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Research Article

Sleep regularity and variability in wheelchair athletes: lockdown and return to sport

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HIGHLIGHTS

• During the COVID-19 lockdown, remote training was necessary to avoid physical loss.
• Sleep changes typically occur during shifts in the day-to-day routine.
• When returning to sport it is critical that athletes are screened for sleep changes, avoiding physical impairments.

ABBREVIATIONS

ASBQ-BR	Athlete Sleep Behavior Questionnaire
CI	Confidence Interval
d	Cohen's effect size
ESS	Epworth Sleepiness Scale
M	Mean
MEQ	Horne & Östberg chronotype
PSQI	Pittsburgh Sleep Quality Index
SD	Standard Deviation
SE	Sleep Efficiency
SRI	Sleep Regularity Index
TST	Total Sleep Time
WASO	Wake After Sleep Onset

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BACKGROUND: COVID-19 disrupted training routines and competitions, with unclear effects on the sleep of wheelchair athletes.
AIM: To compare sleep in professional wheelchair basketball players during lockdown (remote training) and after the return to in-person sport.
METHODS: Six players wore wrist actigraphy for 10 consecutive days at two time points: (1) lockdown and (2) ~2 months after return to sport. Daily sleep diaries and questionnaires were collected. Athletes showed good sleep quality in both periods (PSQI).
RESULTS: Group differences were not statistically significant (n=6), but directionally consistent, within-subject effects emerged: (i) higher sleep latency on training days during lockdown and (ii) greater total sleep time on rest days during lockdown. Daytime sleepiness (ESS) tended to be higher in lockdown.
INTERPRETATION: Despite stable perceived sleep quality, the return to organized training was associated with shorter sleep duration but lower sleepiness and reduced latency on training days, suggesting a shift toward more efficient, functionally restorative sleep with a structured routine.

KEYWORDS: Para-Athletes | Sleep | COVID-19 | Return to sport

INTRODUCTION

Regular physical exercise generally improves sleep quality; however, among athletes, factors such as high training loads, individual stressors, and constraints in personal life can impair sleep [1]. In 2020, the COVID-19 pandemic profoundly disrupted the training–sleep relationship. In Brazil, measures to mitigate viral spread included cancelling amateur and professional sporting events [2], compelling many athletes to train remotely at home to prevent declines in aerobic fitness, strength, flexibility, and other adaptations [3,4]. Social isolation also reduced training frequency and altered daily routines, with reports of longer time in bed, greater daytime sleepiness, and ~25% increases in sleep latency [5].

For wheelchair athletes, challenges were even more pronounced. With reduced face-to-face contact between athletes and staff, team dynamics deteriorated, and mobility barriers—exacerbated by limitations in public transportation—further restricted access to training resources [6]. These logistical constraints were compounded by comorbidities associated with physical disability (e.g., diminished respiratory capacity), which could aggravate COVID-19 outcomes and, together with reduced mobility, hinder adequate nutritional and physical conditioning [7]. Even outside pandemic contexts, wheelchair athletes often exhibit sleep changes across competitive periods—decreased total sleep time and efficiency and increased wake after sleep onset during competition compared with training or rest [8]. In addition, during the pandemic, heightened anxiety, perceived sport devaluation after event cancellations, and burnout were also reported, with implications for pain and injury risk [9,10].

Based on this context, we hypothesized that prolonged isolation—via increased sedentary behavior and screen exposure—would worsen sleep quality, whereas the gradual resumption of sport participation would be associated with improvements in sleep. Therefore, this study aimed to evaluate the sleep quality and sleep–wake rhythm of wheelchair basketball players at two time points: (1) during the COVID-19 pandemic, when athletes trained remotely at home, and (2) after their return to sport.

METHODS

Fifteen professional wheelchair basketball athletes from a nationally relevant club and Brazilian BCR draftees were invited. The protocol was approved by UNICAMP's Research Ethics Committee (4601042) and registered at ClinicalTrials (RBR-6jkk47); all participants provided written informed consent.

Data were collected in two phases:

(1) Lockdown — in the semester following the first year of restrictions, with home-based training delivered online (Google Meet), Mon–Fri 19:00–20:30.

