
| Efficiency (%) | 82 ±9 | 85 ± 13 | 0.59 | 3% | 0.2 |
| Latency (minutes) | 35 ± 13 | 24 ± 20 | 0.14 | -33% | 0.7 |
| Awakenings (minutes) | 42 ± 16 | 40 ± 20 | 0.86 | -4% | 0.1 |

TTS = total sleep time; * p < 0.05.

DISCUSSION

In the present study, we present the elaborated intervention protocol for the elite athletes of the Brazilian swimming team to conform to the new time of competition in the Olympic Games Rio 2016. Besides, we have also investigated if there were any differences between the RT and CT of the athletes in relation to their competition timetable. We identified improvement for the RT (Δ = -2.2% à -1.0%; ES = 0.2 to 0.5) during the competition only for the athletes who participated in the finals of their competition. Our intervention (sleep hygiene) also offered improvement upon the variables of quality and quantity of sleep. Evidences point out that room light, per se, associated with the use of smartphones, watching TV during the night may delay the sleep phase and reduce sleep quality as well as sleep quantity. In general, during the training days and transmeridian trips, as well as, before and during sporting competitions, the sleep time decreases and there are impairments upon the sleep quality and the sporting performance as well.\textsuperscript{16,22} This was also demonstrated in the athletes of the present study during the baseline period. However, after the present intervention, it was possible to observe improvement upon the evaluated sleep variables.

We observed improvement in the total time awake (decrease), sleep latency (decrease) and total sleep time (increase). Sleep is a fundamental biological component for cognition, energy restoration and brain energetic metabolism.\textsuperscript{21} In relation to the rhythm wake-sleep, for example, during the REM, there is cognitive restoration (learning and memory)\textsuperscript{24} as well as, peaks of release of testosterone hormone.\textsuperscript{25} During Non-REM sleep (NREM), there is huge release of the growth hormone (GH) promoting tissue restitution and several other benefits,\textsuperscript{23} which demonstrates the importance of the night sleep for the consolidation of the biological processes, mainly in athletes. Although sleep reestablishes psychological, cognitive and physiological functions that are considered critical for a best recovery and psychomotor performance, other behavioral and environmental situations might interfere on athletes’ sleep.\textsuperscript{25} In relation to chronotype, the majority of the athletes (64%) were classified as indifferent, which facilitated the temporary alteration of the training timetables, without causing many problems for the athletes. The state of entrainment the circadian rhythm is the main factor of performance.\textsuperscript{22} The participant athletes of the present study were preparing themselves for the Olympic Games Rio 2016 and training twice a day, during time of the competition events. With this, the fact of delaying athlete’s sleep became fundamental for competitions that were taking place during night. This strategy was part of the intervention that contributed for athlete’s preparation for games.
Scientific literature has suggested light therapy in order to entrain the circadian rhythm, delaying or advancing the phase of the sleep-wake cycle. Several studies have reported that single pulses of bright light during determined times, are capable of generating important circadian alterations,2,29 primarily caused by the entrainment of the core temperature phase or the suppression of the release of the melatonin hormone.28 The application of light at the beginning of the end of the subjective night/ beginning of morning, promotes the temporal entrainment (delaying or advancing phase) of the sleep-wake cycle.8,9 In the present study, the athletes received light at the beginning of the subjective night (biological) with the intent of delaying the biological clock for the competitions. Literature’s reported results have evidenced improvement upon sporting performance at the beginning of the night.1,5,7 In a study conducted with swimmers, it was verified that the performance was better at night for athletes who regularly trained at night, meanwhile, the performance’s circadian variation was abolished in individuals who trained only during the morning.6 This fact corroborates with the findings of our study, mainly because we conducted the interventions at the same timetable stipulated by the Olympic Games’ competition calendar and observed that the results of RT and CT did not suffer any decline. In swimming, these variables are indispensable for speed and power competitions. This way, we can point out that the application of light and the performing of training during the time of the events were able to maintain the times of release and of competition of those athletes in the swimming events, demonstrating therefore the efficacy of this intervention. Light per se, especially the light with short-wavelength (fluorescent light) acts acutely on the increase of the wake state.29 Additionally, the adaptations to the training are bigger during the day on which the training is regularly conducted.11 Improvements anteriorly reported in the sporting performance during the afternoon and beginning of the night, may be attributed to the manipulation of body temperature11,13 or to changes the circadian rhythms.5 Moments of major alert and attention, quick response to a stimulus, major muscle strength, better aerobic and anaerobic power, as well as better parameters of flexibility, coincide with the acrophase of core temperature.13 The elevation of core temperature promotes vasodilation, increases the blood supply to muscles, improving glycolysis, glycogenolysis and muscle strength.30 Facing this context, the literature points out that psychomotor performance is influenced by the circadian rhythm of the core temperature.29 Therefore, from the point of view of Chronobiology, the entrainment of the circadian rhythm of the core temperature to the time of the targeted event, contributes for the improvement or the maintenance of sporting performance obtained during the daily training sessions and we were able to demonstrate that the interventions of sleep hygiene, light applications and the alteration of the training timetable to coincide with the exact time of swimming competitions, were capable of maintaining the results of RT and CT in the Olympic Games Rio 2016, which may have occurred in function of the physiological alterations and a possible entrainment of the phase.

CONCLUSION

We concluded that the presented intervention was effective in minimizing any effect of the time of competition upon the performance of RT and CT of elite athletes of the Brazilian swimming team. This way, we suggest that the sporting calendar and the time of the events be considered at the moment of the sporting planning for athletes of the swimming team, in order for the athletes may always be able to express their best sporting performance, not influenced by circadian factors.

ACKNOWLEDGMENTS

The authors would like to thank Universidade Federal de Minas Gerais (UFMG), Centro de Estudos em Psicobiologia e Exercício (CEPE), Centro Multidisciplinar em Sonolência e Acidentes (CEMUSA), FUNDEP/UFMG, CNPq, CAPES, Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG), Comitê Olímpico do Brasil (COB) and Laboratório do Comitê Olímpico do Brasil for support and assistance with this research.

All authors declare no potential conflict of interest related to this article.

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