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Sleep quality and pain after different types of acute aerobic exercise

Qualidade do sono e dor após diferentes tipos de exercício aeróbico agudo

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Abstract – The study aimed to evaluate the effects of single continuous running and interval running on the sleep profile of healthy young males. Twelve young and healthy university students were recruited. Initially, they underwent an anthropometric assessment and answered a battery of questionnaires to trace the psychobiological profile (Epworth Sleepiness Scale, Pittsburgh Sleep Quality Index, Mini-Sleep Questionnaire, STAI-trait, Insomnia Severity Index, and IPAQ). After an initial evaluation, the volunteers were submitted to three situations: basal (without exercise), continuous running (30 minutes, 12-14 on the Borg Scale), and interval running (6 bouts of 2.5 min x 2.5 min, 15-17 on the Borg Scale). In the three conditions, they answered four questionnaires the following day upon waking up: Sleep diary, STAI-state, Visual Analogue Pain Scale, and Total Recovery Quality Scale. When analyzing the Total Recovery Quality Scale in both runs, significant results indicated that the volunteers did not feel completely recovered. However, significant results for pain level, sensation upon waking, and the sleep diary only after the continuous run. This study confirms the theory of body restoration since the volunteers had a more restful sleep after performing the most intense exercise than after continuous running. Thus, high-intensity interval exercise can be used in training to improve sleep quality.

Key words: Physical exercise; Sleep; Sleep quality; Running.

Resumo – *O objetivo deste estudo foi avaliar os efeitos da corrida contínua e da corrida intervalada no perfil de sono de jovens saudáveis do sexo masculino. Foram recrutados 12 universitários, jovens e saudáveis. Inicialmente, foram submetidos a uma avaliação antropométrica e responderam uma bateria de questionários para traçar o perfil psicobiológico (escala de sonolência excessiva de Epworth, índice de qualidade de sono de Pittsburgh, mini questionário do sono, IDATE-traço, índice de gravidade de insônia e IPAQ). Após a avaliação inicial, os voluntários foram submetidos a três situações: basal (sem exercício), corrida contínua (30 minutos, 12-14 na escala de Borg) e corrida intervalada (seis tiros de 2,5 min x 2.5 min, 15-17 na escala de Borg). Nas três condições, eles responderam quatro questionários na manhã seguinte ao acordar: diário do sono, IDATE-estado, escala analógica visual de dor e escala de qualidade total de recuperação. Foram encontrados resultados significativos ao se analisar a escala de qualidade total de recuperação em ambas as corridas, indicando assim que os voluntários não se sentiram completamente recuperados, mas foi apenas após a corrida contínua que resultados significativos foram observados para nível dor, sensação ao acordar e no diário de sono. Neste estudo, foi confirmada a teoria de restauração do corpo, uma vez que após a realização do exercício mais intenso, os voluntários tiveram um sono mais reparador do que após a corrida contínua. Assim, conclui-se que o exercício intervalado de alta intensidade pode ser utilizado no treinamento para também melhorar a qualidade do sono.*

Palavras-chave: *Exercício físico; Sono; Qualidade do sono; Corrida.*

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INTRODUCTION

Sleep represents an emergent set of many physiological processes under primarily neurobiological regulation that impact many physiological systems and occupies between 20% and 40% of the daily routine[1], distributed in the stages of NREM (non-rapid eye movements) and REM (rapid eye movements)[2]. This biological process plays a critical role in systemic brain and physiological functions, including metabolism, appetite regulation, and functioning of immune, hormonal, and cardiovascular systems[3]. Sufficient duration, good quality, adequate regularity, and absence of disturbances are important resources for identifying healthy sleep[4].

While pharmacologic interventions are a common treatment for sleep disorders[5], exercise is a low-cost and nonpharmacologic intervention readily available to most adults, offering a potential complementary or alternative approach for improving sleep that is particularly appealing in a public health setting[6].

In this context, three theories address the role of physical activity in the sleep profile and body recovery. The first is the thermoregulation theory, which states that physical exercise at an intensity average of 70% of VO_2max would increase body temperature[7]. Such an increase would generate a sequence of reactions such as vasodilation, increased sweat production, and reduced metabolic rate[7]. By decreasing the temperature, the body ends up creating an adequate environment for the beginning of sleep, generating higher slow-wave sleep (SWS) and total sleep time (TST), as well as lower REM sleep, sleep onset latency (SOL), and wake-after sleep onset (WASO)[8].

