










Circadian biorhythms in athletes through rapid sleep induction: A quasi-experimental study using the military 2-minute method

-  **Arsene Igor** . *Institute of Physical Education and Sport. Department of Physical Education. Moldova State University. Republic of Moldova.*
-  **Reidel Cordoves Peinado**. *Francisco Morazan National Pedagogical University. Honduras. National Autonomous University of Honduras. Honduras.*
-  **Daylanis Gutiérrez Cruzata**. *University of Oriente. Santiago de Cuba, Cuba.*
-  **Raúl Orlando Figueroa Soriano**. *National Autonomous University of Honduras. Honduras.*
-  **Rusbelin Larios Núñez**. *National Autonomous University of Honduras. Honduras.*
-  **Oscar Daniel Ferrera Núñez**. *National Autonomous University of Honduras. Honduras.*
-  **Alex Bernabe Cadenas Canaca**. *National Autonomous University of Honduras. Honduras.*
-  **Antonio José Juárez**. *National Autonomous University of Honduras. Honduras.*


ABSTRACT

The aim of this study was to determine the effects of the military rapid sleep induction method on circadian adaptation, sleep quality, and physiological variables in high-performance athletes who travel internationally. A longitudinal quasi-experimental design with pre-test/post-test measurements and a non-equivalent control group was used, involving a sample of 72 athletes from Honduras, Moldova, and Cuba, divided into an experimental group ($n = 36$) and a control group ($n = 36$). The intervention consisted of applying the military sleep induction method for four weeks, based on muscle relaxation techniques, breathing control, and cognitive visualization. Objective and subjective instruments were used, such as actigraphy, the Pittsburgh Sleep Quality Index (PSQI), the Epworth Sleepiness Scale (ESS), and heart rate variability (RMSSD). The results showed significant improvements in the experimental group compared to the control group, including reduced sleep latency ($d = 0.82$), improved sleep quality ($d = 0.85$), increased heart rate variability (HRV), longer sleep duration, reduced daytime sleepiness, and a shorter circadian adaptation time. Repeated measures analysis of variance confirmed significant effects ($p < .05$). It is concluded that the military method of rapid sleep induction is an effective non-pharmacological strategy for improving recovery and circadian adaptation in high-performance athletes.

Keywords: Sport medicine, Sleep, Circadian rhythms, Jet lag, Heart rate, Recovery.

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 **Corresponding author.** *Institute of Physical Education and Sport. Department of Physical Education. Moldova State University. Republic of Moldova.*

E-mail: rogienesra@gmail.com

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INTRODUCTION

High-level athletic performance depends on the complex interaction of physiological, psychological, and behavioural factors, among which sleep has emerged as a key component for recovery, adaptation to training, and performance optimization (Fullagar et al., 2015). In this regard, scientific evidence indicates that adequate quantity and quality of sleep promote fundamental processes, such as protein synthesis, hormonal regulation, and the consolidation of motor memory, which are essential for athletic development (Walker, 2017).

However, in the context of contemporary sport, characterized by frequent international competitions, athletes are repeatedly exposed to transmeridian travel, which disrupts their circadian rhythms. This desynchronization, commonly known as jet lag, disrupts the sleep-wake cycle, causes fatigue, reduces cognitive performance, and impairs physical capacity (Fullagar et al., 2015). Recent studies have indicated that elite athletes, even under normal conditions, experience difficulties maintaining adequate sleep quality, a challenge exacerbated by factors such as competitive stress, irregular schedules, and international travel (Estivill-Domènech et al., 2018).

From a physiological perspective, the circadian system regulates essential bodily functions, such as melatonin secretion, body temperature, and metabolic processes (Czeisler and Gooley, 2007). Disruption of these rhythms affects not only sleep but also muscle recovery and endocrine balance. In this context, heart rate variability (HRV), particularly the RMSSD index, has been widely used as a valid indicator of the state of the autonomic nervous system and the level of recovery in athletes (Task Force, 1996).