(2) Return to sport — in months 1 and 3 after activities were authorized, with in-person physical/game training Mon, Tue, Thu, Fri 17:30–21:30.

Experimental Design

Athletes were recruited via the team's technical staff; those who agreed provided written informed consent. Online questionnaires were completed at two time points—during lockdown and ~60 days after the return to sport—including the Pittsburgh Sleep Quality Index (PSQI), Epworth Sleepiness Scale (ESS), Horne & Östberg chronotype (MEQ), and the Athlete Sleep Behavior Questionnaire (ASBQ-BR). In each phase, participants wore a wrist actigraph for 10 consecutive days and completed daily sleep diaries; all procedures followed COVID-19 safety protocols.

Experimental Procedure

Anamnesis: A baseline anamnesis questionnaire characterized the sample, covering injury type, functional classification, age, height, weight, diet, and any COVID-19–related routine changes.

Pittsburgh Sleep Quality Index (PSQI): It was used to quantify the subjective sleep quality in the previous month. This questionnaire consists of 19 questions grouped into seven groups with a scale of 0 to 3 each [11]. Individuals without sleep complaints were considered if their score ≤5. In addition to its score, the Pittsburgh questionnaire also assesses sleep latency and efficiency.

Chronotype Questionnaire: Horne and Östberg's questionnaire was used to classify athletes' chronotypes (evening, neither, morning). This questionnaire is composed of questions related to the times in which individuals prefer to carry out their day-to-day activities [12].

Epworth Sleepiness Scale: This questionnaire aims to analyze complaints related to excessive daytime sleepiness. The scale ranges from 0 to 3, in which 0 refers to no chance of falling asleep and 3, to the maximum chance of falling asleep [13]. Individuals with a total sum ≥10 are classified as people with high daytime sleepiness.

Athlete Sleep Behavior Questionnaire (ASBQ-BR): It aims to evaluate athletes' sleep behavior. It is composed of 18 questions with a score ranging from 1 to 5, in which 1 refers to "never" and 5, to "always"; after summing scores of ≤36 classified as having a good sleep behavior, whereas scores from 37 to 41 are classified as moderate sleep behavior and scores above 42, as poor sleep behavior [14].

Actigraphy: Sleep–wake patterns were assessed with a watch-like actigraph worn on the non-dominant wrist. The device uses a tri-axial 12-bit accelerometer sampled at 25 Hz, with data aggregated into 1-min epochs. Participants wore it 24 h/day to capture the activity–rest cycle, removing it only for water exposure and during training. Total sleep time, sleep latency, sleep efficiency, and wake after sleep onset (WASO) were derived in WatchWare, which identifies sleep onset/offset and awakenings using proprietary thresholds applied to movement, external/skin temperature, and light-intensity signals.

Sleep Diary: This questionnaire accompanying the actigraphy has questions regarding the quality of athletes' sleep [15].

Sleep Regularity Index (SRI): The sleep regularity index was used to analyze whether the athletes were in the same state (sleeping or awake) two or more times within the same 24-hour period. To achieve this index, a score ranging from 0 to 100 is used, in which the closer to 100, the more uniform the routine. This method classified athletes into regular, intermediate, or irregular sleepers [16].

Sleep Variability: Sleep variability is measured from night to night during the period wearing the actigraphy. To perform this measurement, the successive difference of the square root of each sleep variable during the nights was used, enabling the identification of possible sleep alterations [17].

Statistical Analysis

The results of this study are expressed as descriptive statistics for data analysis: mean (M) ± standard deviation (SD) and 95% confidence interval (95% CI). The Shapiro Wilk's normality test was performed to verify data distribution. A paired t-test was performed to compare the sleep-wake characteristics in both routines (lockdown and return to sport). Cohen's effect size (d) was used to determine trivial ($d < 0.2$), small ($0.2 < d < 0.5$), medium ($0.5 < d < 0.8$), and large ($d > 0.8$) effect sizes [18]. In addition to reporting effect sizes and

95% CIs, we conducted a post hoc sensitivity/power analysis for paired tests (α = 0.05, two-tailed). With n = 6, the minimal detectable effect at 80% power is Cohen's $dz \approx 1.4$; the observed effects yielded power ≈ 0.38–0.44.

