

Chronobiology International

The Journal of Biological and Medical Rhythm Research

ISSN: 0742-0528 (Print) 1525-6073 (Online) Journal homepage: www.tandfonline.com/journals/icbi20

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To cite this article: Liza Rozman , João Barreira , João Brito , Júlio A. Costa & Cátia Reis (17 Mar 2026): High evening smartphone use drives sleep debt and lower morning affect in athletes, Chronobiology International, DOI: [10.1080/07420528.2026.2643807](https://doi.org/10.1080/07420528.2026.2643807)

To link to this article: <https://doi.org/10.1080/07420528.2026.2643807>



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Published online: 17 Mar 2026.



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High evening smartphone use drives sleep debt and lower morning affect in athletes

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ABSTRACT

In athletic populations, adequate sleep is critical for performance, recovery, and emotional well-being. However, behavioural habits such as late-night smartphone use may disrupt sleep and circadian alignment, leading to sleep debt and impaired morning functioning. This study examined associations between pre-sleep smartphone use, sleep debt (defined as the difference between average sleep duration on work/schooldays and free days), and morning affect in athletes. A sample of 174 Portuguese athletes (aged 15–65) completed questionnaires assessing sleep patterns, pre-sleep smartphone use, and morning affect. Participants were grouped as high (daily) vs. low/moderate (≤ 6 days/week) smartphone users. Greater sleep debt significantly predicted lower morning affect ($\rho = -0.215$, $p = 0.004$), especially among high smartphone users ($\rho = -0.30$, $p = 0.001$). While smartphone use did not significantly predict sleep debt, high use was marginally associated with lower morning affect. Mediation analysis showed sleep debt did not account for the association between smartphone group and next-day morning affect, suggesting a more direct association with bedtime screen exposure. Findings indicate that frequent pre-sleep smartphone use is associated with poorer mood upon waking, reflecting immediate sleep disruptions rather than accumulated sleep loss. Given prevalent evening screen use in athletes, promoting healthier pre-sleep routines may support emotional recovery and performance readiness.

ARTICLE HISTORY

Received 16 September 2025
Revised 26 February 2026
Accepted 5 March 2026

KEYWORDS

Pre-bed screen time; circadian disruption; athlete recovery; bedtime habits; sleep behaviour

Introduction



Sleep is a fundamental biological process critical for athletic performance, health, and emotional well-being. It supports cognitive functioning, emotional regulation, physiological recovery, and injury prevention (Fullagar et al. 2015; Watson 2017). Evidence shows that enhanced sleep quality and duration in athletes improves performance outcomes via faster reaction times, stable hormone regulation, and greater endurance (Fullagar et al. 2015). Moreover, adequate sleep may reduce the risk of illness and injury, sustaining long-term athletic development (Fullagar et al. 2015).

Despite its importance, sleep is frequently compromised by behavioural and environmental factors, especially the growing prevalence of nighttime smartphone use (Grandner et al. 2025). These devices, particularly among younger populations, combine blue light exposure with emotionally and cognitively stimulating


content, delaying melatonin release, disrupting circadian rhythms, and impairing sleep quality (Vhaduri and Poellabauer 2018; Grandner et al. 2025). During intense training or travel, athletes may face mismatches between sleep need and opportunity, leading to sleep debt which can contribute to mood disturbances, impaired cognition, and reduced performance (Thun et al. 2015).

Sleep's restorative effects can be indirectly assessed via morning affect, the emotional state upon waking (Carciofo 2023). Negative morning affect has been linked to disrupted sleep architecture and circadian misalignment, factors that may hinder athletic recovery and readiness (Carciofo 2023).

Although prior studies have examined sleep debt and smartphone use separately in general populations, few have explored their interactive impact in athletes, a group particularly vulnerable to screen-related sleep disruption and highly reliant on optimal recovery.

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 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/07420528.2026.2643807>

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Given the widespread use of smartphones before bed, understanding their effect on sleep and mood in athletic contexts is increasingly relevant.

This study aimed to determine whether frequent pre-sleep smartphone use is associated with increased sleep debt and, in turn, worse morning affect upon waking and whether sleep debt mediates this relationship. We also examined the direct association between sleep debt and morning affect and any potential interaction effects by smartphone use level.