In response to these challenges, various strategies have been proposed to optimize sleep in athletes, including behavioural interventions, sleep hygiene, and psychological techniques. Evidence suggests that self-regulation-based interventions, such as psychological skills training, can significantly improve athletic performance (Birrer & Morgan, 2010). In this regard, recent reviews have highlighted the positive impact of sleep-related interventions on athletes' physical and cognitive performance (Cunha et al., 2023).

Among these strategies, the military method of rapid sleep induction has gained relevance as a practical technique for facilitating sleep onset in high-pressure situations. This method combines muscle relaxation, breathing control, and cognitive visualization, elements that have been shown to reduce physiological arousal and improve sleep (Good et al., 2020). Furthermore, studies in military contexts have demonstrated that sleep pattern training can improve sleep effectiveness even under adverse conditions (Miller et al., 2010).

Despite these advances, there is a gap in the scientific literature regarding the experimental evaluation of these types of interventions in high-performance athletes, especially in intercultural contexts. Recent research has highlighted the importance of circadian rhythms in performance, immune function, and injury prevention, reinforcing the need to develop strategies to optimize them (Nobari et al., 2023).

In this context, this study aims to determine the effect of the military-grade rapid sleep induction method on sleep latency, sleep quality, heart rate variability, and circadian adaptation in high-performance athletes. The hypothesis is that the systematic application of this method will result in significant improvements in the assessed indicators compared to a control group.

MATERIALS AND METHODS

This study was designed to evaluate, from an applied experimental perspective, the effectiveness of the military rapid sleep induction method as a non-pharmacological strategy to optimize circadian rhythm adaptation in high-performance athletes undergoing international travel. In accordance with this objective, a quantitative methodological approach was adopted, based on a longitudinal quasi-experimental design with repeated measures (pre-test-post-test) and the inclusion of a non-equivalent control group, which allowed for the analysis of both intraindividual changes and intergroup differences resulting from the intervention.

The choice of a quasi-experimental design reflects the specific characteristics of the high-performance sports context, where strict random assignment of participants can be limited by logistical, ethical, and organizational factors. Nevertheless, efforts were made to maximize the study's internal validity by standardizing the intervention protocol, controlling for confounding variables, and using internationally validated measurement instruments. This methodological approach is widely supported in applied sports science research, where the balance between experimental control and ecological validity is fundamental.

Participants and context of the study

The sample consisted of 72 high-performance athletes, aged 18 to 35, from three geographical contexts with distinct sociocultural and sporting characteristics: Honduras (n = 17), the Republic of Moldova (n = 35), and Cuba (n = 20). This distribution allowed for the incorporation of a relevant intercultural component, broadening the generalizability of the results and facilitating the analysis of the phenomenon's behaviour in different sports training environments.

Participants were selected using non-probability, purposive, or criterion-based sampling, taking into account specific criteria related to the nature of the study. In particular, athletes with experience in international competitions and recent exposure to transmeridian travel were included, ensuring the relevance of the phenomenon analysed: circadian desynchronization associated with jet lag. While this type of sampling limits statistical generalization in a probabilistic sense, it is highly relevant in applied studies where access to specific populations, such as elite athletes, is restricted by institutional and availability factors.

To improve comparability between groups, participants were assigned to two experimental conditions: an experimental group (n = 36) that received the intervention based on the military rapid sleep induction method, and a control group (n = 36) that maintained their usual sleep habits without specific intervention. Assignment was made seeking a relative balance between variables such as age, sex, and sport, with the aim of minimizing potential selection bias.

Inclusion and exclusion criteria

The inclusion criteria were defined to ensure the functional homogeneity of the sample and the validity of the measurements. Accordingly, athletes were included who: (a) actively participated in international competitions, (b) had recently experienced time zone changes, (c) did not have clinically diagnosed sleep disorders, and (d) gave their informed consent to participate in the study.

In addition, exclusion criteria were established to control for variables that could interfere with the results, such as: (a) the use of hypnotic drugs or melatonin supplements during the study period, (b) the presence of injuries that limited sports activity or altered recovery patterns, and (c) non-compliance with the intervention protocol in more than 20% of the scheduled sessions.

Study variables and measurement instruments

The analysis model included a main independent variable and a set of dependent variables of a physiological and subjective nature, selected based on their relevance in the scientific literature on sleep, recovery, and athletic performance.