RESULTS

Of the 15 invited players, our sample consisted of six male wheelchair basketball players due to lockdown restrictions and distance issues to reach every player's household. Participants were aged 34.83±10.16 years and 1.68±0.21-m tall with 76.56±22.77 Kg body mass and average of 12 years of practice in the modality.

Chronotype results showed that four athletes were moderate morning and two moderate evening chronotype.

Regarding the cause of their physical disability, athletes had scoliosis (1), spinal cord injuries (2), myelomeningocele (1), lower limb amputation (1), and poliomyelitis (1).

Table 1 summarizes self-reported sleep outcomes (PSQI, ESS, MEQ, ASBQ-BR) across lockdown and return to sport. Although no group-level differences reached statistical significance (all p > 0.05), daytime sleepiness (ESS) showed a moderate-to-large within-subject effect indicating higher sleepiness during lockdown (dz = 0.79).

Table 1. Questionnaire-based sleep metrics (PSQI, ESS, ASBQ-BR) during lockdown and after return to sport.

	Lockdown M± SD	Return to sport M± SD	P	Cohen's d	95% CI
PSQI Score	4.9±1.70	5.3±1.70	0.73	0.133	−0.616; 0.873
PSQI - Latency (min)	15.47±7.18	18.57±6.26	0.31	0.414	−0.376; 1.175
PSQI - Sleep Efficiency (%)	89.67±8.25	85.64±13.52	0.57	0.238	−0.535; 0.968
Epworth Score	9.22±3.36	7.3±3.35	0.08	0.786	−0.096; 1.162
ASBQ Score	36.35±3.17	34.97±3.21	0.21	0.529	−0.286; 1.307

Paired- sample T-test (p < .05). CI: confidence interval. Cohen's effect size (d): trivial (d < 0.2), small (0.2 < d < 0.5), medium (0.5 < d < 0.8), and large (d > 0.8). PSQI: Pittsburgh Sleep Quality Index, ABSQ: Athlete Sleep Behavior Questionnaire. Normality values for sleep variables according to OHAYON et al. (2017)[16]: Sleep latency <20 minutes and sleep efficiency >85%.

Table 2 presents actigraphy-derived sleep outcomes across lockdown vs. return to sport and by day type (training vs. rest). Although group-level comparisons did not reach statistical significance (all p > 0.05), we observed large within-subject effects for (i) sleep latency on training days—higher during lockdown (dz = 0.92)—and (ii) total sleep time on rest days—also higher during lockdown (dz = 0.98).

Table 2. Wheelchair basketball athletes' actigraphy results during lockdown and return to sport.

	Lockdown M ± SD	Return to Sport M ± SD	p	Effect Size	95% CI
GENERAL					
Latency (min)	26.592±9.031	29.635±24.525	0.696	−0.169	−0.968; 0.645
TST (min)	384.693±124.203	346.305±77.0.23	0.305	0.466	−0.402; 1.294
SE (%)	92.167±5.776	92.667±2.805	0.707	−0.162	−0.961; 0.652
WASO (min)	20.098±6.586	24.580±16.112	0.478	−0.313	−1.120; 0.524
TRAINING DAYS					
Latency (min)	30.477±12.489	16.503±10.929	0.073	0.922	−0.081; 1.867
TST (min)	387.497±96.028	361.753±98.683	0.477	0.314	−0.523; 1.122
SE (%)	91.500±6.156	94.000±2.757	0.236	−0.549	−1.393; 0.339
WASO (min)	31.437±23.321	25.320±17.520	0.255	0.525	−0.357; 1.363
REST DAYS					
Latency (min)	23.702±9.469	18.747±8.362	0.410	0.367	−0.480; 1.180
TST (min)	430.152±169.591	326.448±77.107	0.061	0.983	−0.042; 1.949
SE (%)	93.167±5.776	91.702±4.111	0.425	0.354	−0.490; 1.166
WASO (min)	29.902±32.235	23.030±16.556	0.405	0.371	−0.476; 1.185

Paired- sample T-test (p < .05). CI: confidence interval. Cohen's effect size (d): trivial (d < 0.2), small (0.2 < d < 0.5), medium (0.5 < d < 0.8), and large (d > 0.8). Normality values for sleep variables according to OHAYON et al. (2017): Sleep latency <20 minutes, sleep efficiency >85%, and wakefulness after sleep onset (WASO) <51 minutes.