Methods

Participants and Procedure

The participants were selected from a dataset of Portuguese athletes who completed the Athlete Sleep Screening Questionnaire to identify clinically significant sleep disturbances in athletes (Samuels et al. 2016), the Munich Chronotype Questionnaire (Reis et al. 2020a), the Pittsburgh Sleep Quality index (Buysse et al. 1989; Gomes et al. 2018) and the reduced Morningness-Eveningness Questionnaire to identify chronotype preference (Loureiro and Garcia-Marques 2015). The questionnaires were distributed through sport organizations across Portugal and was administered online via Microsoft Forms, it took approximately 15 to 20 min to complete. Inclusion criteria required participants to be between 15 and 65 y of age and to be actively involved in competitive sport at Level 2 or higher according to the training and performance classification (McKay et al. 2021), corresponding to athletes competing at the national level or above. Participants classified as Level 0 (sedentary) or Level 1 (recreationally active) were excluded.

Measures

Smartphone Use Before Bedtime

Smartphone use before bedtime was assessed with a single item asking how often participants used their smartphone within 1 h before going to sleep, with response options “never,” “1–3 times/week,” “4–6 times/week,” and “every day.” These responses were coded as an ordinal variable (1–4) and, for the primary analyses, further grouped into two categories: Low/Moderate use (≤ 6 days/week; “never,” “1–3,” “4–6 times/week”) and High use (“every day”). This cut-off was chosen a priori based on the empirical distribution of the data, as 77% of athletes reported daily pre-sleep smartphone use while the remaining three categories

each contained relatively few participants (2–15% of the sample), which limited stable estimation of separate category-specific effects.

Morning Affect

Morning affect was assessed using the item: “During the first half hour after waking up in the morning, how do you feel?” from the reduced Morningness-Eveningness Questionnaire (Loureiro and Garcia-Marques 2015). Responses were recorded on a 4-point Likert scale ranging from 1 = Very tired to 4 = Very refreshed, with higher scores indicating more positive morning affect.

Sleep Timing and Duration

Participants provided typical bedtimes and sleep durations for both work/schooldays and free days through the Munich Chronotype Questionnaire (MCTQ) (Reis et al. 2020a).

Sleep Debt

Sleep debt was calculated as the difference between participants’ self-reported average sleep duration on work/schooldays and on their free days. A positive value indicated reduced sleep on work/schooldays compared to free days, representing accumulated sleep debt.

Covariates

Participants self-reported age and biological sex. Age was treated as a continuous variable. Covariates were selected to account for chronobiological, occupational, competitive, and lifestyle factors that could influence sleep and morning affect. MSF_{sc} (sleep-corrected mid-sleep on free days) derived from the MCTQ was included as a proxy for chronotype, with higher values indicating a later sleep chronotype. Competitive level was coded according to a standardized training and performance framework (McKay et al. 2021), with four ordered categories: Level 2 (regularly trained; regular training ≥ 3 times/week with local representation and structured competition goals), Level 3 (highly trained/national level; regular, structured training and competition at national level), Level 4 (elite/international; competing internationally with high sport-specific competence), and Level 5 (world-class; internationally or Olympically medalled athletes, world record holders or top-ranked performers). Employment/study status was assessed with the item “In addition to being an athlete, do you have a full-time or part-time job/school?” and coded into four categories: student, full-time work, part-time work, and no additional job or study. Sleep-related and lifestyle behaviours were included as ordinal covariates and were taken from the Athlete Sleep Screening Questionnaire (ASSQ). Nap

frequency was coded as 0 = “none,” 1 = “one or two,” 2 = “three or four,” and 3 = “five to seven” naps per week. Additionally, the ASSQ contains the question regarding sleep medication (“How many times per week do you use sleep medication (prescribed or not)?”), which was coded on the same 0–3 scale (from “none” to “five to seven” times per week). Daily caffeine intake was coded as 0 = “less than once per day,” 1 = “1–2 times per day,” 2 = “3 times per day,” 3 = “4 times per day,” and 4 = “5 or more times per day.”