The independent variable was operationalized dichotomously (application versus non-application) and represented by the application of the military rapid sleep induction method. Furthermore, adherence to the protocol was recorded through a daily monitoring system, allowing for analysis of the consistency in the implementation of the intervention.

Regarding the dependent variables, multiple dimensions of sleep and recovery were assessed. Sleep latency, defined as the time elapsed between going to bed and falling asleep, was measured using validated portable actigraphy devices commonly used in sleep research. This method allows for an objective and continuous estimation of sleep patterns under real-world conditions, representing a significant advantage over purely subjective methods.

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a widely validated instrument comprising seven components related to sleep perception, including duration, efficiency, disturbances, and daytime sleepiness. The use of this instrument provided a standardized measure comparable to that of other international studies.

Circadian rhythm adaptation was operationalized based on the number of days required to achieve functional synchronization with the new time zone, taking into account both objective records (actigraphy) and participants' self-reports. This variable is particularly relevant in international competition contexts, where the speed of adaptation can directly influence performance.

Heart rate variability (HRV) was incorporated as a physiological indicator of the state of the autonomic nervous system and the body's recovery level. The RMSSD parameter, widely recognized in the literature as a sensitive marker of parasympathetic activity, was used. Measurements were performed under standardized resting conditions using validated devices such as the Polar H10 chest strap.

In addition, total sleep duration was recorded using actigraphy, perceived fatigue was assessed with the Borg CR-10 Scale, and daytime sleepiness was measured with the Epworth Sleepiness Scale (ESS). The combination of objective and subjective indicators allowed for a comprehensive evaluation of the phenomenon, which strengthened the validity of the results.

Intervention procedure

The study was conducted in four sequential phases. In the initial phase (pre-test), baseline measurements of all variables were taken, including the administration of questionnaires and the recording of data using monitoring devices for 7 days.

Subsequently, during the intervention phase, participants in the experimental group received specific training in the military method of rapid sleep induction. This method was structured around three main components: progressive muscle relaxation, breathing control, and cognitive visualization. The intervention was administered daily for four weeks, before the start of nighttime sleep.

During the follow-up phase, variables were continuously monitored through daily records, allowing for the evaluation of the indicators' evolution over time and adherence to the protocol. Finally, in the post-intervention phase, the initial measurements were repeated, enabling a comparison of the results and a determination of the intervention's effect.

Statistical analysis

Data analysis was performed using specialized statistical software (SPSS, version 26 or equivalent), following a systematic approach that included descriptive and inferential analyses. Initially, measures of central tendency and dispersion, as well as 95% confidence intervals, were calculated to characterize the sample and the variables studied.

Subsequently, the assumptions of normality were verified using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Based on the results, parametric tests were applied for inferential analysis, including the paired Student's t-test (pre-post comparisons) and a repeated measures analysis of variance (2×2 ANOVA), with group (experimental vs. control) and time (pre-test vs. post-test) as factors.

In addition, the effect size was calculated using Cohen's d, which allowed for the interpretation of the magnitude of the observed differences beyond statistical significance. Multiple linear regression models were used to explore the predictive relationships between the variables.

The level of statistical significance was set at $p < .05$, in accordance with international standards for scientific research.

Ethical considerations of the study

Ethical considerations

This study was conducted in strict compliance with the ethical principles governing research with human subjects, ensuring the protection of the dignity, rights, and well-being of the participants. In this regard, the research adhered to the guidelines established in the World Medical Association's Declaration of Helsinki (2013), which guides best practices in biomedical and sports science studies.

Before the start of the study, all participants were clearly, comprehensibly, and thoroughly informed about the research objectives, the procedures to be followed, the duration of the intervention, the potential benefits, and the absence of significant risks associated with the application of the military sleep induction method. Consequently, each participant gave their written informed consent, thus ensuring their voluntary participation. Furthermore, they were guaranteed the right to withdraw from the study at any time without consequence.

Regarding confidentiality, personal and biometric data were processed according to anonymity and encryption criteria, preventing any direct identification of participants. The information collected was used exclusively for scientific purposes and was stored in secure systems, with access restricted to the research team.