During lockdown, the Sleep Regularity Index (SRI) among the six athletes ranged from 57.69 to 88.38 (mean 75.89 ± 11.48). After the return to sport, it ranged from 61.89 to 82.50 (mean 73.33 ± 7.67). The paired comparison showed no significant difference between periods (p = 0.55), with a small effect size (d = 0.25; 95% CI −0.56 to 1.06). Individually, three athletes increased their SRI (A1: 69.93→78.26; A2: 57.69→61.89; A4: 74.35→78.33), while three decreased (A3: 88.38→82.50; A5: 77.67→70.13; A6: 87.37→68.87).

During lockdown two athletes were classified as regular sleepers and one as irregular; after the return, all athletes fell within the intermediate regularity range.

When we analyzed the sleep variability of wheelchair basketball athletes, we found no statistical differences between the two moments, but we can observe that during the return to sport, athletes showed lower sleep variability for TST, latency, and WASO (Figure 1).

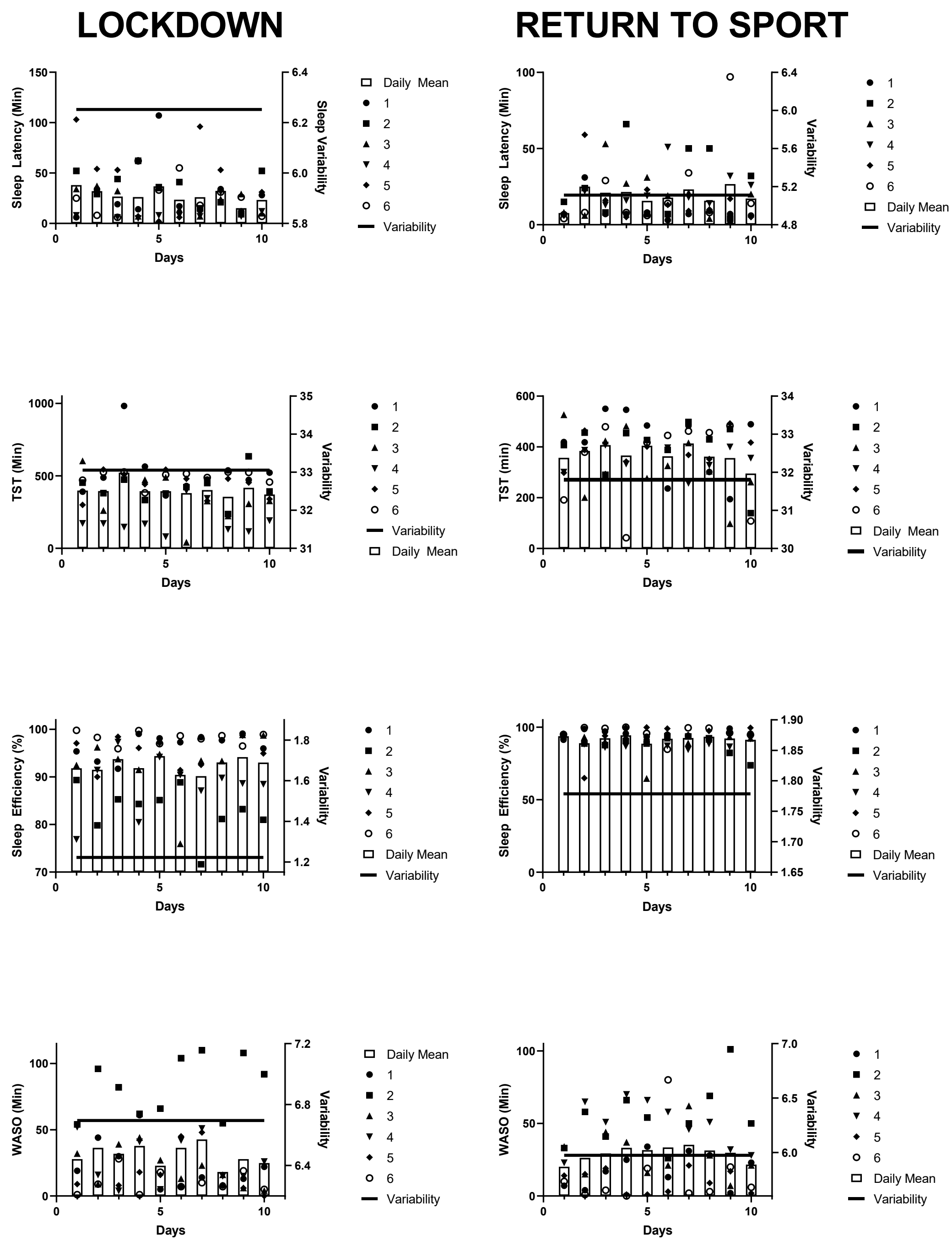

Figure 1. BCR athletes' sleep variability during lockdown and upon their return to sport. Wheelchair basketball athletes' sleep variability. The continuous line represents the variability of sleep in the analyzed period; the bars represent the daily averages of sleep variables and the symbols the daily values of each athlete.

DISCUSSION

This Research Note examined wheelchair basketball players' sleep quality, sleep–wake patterns, Sleep Regularity Index (SRI), and night-to-night variability during COVID-19 lockdown and after the return to sport. Although group-level differences did not reach statistical significance in this small sample, three directionally consistent patterns emerged—(i) good sleep quality in both periods (per Ohayon's criteria), (ii) lower total sleep time on rest days after the return vs. lockdown (dz = 0.98), and (iii) higher sleep latency on training days during lockdown vs. post-return (dz = 0.92)—indicating meaningful effects that likely fell below the detectable threshold for n = 6 rather than true null findings. SRI fluctuated across individuals, with only one athlete classified as "regular."