Statistical Analyses

Prior to analysis, data were screened for outliers and assessed for normality. The Shapiro – Wilk test indicated non-normal distributions of morning affect in both smartphone use groups. Given the non-normal distribution, associations were examined using Spearman’s rank correlations, and the structural equation model used maximum likelihood estimation with bootstrapped standard errors and confidence intervals (1,000 bootstrap samples) to provide robust inference for indirect and direct effects. Non-numeric and anomalous entries were excluded using listwise deletion. Nonnumeric entries included free-text responses or strings in numeric fields. Anomalous sleep values were defined as clearly implausible entries (e.g. bed- wake times that could not be reconciled with overnight sleep). The full exclusion criteria can be observed in Figure S1 (supplementary materials). All regression and mediation models used complete cases. Participants were categorized into “High” (daily use) and “Low/Moderate” (≤ 6 times/week) pre-sleep phone use groups, to improve statistical power. Spearman’s rank correlations assessed associations between sleep debt and morning affect; linear regression models tested mediation by sleep debt, controlling for age, sex, MSF_{sc} ,

competition level, frequency of naps, medication use, caffeine intake and employment status. Interaction terms and stratified analyses explored subgroup differences. A structural equation model (SEM) using *lavaan* evaluated indirect effects of smartphone use on morning affect via sleep debt. Analyses were conducted in R (v4.3.1). Significance threshold was set at $p < 0.05$.

Results

The final sample comprised 174 athletes, aged 15–65 y ($M = 24.6$, $SD = 11.44$), with 58% identifying as male ($N = 100$) and 42.5% as female ($N = 74$). Smartphone usage before sleep was widespread with 77.2% of participants reporting daily use within one hour before bedtime (classified as “High” users), while 22.8% were categorized as “Low/Moderate” users (Figure 1), supporting the fact that frequent bedtime smartphone use is common among athletes in this sample. For phone usage before sleep comparisons see Table 1.

Association Between Sleep Debt and Morning Affect

Sleep debt was negatively associated with morning affect. Spearman’s rank correlation yielded $\rho = -0.215$, $p = 0.004$, with an adjusted p -value of 0.007 following Benjamini-Hochberg correction. The regression model testing the interaction between sleep debt and smartphone use was statistically significant, $F(11,162) = 1.99$, $p = 0.033$, accounting for approximately 5.9% of the variance in morning affect (adjusted $R^2 = 0.059$). Sleep debt significantly predicted lower morning affect ($\beta = -0.07$, $p = 0.008$), suggesting that greater sleep debt was associated with worse mood in the morning. However, the interaction between sleep debt and smartphone use group was not statistically significant

Table 1. Participant characteristics and key variables by pre-sleep smartphone use group.

	Total sample (n = 174)	High use (daily, n = 134)	Low/Moderate use (≤ 6 days/week, n = 40)	p -value
Smartphone use group, n (%)	174 (100%)	134 (77%)	40 (23%)	
Age (years)	21.96 ± 8.8 [15–59]	21.5 ± 8.6 [15–59]	23.5 ± 9.4 [15–50]	0.242
Sex, n (%)				0.201
Male	100 (57.5%)	73 [54.5%]	27 [67.5%]	
Female	74 (42.5%)	61 [45.5%]	13 [32.5%]	
Competitive level, n (% of total)				
Level 2 - regularly trained	48 (27.6%)	–	–	
Level 3 - national level	113 (64.9%)	–	–	
Level 4 - elite/international	12 (6.9%)	–	–	
Level 5 - worldclass	1 (0.6%)	–	–	
Sleep debt (h)	–	1.67 ± 2.39 [–7.00 - 15.50]	1.58 ± 1.91 [–6.00 - 6.00]	0.796
Morning affect	–	2.30 ± 0.67	2.58 ± 0.81	0.055
MSF_{sc} (h)	–	7.64 ± 4.99 [–7.50 - 16.00]	8.85 ± 5.29 [0.00 - 15.33]	0.205
Medication use	–	1.10 ± 0.47	1.18 ± 0.50	0.120

Descriptive statistics for age, sex, competitive level, sleep debt, and morning affect are presented for athletes with High (daily) versus Low/Moderate (≤ 6 days/week) smartphone use within 1 hour before bedtime, as well as for the total sample ($N = 174$). Continuous variables are shown as mean ± SD with range in brackets; categorical variables are reported as n (%).