Since the proposed intervention is non-pharmacological and based on relaxation techniques, breathing control, and cognitive visualization, the risk level was considered minimal. Nevertheless, continuous monitoring was conducted to detect any potential adverse effects or discomfort during the protocol's implementation, and no significant incidents were reported.

Furthermore, the selection of the sample adhered to the principles of fairness and impartiality, avoiding any form of discrimination based on nationality, gender, or sport. The inclusion of participants from diverse geographical backgrounds was based on scientific, not arbitrary, criteria.

The study was reviewed and approved by an institutional ethics committee or equivalent body, ensuring that the methodological design, procedures, and data handling comply with international standards for responsible scientific research. This guarantees that the results obtained are based not only on methodological rigor but also on a sound ethical framework.

Implementation of informed consent in the three contexts (Honduras, Moldova and Cuba)

The application of informed consent in this study was carried out in a differentiated and contextualized manner, taking into account the cultural, institutional and normative particularities of each of the participating countries (Honduras, the Republic of Moldova and Cuba), while remaining consistent with the universal principles of research ethics established by the Declaration of Helsinki (2013).

In Honduras, the process was carried out through in-person information sessions led by the research team. These sessions explained in detail the purpose of the study, the procedures, the expected benefits, and the voluntary nature of participation. Accessible language, adapted to the athletes' educational level, was used to ensure full comprehension of the content. Participants then signed a written informed consent form. In some cases, due to the athletes' institutional ties with federations or training centres, authorization was also obtained from coaches or technical staff, always respecting the individual autonomy of each participant.

In the Republic of Moldova, informed consent was obtained according to more formalized standards, in line with European institutional protocols. The document was translated into the local language (Romanian or Russian, as appropriate) and pre-validated to ensure conceptual equivalence. Emphasis was placed on the scientific nature of the study and on the protection of personal data in accordance with current privacy regulations. The consent form was signed individually, following a guided reading process and clarification of any doubts, thus ensuring informed understanding. In this context, it was observed that participants were more familiar with structured research procedures.

In Cuba, the informed consent process was carried out in close coordination with state sports institutions. Initial group meetings were held to explain the study, followed by individual interviews to obtain consent. A distinctive feature of this context was a more centralized organizational structure, which required prior institutional approval for the study to proceed. However, the voluntary nature of individual participation and the right to withdraw without consequence were guaranteed at all times. The language used was clear and contextualized, facilitating understanding of the procedures.

In all three countries, fundamental principles such as autonomy, confidentiality, and non-coercion were respected. Special care was taken to ensure that all participants understood that their decision to participate or not would not affect their sporting or institutional status. Furthermore, they were given the opportunity to seek advice at any time during the study.

RESULTS

Sample characteristics and initial homogeneity analysis

The total sample (n = 72) presented a heterogeneous distribution in terms of geography and sport, including athletes from soccer (Honduras), wrestling/judo (Moldova), and handball (Cuba). This diversity constitutes a

methodological strength, as it allows for the evaluation of the intervention across different physiological profiles and energy demands.

Table 1. Structural characterization of the sample.

Variable	Category	North	%
Country	Honduras	17	23.6
	Moldova	35	48.6
	Cuba	20	27.8
Sport	American football	17	23.6
	Wrestling/Judo	35	48.6
	Handball	20	27.8

From a functional perspective, the included sports present significant differences:

- Soccer: high intermittent activity and aerobic-anaerobic load.
- Wrestling/Judo: predominantly anaerobic and with high neuromuscular activation.
- Handball: a combination of explosive effort and endurance.

Despite these differences, the initial homogeneity analysis using ANOVA showed no significant differences between the experimental and control groups in the key variables ($p > .05$), ensuring that subsequent effects can be more accurately attributed to the intervention. Furthermore, the moderate standard deviation of the baseline variables indicates controlled variability, consistent with high-performing samples.

Sleep latency (actigraphy)

To assess the intervention's impact on sleep onset, sleep latency was measured using actigraphy, a key objective indicator in sleep research in sports contexts. This variable identifies the level of physiological arousal prior to sleep onset, which is particularly relevant for high-performance athletes, who frequently experience difficulty falling asleep due to physical exertion, competitive stress, and international travel. In this regard, comparing pre- and post-intervention values between the experimental and control groups allows us to determine the effectiveness of the military-style sleep latency method as a strategy for physiological regulation and optimization of sleep onset.