The second energy conservation theory postulates that both the total sleep time and the intensity of SWS increase proportionally to the energy expenditure before the sleep period[7]. Thus, sleep takes on the role of saving energy or preventing energy stores from being depleted[7].

Finally, the third theory of body restoration complements the second. The theory of body restoration predicts that sleep should facilitate the recovery of damage caused to the body during the waking period[7]. Thus, highly catabolic activities during the day would facilitate a highly anabolic sleep[9].

Hence, this study aims to investigate the effect of aerobic exercise intensity on the sleep profile of healthy men.

METHOD

Subjects

Twelve healthy young, lean men between 18 and 25 years of age and physically active (who practiced physical exercise for at least one year, twice a week) were recruited from the academic community of UNIFESP – Baixada Santista (through online sharing in social media and e-mail). Exclusion criteria covered history of any chronic medical condition, sleep disorder, or a BMI> 29.9 kg/m^2. All volunteers were informed about the research, and those who agreed to participate signed an informed consent form. The protocol was written following the standards established by the Declaration of Helsinki, and the study was approved by the Ethics Committee of the Federal University of São Paulo / Hospital São Paulo (UNIFESP) (# 1686-08).

Procedures

Pre-experimental protocol

Initially, the volunteers answered a battery of sleep profile assessment questionnaires and a questionnaire that assessed habitual physical activity levels. For this purpose, we applied the Epworth Sleepiness Scale[10], the Pittsburgh Sleep Quality Index[10], the Insomnia Severity Index[11], the Mini Sleep Questionnaire[12], the State-Trait Anxiety Inventory (STAI)[13], and the International Physical Activity Questionnaire (IPAQ - short version)[14]. Before applying these instruments, it was recommended that all volunteers answered them honestly, ensuring the total confidentiality of their responses.

Following the questionnaires, to assess if they met the inclusion criteria, the volunteers underwent an anthropometric evaluation, performed using a digital scale Orange Tech® model YHF6331C, an anthropometric measuring tape Cescorf®, and a stadiometer Sanny® model Standart.

Experimental protocol

The volunteers were submitted to a crossover protocol under three different conditions: baseline – evaluation in the morning after a regular sleep night in a day without exercise; continuous running – evaluation in the morning after a regular sleep night in a day with continuous running for 30 minutes in moderate intensity (12 to 14 in Borg Scale of Perceived Exertion); and interval running – evaluation in the morning after a regular sleep night in a day with interval running in high intensity (1:1) with 2.5 minutes running in 15 to 17 in Borg Scale of Perceived Exertion separated by 2.5 minutes active recovery (Figures 1A and 1B). Four questionnaires were applied for all conditions: Sleep Diary[15], The State-Trait Anxiety Inventory (STAI)[13], Visual Analog Scale for Pain[16], and Recovery Total Quality Scale[17].

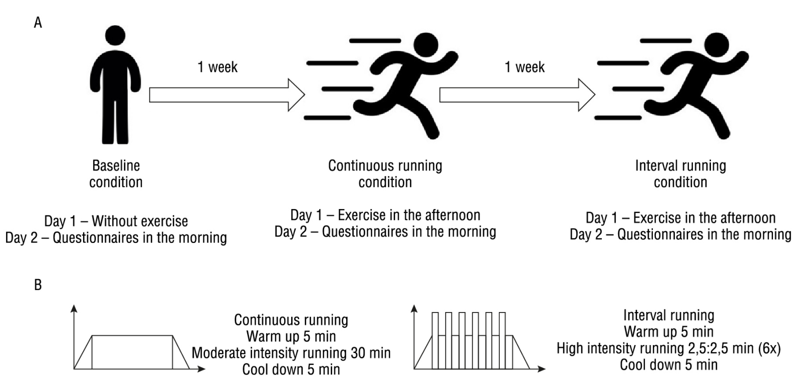

Figure 1. Study Design.

Statistical analysis

The normality curve was determined by the Shapiro-Wilk Test. Following the data being classified as normal, a descriptive analysis was performed, followed by one-way ANOVA with Duncan Test. The data were then presented as mean ± standard deviation, at a significance level of $p < 0.05$, with an The effect size of ($\eta2$) ≥ 0.30 and observed power of (ω) ≥0.80. All analyses were conducted on Statistica version 12.0.

RESULTS

Table 1 shows the data results for the sample composed of young, eutrophic individuals with a low waist-to-hip ratio, indicating low cardiovascular risk.

Table 1. Sample characteristics.