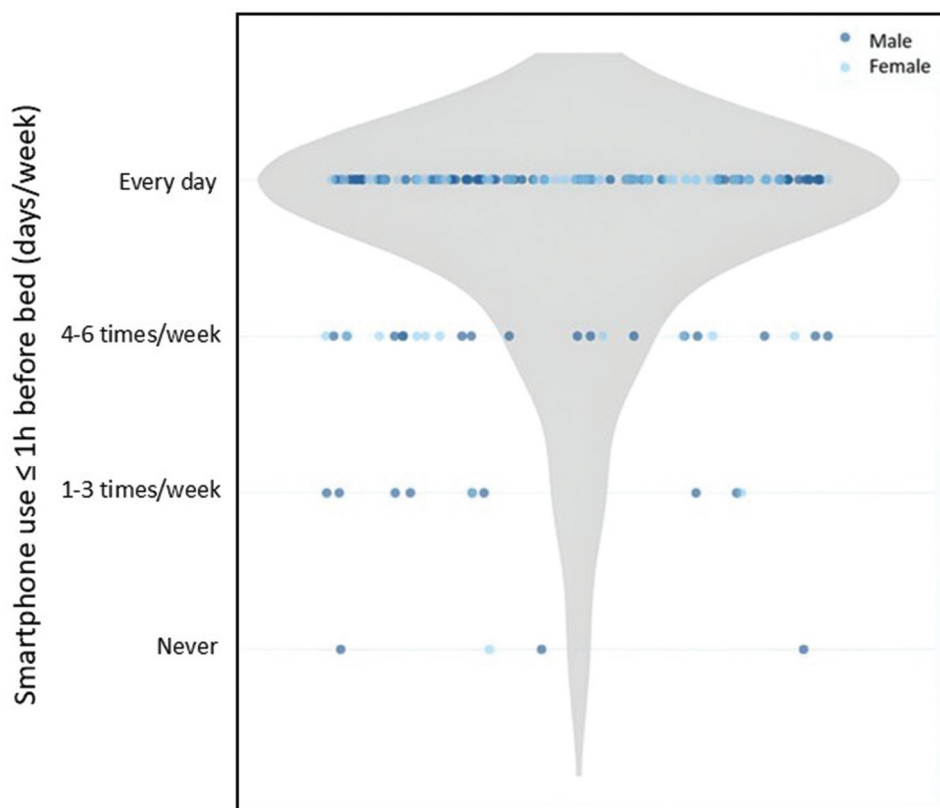


Figure 1. Distribution of pre-sleep smartphone use in athletes. Violin plot showing the overall distribution of pre-sleep smartphone use coded as days per week (1 = “never,” 2 = “1–3 times/week,” 3 = “4–6 times/week,” 4 = “every day”). The shaded violin represents the full sample, while individual points are coloured by sex (male = dark blue vs female = light blue), illustrating that daily pre-sleep smartphone use is common in both sexes, with most athletes clustering at “every day.” In the printed version, individual points are coloured by sex (male=dark grey vs female=light grey).

($\beta = 0.063$, $p = 0.346$), nor was the main effect of phone use group ($\beta = 0.165$, $p = 0.321$). The effect size for the overall model was Cohen’s $f^2 = 0.135$, corresponding to a medium magnitude (Cohen’s $f = 0.367$). Stratified correlation analyses (Figure 2) revealed that the negative association between sleep debt and morning affect was more pronounced among high smartphone users ($\rho = -0.30$, $p = 0.001$, adjusted $p = 0.001$), while no significant association was observed in the low/moderate group ($\rho = 0.02$, $p = 0.880$, adjusted $p = 0.880$). Moreover, medication use significantly predicted lower morning affect ($\beta = -0.233$, $p = 0.046$), indicating an association between medication use and morning affect. In contrast, phone use group, age, sex, and other covariates, including chronotype (MSF_{sc}), were not statistically significant predictors of morning affect in the main regression model.

As a sensitivity check, we repeated the analyses using the original 4-level ordinal smartphone-use variable instead of the binary High vs Low/Moderate grouping. In these models, smartphone-use category was not

associated with sleep debt (Spearman $\rho = -0.00$, $p = 0.950$) and showed a small, non-significant negative association with morning affect ($\rho = -0.14$, $p = 0.063$; regression $\beta = -0.08$, $p = 0.340$). The interaction between sleep debt and smartphone-use category was also non-significant. Thus, treating smartphone use as ordinal did not reveal stronger or qualitatively different effects and the overall pattern remained consistent with the primary analyses: sleep debt was the main robust correlate of lower morning affect, whereas pre-sleep smartphone use showed only a small, marginal association with morning affect and no association with sleep debt.