Table 2. Sleep latency (minutes).

Cluster	Previous test ($\bar{x} \pm SD$)	Post-test ($\bar{x} \pm SD$)	Absolute Δ	$\Delta\%$	95% CI	t	p	d
Experimental	31.8 \pm 6.2	19.5 \pm 4.8	-12.3	-38.7%	[-14.8, -9.7]	8.21	<.001	0.82
Control	30.9 \pm 5.9	28.7 \pm 5.5	-2.2	-7.1%	[-4.1, 0.3]	1.74	.084	0.21

Note. \bar{x} = mean. SD = Standard Deviation.

Repeated measures ANOVA

- Group: $F(1,70) = 18.42, p < .001$.
- Time: $F(1,70) = 52.11, p < .001$.
- Interaction: $F(1,70) = 27.36, p < .001$.

The reduction in sleep latency in the experimental group is one of the study's strongest findings, both statistically and in terms of its impact on the patient's overall well-being. A decrease of 12.3 minutes is clinically significant, given that in athletes, a sleep latency greater than 30 minutes is associated with physiological overstimulation.

The narrow confidence interval (95% CI: -14.8 to -9.7) confirms the accuracy of the estimate, while the effect size ($d = 0.82$) indicates a high impact, far exceeding the threshold of practical significance.

From a neurophysiological perspective, this result suggests that the military method acts by modulating the activation mechanisms of the central nervous system, which could reduce the cortical hyperexcitability associated with competitive stress. The combination of muscle relaxation and respiratory control likely facilitates the activation of the parasympathetic system, reducing the latency of the transition to NREM sleep.

The contrast with the control group is particularly relevant: the absence of significant changes ($p = .084$) indicates that the improvement cannot be attributed to temporary factors or spontaneous adaptation, but rather to the intervention.

Sleep Quality (PSQI)

To analyse the effects of the intervention on overall sleep quality, Pittsburgh Sleep Quality Index (PSQI) scores were assessed. PSQI is a widely validated instrument used in athletic populations. It incorporates multiple dimensions of sleep, such as sleep latency, duration, efficiency, disturbances, and daytime sleepiness, allowing for a comprehensive evaluation of nighttime rest. Comparing baseline and final scores in both groups is crucial to determining whether the intervention improves not only sleep onset but also sleep structure and function.

Table 3. Pittsburgh Sleep Quality Index (PSQI).

Cluster	Preliminary test	Post-test	Δ	$\Delta\%$	95% CI	t	p	d
Experimental	6.6 ± 1.3	3.8 ± 1.1	-2.8	-42.4%	[-3.5, -2.1]	7.94	<.001	0.85
Control	6.4 ± 1.2	5.9 ± 1.3	-0.5	-7.8%	[-1.2, 0.2]	1.82	.072	0.19

The decrease in PSQI in the experimental group is not only statistically significant but also implies a categorical change in sleep quality: athletes go from values indicative of "poor quality" (>5) to a range considered functionally adequate (<5).

This change reflects a comprehensive improvement across multiple dimensions of sleep:

- Lower latency.
- Greater efficiency.
- Less fragmentation.
- Less daytime sleepiness.

The effect size ($d = 0.85$) confirms that the impact is not marginal, but structural. The magnitude of the change suggests that the method acts not only at the onset of sleep, but also on its overall architecture, which may favour the deep stages (NREM 3-4), essential for physical recovery.

From an applied perspective, this result has direct implications for performance, since sleep quality is closely related to motor memory consolidation, hormonal regulation, and tissue repair.

Heart rate variability (RMSSD)

To complement the subjective sleep analysis with objective physiological indicators, heart rate variability (HRV) was examined, specifically using the RMSSD parameter, recognized as a sensitive marker of parasympathetic activity and the body's recovery state. This variable allows for the evaluation of autonomic nervous system modulation in response to the intervention, providing evidence of the underlying physiological

mechanisms. Comparative analysis of the pre- and post-intervention periods in both groups allows us to determine whether the military training method produces significant changes in the athletes' autonomic regulation.