Variables	Mean ± S.D.
Age (years)	23.58 ± 1.90
Weight (kg)	79.85 ± 8.64
Height (m)	1.79 ± 0.06
BMI (kg/m2)	24.91 ± 2.75
Neck circumference (cm)	38.17 ± 1.91
Waist circumference (cm)	82.26 ± 5.44
Hip circumference (cm)	99.88 ± 5.03
Waist-hip ratio (score)	0.82 ± 0.03

S.D. = standard deviation; BMI = Body Mass Index; kg = kilograms; m = meters; cm = centimeters.

Table 2 shows the data on the psychobiological profile and level of physical activity. The sample consisted of physically active individuals with a medium level of trait anxiety. Regarding sleep, the sample presented daytime sleepiness considered normal and a threshold score for insomnia; however, according to two questionnaires (PSQI and Mini Sleep Questionnaire), individuals had good sleep.

Table 2. Baseline Assessment.

Variables	Mean ± S.D.
IPAQ (MET)	4574.27 ± 3101.87
STAI Trait (score)	37.75 ± 10.82
ESS (score)	8.92 ± 3.87
PSQI (score)	4.83 ± 3.81
ISI (score)	7.25 ± 5.10
Mini-Sleep (score)	21.42 ± 4.19

S.D. = standard deviation; IPAQ = International Physical Activity Questionnaire; STAI = State-Trait Anxiety Inventory; ESS = Epworth Sleepiness Scale; PSQI = Pittsburgh Sleep Quality Index; ISI = Insomnia Severity Index; MET = Metabolic Equivalent of Task.

Figure 2 presents the results for the psychobiological parameters (sleep, anxiety, pain, and recovery). The sleep diary score showed the main effect [$F_{(2,30)}$=3.87; p=0.03; $\eta2$=0.31] with lower scores for the continuous running condition compared to the baseline condition (p=0.01). Meanwhile, the Visual Analog Scale for Pain showed the main effect [$F_{(2,31)}$=3.48; p=0.04; $\eta2$=0.18] with higher scores in the continuous running condition compared to the baseline condition (p=0.01). Moreover, the Recovery Total Quality Scale showed the main effect [$F_{(2,32)}$=3.78; p=0.03; $\eta2$=0.19] with higher scores in the baseline condition compared to both exercise conditions (p=0.02). In turn, no difference was found for the STAI state score.

Figure 3 presents the results of the domains of the sleep diary. The sensation after waking up showed the main effect [$F_{(2,33)}$=3.43; p=0.04; $\eta2$=0.17] with lower scores observed in the continuous running condition compared to the baseline condition (p = 0.02). No differences were found for sleep quality, sleep latency, or total sleep time.

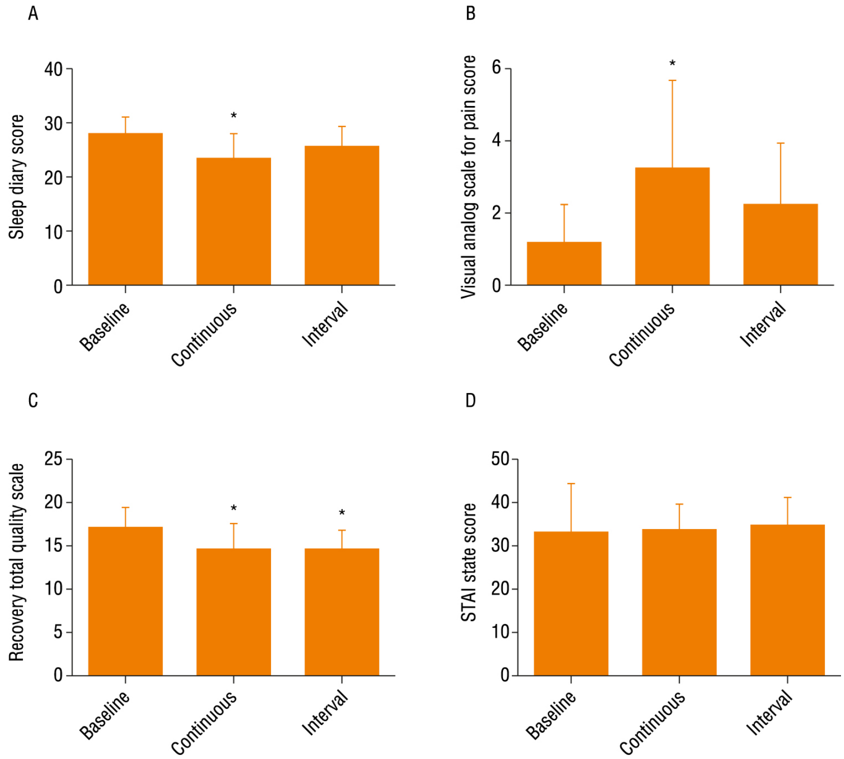

Figure 2. Psychobiological parameters. Note: * different from baseline, $p < 0.05$