Mechanistic considerations. Pandemic restrictions cancelled events and prolonged isolation, disrupting training structure and social cues, both of which anchor circadian timing and habits [20,21]. Reduced daylight exposure and increased evening screen use during confinement plausibly delayed circadian phase and suppressed melatonin, lengthening sleep latency and elevating daytime sleepiness [22,23]. As activity resumed, re-established schedules and in-person sessions likely restored stronger zeitgebers and improved functional sleep despite shorter TST—consistent with athlete data showing more sleep and sleepiness in lockdown vs. better daytime functioning post-return [5,21]. Additionally, exercise timing and intensity can modulate sleep: evening sessions generally do not harm sleep, but vigorous work finishing ≤1 h before bedtime may prolong latency—a pattern compatible with our training-day effects [22,23]. Finally, sleep regularity is sensitive to stable daily timing and light cues; shifts from remote (19:00–20:30) to in-person (17:30–21:30) training could explain the SRI oscillations observed [24,25].

Our actigraphy results align with reports in able-bodied and Paralympic cohorts: athletes typically sleep longer on rest days than on training days and often exhibit higher latency on training days, patterns we also observed [22,23]. In Paralympic samples, differences in TST and WASO across routine phases are common; here, TST differences emerged, while WASO did not [8].

Limitations include the small sample size and pandemic-era constraints on recruitment/scheduling, which limit statistical power and generalizability. Given the small sample (n = 6), a post hoc sensitivity analysis indicated that achieving 80% power would require very large effects (Cohen's dz ≈ 1.4; see Methods); therefore, non-significant tests are compatible with limited power rather than definitive evidence of no effect. Even so, objective monitoring across two real-world phases provides pragmatic insight into how routine structure and timing cues modulated sleep in wheelchair basketball.

CONCLUSION

In conclusion, players maintained good sleep quality across the transition. The return to organized training was associated with shorter TST but lower daytime sleepiness and reduced latency on training days, suggesting that schedule regularity, social/zeitgeber restoration, and appropriate exercise timing support more efficient, functionally restorative sleep. Future work should experimentally test whether stabilizing training times, daytime light exposure, and evening screen hygiene improve SRI and daytime functioning in larger Paralympic samples.

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