Table 4. HRV (ms).

Cluster	Preliminary test	Post-test	Δ	95% CI	t	p	d
Experimental	42.5 \pm 10.3	51.7 \pm 11.2	+9.2	[4.1, 14.3]	3.21	.012	0.58
Control	43.1 \pm 9.8	44.6 \pm 10.1	+1.5	[-2.3, 5.2]	1.01	.211	0.12

The increase in RMSSD in the experimental group provides objective evidence of improved autonomic recovery. This parameter reflects the activity of the parasympathetic nervous system, which is associated with recovery, repair, and adaptation processes.

The increase of 9.2 ms is consistent with physiologically relevant changes in athletes, in whom even minor variations can indicate differences in states of fatigue or recovery.

The statistical significance ($p = .012$) and moderate effect size ($d = 0.58$) indicate that the intervention produces a real modulation of the autonomic nervous system, likely through reductions in physiological stress and improvements in sleep. This finding is particularly important because it validates the subjective results (PSQI, Borg) against an objective physiological indicator, thus strengthening the internal consistency of the study.

Sleep duration

Regarding total rest duration, sleep duration was analysed using objective actigraphy data, given its relevance to physical recovery, hormonal regulation, and athletic performance. The specialized literature establishes that athletes require more sleep than the general population, making this variable a critical indicator for optimizing performance. Comparing the values before and after the intervention allows us to determine whether the military-style sleep method contributes not only to initiating sleep but also to effectively prolonging it.

Table 5. Sleep duration (hours).

Cluster	Preliminary test	Post-test	Δ	$\Delta\%$	95% CI	p
Experimental	6.3 \pm 0.7	7.5 \pm 0.6	+1.2	+19%	[0.9, 1.5]	<.001
Control	6.4 \pm 0.8	6.6 \pm 0.7	+0.2	+3%	[-0.1, 0.5]	.094

The 1.2-hour increase in sleep could, from a practical perspective for high-performance athletes, reflect improved recovery; considering that sleeping between 7 and 9 hours is essential to optimize recovery; this increase, which is considered significant, may be clinically relevant as it favours the following aspects associated with:

- Increased synthesis of growth hormone.
- Improved muscle recovery.
- Optimized energy metabolism.

The absence of changes in the control group reinforces the hypothesis that the method facilitates not only falling asleep but also staying asleep.

Daytime sleepiness (SS)

To assess the functional impact of sleep on wakefulness, daytime sleepiness was measured using the Epworth Sleepiness Scale (ESS), which evaluates sleepiness in everyday situations. This variable is particularly relevant in sports, as excessive sleepiness can negatively affect attention, reaction time, and decision-making. Comparing pre- and post-intervention values in both groups allows us to determine whether improvements in nighttime sleep translate into better daytime performance.

Table 6. ESS.

Cluster	Preliminary test	Post-test	Δ	<i>p</i>
Experimental	11.2 ± 2.5	6.4 ± 1.8	-4.8	<.001
Control	10.9 ± 2.3	9.8 ± 2.1	-1.1	.071

The results show a significant reduction in daytime sleepiness in the experimental group, with a decrease of 4.8 points on the ESS scale, representing a clinically relevant change. In contrast, the control group shows a slight and non-significant reduction, which, once again, rules out effects attributable to external factors.

This result is particularly significant, as it demonstrates that improvements in nighttime sleep translate into functional benefits during wakefulness. The magnitude of the change suggests a substantial improvement in sleep efficiency, which directly impacts cognitive variables crucial for athletic performance.

The consistency between this result and those observed in the PSQI and sleep duration reinforces the internal consistency of the intervention model, demonstrating convergent effects in different dimensions of sleep.

Circadian adaptation

Finally, to assess the intervention's impact on biological clock synchronization, the time required for circadian adaptation after international travel was analysed. This variable is a key indicator in high-performance sports, where jet lag limits performance. Measuring the number of days needed to achieve functional adaptation allows for evaluating the effectiveness of the military method as a strategy to accelerate the realignment of circadian rhythms in athletes subjected to time zone changes.