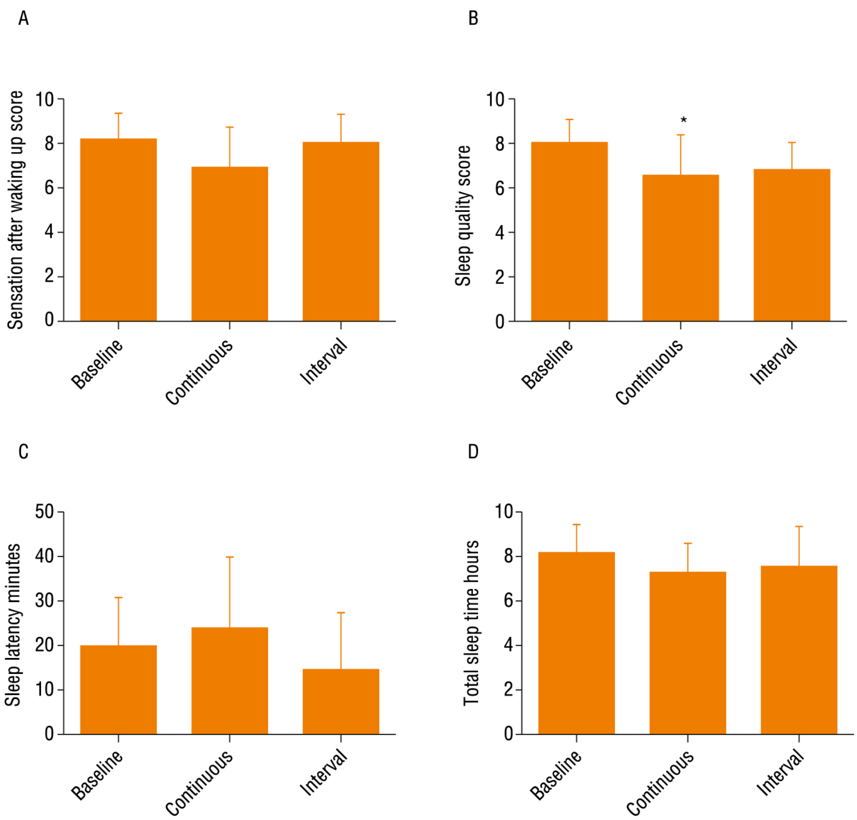

Figure 3. Domains of the sleep diary. *different from baseline, $p < 0.05$.

DISCUSSION

This study aimed to evaluate whether different acute physical exercise protocols could cause changes in the sleep profile, anxiety, perception of pain, and recovery after exercise in young males. In terms of sleep diary, a difference was observed when comparing the protocols of continuous and interval exercises, with the experimental condition of continuous exercise showing a worsening of the scores compared to the baseline condition, suggesting that sleep was worse after continuous running and had no significant changes in interval running. Regarding the Total Quality of Recovery Scale, both protocols had significant results compared to the baseline, indicating that the subjects did not feel completely recovered upon waking up. However, it was only after continuous running that the sensation upon waking up and the late pain scores were significantly worse than the baseline, even though the volunteers slept for a similar number of hours in all situations. In turn, the results for anxiety showed no significant differences between the groups.

Physical exercise and sleep have a bidirectional relationship in which one can influence the other; for this reason, regular physical exercise is one of the main strategies for sleep hygiene[18]. The time at which the exerce is performed is among the factors involved in its beneficial effects. According to the American Sleep Association[19], high-intensity exercise performed at night can increase arousal at bedtime and impair subsequent nighttime sleep, and it should be done at low or moderate intensity. In contrast, for those who have good sleep quality, vigorous exercise performed close to bedtime does not seem to affect sleep and may even increase the amount of deep sleep[20]. As our study was conducted with young, healthy individuals who had good sleep quality, the intense running performed in the afternoon did not affect the subjects' sleep quality. From another point of view, intense exercise affects the periphery and brain metabolic systems, with the metabolic demand exceeding the metabolic supply, and increased formation of adenosine from AMP. Hence, adenosine depresses neuronal activity through pre- and post-synaptic actions, thus facilitating sleep[21]. However, in the moderate run, the volunteers showed decreased sleep quality and a worsening sensation when waking up. The increased perception of pain and decreased recovery scores could be an explanation to such findings. Pain after exercise can directly influence sleep quality, and the mechanisms can be explained by a biopsychosocial model involving factors such as positive and negative effects, dopamine concentrations in the brain, opioid systems, degree of inflammation, age, ethnicity, and sex[22]. Consequently, the recovery result of sleep can be influenced by the increase in pain since this recovery can be determined by three factors: total sleep time, sleep quality, and circadian rhythm[23]. Therefore, continuous running may have triggered more pain, which impaired the sleep of these subjects and made them feel less recovered the next day.