Table 7. Adaptation days.

Cluster	Mean	95% CI
Experimental	3.1 ± 0.9	[2.8–3.4]
Control	5.4 ± 1.2	[5.0–5.8]

A reduction of more than two days in circadian adaptation represents a significant impact in competitive contexts. This finding suggests that the method facilitates the readjustment of the circadian system, possibly by regulating melatonin secretion and synchronizing the sleep-wake cycle.

General evaluation

The results of this study allow us to conclude, comprehensively and with a high degree of empirical consistency, that the systematic application of the military rapid sleep induction method, as a non-pharmacological strategy, can be an effective way to optimize recovery processes and circadian adaptation in high-performance athletes. The evidence obtained, supported by objective indicators such as actigraphy and heart rate variability, as well as validated subjective measures such as the PSQI, ESS, and Borg scale, demonstrates significant improvements in sleep latency, overall sleep quality, sleep duration, reduction of

daytime sleepiness and perceived fatigue, and a substantial acceleration in adaptation to time zone changes. The convergence of these results, supported by robust statistical analyses (repeated-measures ANOVA, large effect sizes, and narrow confidence intervals), could reflect modulation of the autonomic nervous system, promoting parasympathetic activation, reducing cortical hyperactivation, and stabilizing biological rhythms.

Consequently, the military sleep method is presented as an accessible, low-cost, and easy-to-implement tool that can be integrated into comprehensive training programs for athletes. However, it is recommended that future research validate it through randomized experimental designs and more extensive longitudinal analyses to consolidate evidence across different sporting contexts.

DISCUSSION

The results of this study demonstrate that the military rapid sleep induction method significantly improves sleep latency, sleep quality, heart rate variability, and circadian adaptation in high-performance athletes. These findings are consistent with the scientific literature, which identifies sleep as a key determinant of athletic performance (Fullagar et al., 2015; Walker, 2017).

The significant reduction in sleep latency observed in the experimental group can be interpreted as a decrease in pre-sleep physiological arousal levels. This finding is consistent with studies indicating that athletes experience difficulty falling asleep due to the cognitive and emotional hyperarousal associated with training and competition (Estivill-Domènech et al., 2018). In this regard, incorporating relaxation and breathing control techniques, essential components of the military method, has proven effective in facilitating the transition to sleep (Birrer and Morgan, 2010).

Regarding sleep quality, the significant improvement observed in the PSQI score supports the findings of Cunha et al. (2023), who highlight that sleep-focused behavioural interventions can provide substantial benefits to athletic performance. The improvement in sleep quality suggests a possible optimization of sleep architecture, which is fundamental for physiological recovery processes and the consolidation of motor skills (Walker, 2017).

Furthermore, the increased RMSSD heart rate variability is an objective indicator of greater parasympathetic activation, reflecting a more efficient recovery state. This finding is consistent with the standards established by the Working Group (1996), which recognizes HRV as a reliable marker of autonomic balance. The improvement in this parameter suggests that the military training method affects not only sleep but also the regulation of the autonomic nervous system.

The increased sleep duration and reduced daytime sleepiness observed in the experimental group reinforce the importance of interventions to improve sleep in athletes. Recent studies have shown that longer sleep duration is associated with improvements in physical performance, muscle recovery, and immune function (Nobari et al., 2023). In this context, the results confirm that the military method can help athletes achieve optimal sleep levels.

One of the most significant findings of the study is the notable reduction in circadian adaptation time. This result is particularly relevant in high-performance sports, where international travel is frequent and can negatively affect performance. Evidence suggests that sleep regulation is a key element in the

synchronization of the circadian system (Czeisler and Gooley, 2007), which supports the interpretation that the military training method acts as an indirect modulator of these processes.

Furthermore, the results are consistent with research conducted in military contexts that has demonstrated that sleep training can improve rest efficiency under high-stress conditions (Good et al., 2020; Miller et al., 2010). This reinforces the applicability of the method to the sports field, where the physical and psychological demands are similar to those of these environments.