Delayed onset muscle soreness (DOMS) is a marker of common cell damage, although the mechanisms involved are yet to be fully understood. It usually appears after exercise-induced muscle damage within eight to 24 hours after the session, with peaks between 24 and 48 hours, generally decreasing within 96 hours[24]. Muscle pain sensations can result from a complex interaction of damage to muscle structure, interrupted calcium homeostasis (Ca^{2+}), and sensitization of inflammatory cell infiltrate nocioceptors[25].

Farias et al.[26] studied different exercise intensities, as in our study, and found no difference between the situations of interval exercise (10 x 60 seconds at 90% of maximum speed / 60 seconds in active recovery at 30% of maximum speed) and continuous exercise (20 min at 60% of maximum speed) at DOMS. Although the interval protocol is performed at high intensity, the exercise session is characterized by low volume, half of which is characterized as active recovery, suggesting that the lower exercise volume may have minimized muscle damage, inflammatory response, and, consequently, the magnitude of DOMS in the participants[26]. Conversely, continuous exercise performed uninterruptedly subjects the muscle fibers to a stimulus with an eccentric component of the running longer compared to the interval exercise, considering the total time of the session in running exercise.

As expected, compared to the control situation, situations with volunteers being submitted to exercise showed a negative result since the exercise stimulus, whether continuous or interval, is characterized as a stressor stimulus to the human organism, providing metabolic and muscular changes aimed at adjusting and mediating homeostatic interruptions in an exercise session[27]. Thus, the body needs an average period of 24 to 96 hours to fully recover from the stimulus of the acute session, and the post-exercise data collection herein was carried out a little more than 12 hours after the individuals performed the exercise, which could explain this result[25,27].

Regarding the volunteers' mood, the anxiety assessment showed that the continuous and interval exercises did not change the average levels of anxiety observed in the baseline situation. The literature shows that regular physical exercise is an alternative to improving mood and decreasing anxiety levels[28]. Aerobic exercise is one of the best strategies for people looking to improve their mood. However, we found no differences in anxiety levels after the two running conditions, possibly because the volunteers in our research are already physically active and healthy, therefore, a single exercise session cannot decrease their anxiety levels.

In addition to anxiety, the motivational aspect must be considered when explaining the relationship between exercise and psychobiological aspects. In the scope of physical exercise, motivation can be understood as the result of the interaction of social, environmental, and individual factors, which will determine the choice for a particular modality and the intensity to be practiced[29]. Bartlett et al.[30] compared continuous running and interval running and concluded that the exercise performed with interval is significantly more motivating than the one performed continuously, which is important for individuals to continue the program. As much as in our study, we do not assess the subjects' motivation; thus, it is worth noting that upon motivation, physical exercise improves other aspects of mood, which could be reflected in sleep as well. Thus, interval running may have been more motivating than continuous running, and this motivational factor could explain the different responses reached after continuous and interval exercises.

Our study included young, healthy, physically active individuals who underwent an exercise protocol in an external environment without direct assessments of sleep or mood. This prevents us from enlarging our findings to other populations or other types of exercise physiologists. Therefore, further studies should address the control of the exercise environment, covering different populations and other exercise times, as well as other sleep and mood assessments (polysomnography, actigraphy, and blood biomarkers), which could help explain the mechanisms involved in the benefits promoted by the practice of physical exercise.

Therefore, we conclude that interval running can represent an option for training physically active individuals, promoting more restful sleep without causing damage to anxiety and increasing the chances of adhering to a training program.

COMPLIANCE WITH ETHICAL STANDARDS

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee –Universidade Federal de São Paulo/ Hospital São Paulo, and the protocol (no. # 1686-08) was written following the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflicts of interest to declare.

Author Contributions

Study design and planning: SPSJ, HKMA; Conducting experiments: SPAJ, HKMA; Data analysis: SPSJ, HKMA, JFTS, IDS; Contribution with reagents/ materials/analysis tools: HKMA, ST; Manuscript writing: SPSJ, HKMA, JFTS, IDS, ST.

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