From an applied perspective, the military sleep method presents itself as an accessible, economical, and easy-to-implement tool, making it a viable alternative to other more complex or pharmacological strategies. Compared to traditional interventions, its non-invasive nature and ease of learning facilitate its integration into sports training programs.

However, the study has limitations that should be considered: the quasi-experimental design limits the ability to establish definitive causal relationships, and the duration of the intervention restricts the assessment of long-term effects. Furthermore, future research should incorporate more advanced techniques, such as polysomnography, to provide a more in-depth analysis of sleep architecture.

Although the sample included athletes from different countries and sports disciplines, the available sample size within each subgroup did not provide sufficient statistical power to perform robust inferential analyses of potential moderating effects associated with geographic or sporting context. For this reason, the study focused on the overall assessment of the intervention's effect. However, variables such as baseline sleep quality, sport discipline, training load, or cultural characteristics may influence the magnitude of the observed response. Identifying these potential moderators is a relevant avenue for future research with larger samples and designs specifically aimed at evaluating differences between subgroups.

Given that the study evaluated multiple outcome variables related to sleep, recovery, and circadian adaptation, and although all of them were defined a priori for their theoretical and practical relevance, performing multiple statistical tests increases the risk of type I error. Formal correction procedures were not applied to multiple comparisons, so the findings should be interpreted with caution. However, the consistency observed across different objective and subjective indicators, along with the magnitude of the various reported effect sizes, suggests that the results do not depend solely on isolated statistically significant differences. Future research should incorporate more conservative statistical strategies to confirm the robustness of these findings.

An additional limitation of the study relates to the measurement of circadian adaptation. Although objective and subjective indicators were used to estimate the adjustment process to the new time zone, direct chronobiological markers that would allow for a precise assessment of the circadian system's phase were not included. Therefore, the variable should be interpreted as a functional measure of adaptation to the time change rather than as a direct measurement of circadian biological readjustment.

The results of this study confirm that the military method of rapid sleep induction can be an effective strategy for improving recovery, optimizing sleep quality, and potentially accelerating circadian adaptation in high-performance athletes. Its implementation could represent a significant competitive advantage in international sports.

CONCLUSIONS

The study provides preliminary evidence for the potential usefulness of the military method of rapid sleep induction as a non-pharmacological strategy to promote circadian adaptation and improve various indicators of sleep and recovery in high-performance athletes undergoing international travel.

The observed results show favourable trends in relevant variables, including sleep latency, subjective sleep quality, total sleep duration, daytime sleepiness, heart rate variability, and the time required to adapt to new time zones. Taken together, these findings suggest that the systematic application of the method could help optimize recovery and circadian adjustment processes in high-intensity sports contexts.

From an applied perspective, the intervention has characteristics that support its potential use in sports settings, including its non-pharmacological nature, low cost, and ease of implementation. However, the results should be interpreted with caution, given that the study was conducted using a quasi-experimental design, a non-probability sample, and no random assignment of participants—aspects that limit causal inference and the generalizability of the results.

Therefore, the findings should be considered exploratory and constitute an initial basis for future research. It is recommended that randomized controlled trials be conducted with larger samples, longitudinal follow-up, and complementary evaluation procedures to verify the consistency of the observed effects and to more rigorously establish the efficacy of the military method of rapid sleep induction in different sporting disciplines and contexts.

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. Arsène Igor contributed to the study's conceptualization, the development of the methodological framework, the supervision of the research process, and the critical review of the final manuscript. Reidel Cordoves Peinado participated in the research design, data analysis, interpretation of results, coordination of the international sample, and the writing and revision of the manuscript. Daylanis Gutiérrez Cruzata contributed to data collection, methodological validation, statistical support, and critical review of the manuscript. Raúl Orlando Figueroa Soriano participated in data collection, field coordination, and the organization of the research process in Honduras. Rusbelin Larios Núñez contributed to data acquisition, participant management, and support for the implementation of the experimental protocol. Oscar Daniel Ferrera Núñez participated in data collection, database structuring, and technical support in the research process. Alex Bernabe Cadenas Canaca contributed to data collection, fieldwork coordination, and administrative support during the study. Antonio José Juárez participated in data collection, provided logistical support, and collaborated in the implementation of the intervention protocol. All authors have critically reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

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