Mediation Analysis: (In)direct Effect of Smartphone Use on Morning Affect via Sleep Debt

A structural equation model was constructed to examine whether sleep debt mediates the relationship between smartphone use and morning affect. The model demonstrated a perfect fit (CFI = 1.000, RMSEA < 0.001, SRMR <

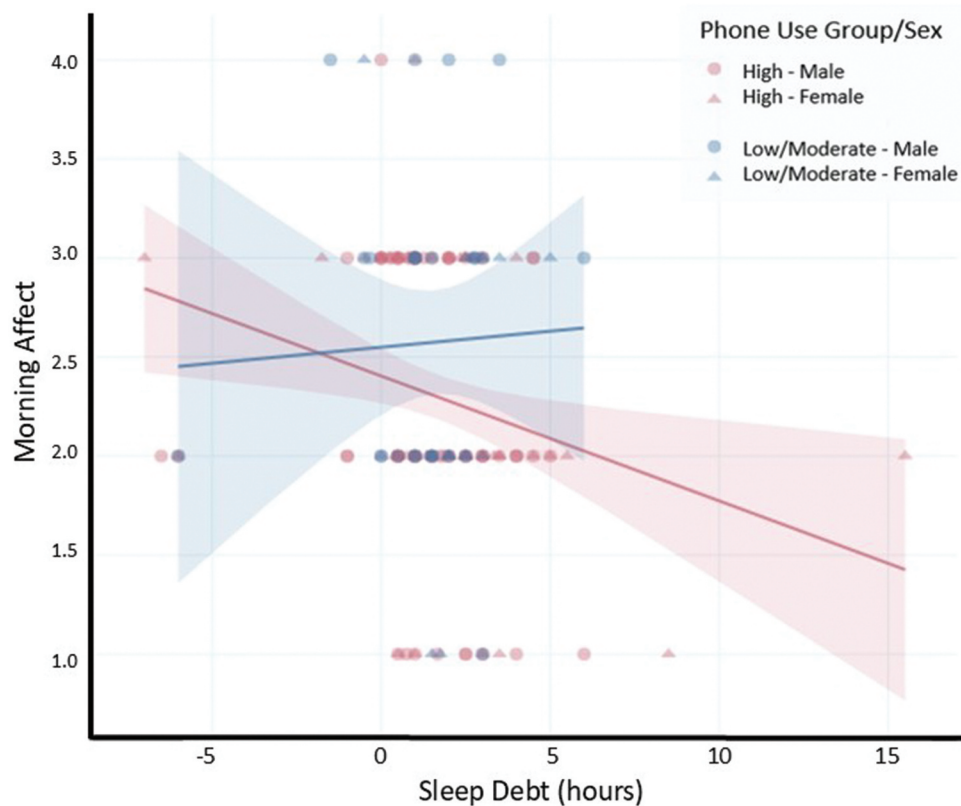


Figure 2. Sleep debt and morning affect by smartphone use group. Scatter plot with fitted regression lines showing the association between sleep debt (hours; free-day sleep duration minus work/school-day sleep duration, positive values indicating more sleep on free days) and morning affect (1–4, higher scores = more positive affect), stratified by pre-sleep smartphone use group. Each line represents the linear fit for high vs low/moderate users and raw data points are coloured by pre-sleep smartphone use group (high = blue vs low/moderate = red) and shaped by sex (male = circle vs female = triangle). In the printed version, raw data points are coloured by pre-sleep smartphone use group (high= dark grey vs low/moderate = light grey).

0.001). The direct effect of smartphone use on sleep debt was very small and not significant (unstandardized $\beta = -0.03$, $SE = 0.37$, 95% CI $[-0.77, 0.66]$, standardized $\beta = -0.01$, $p = 0.941$). Sleep debt significantly predicted morning affect $\beta = -0.06$, $SE = 0.03$, 95% CI $[-0.13, -0.02]$, standardized $\beta = -0.19$, $p = 0.029$, whereas the direct effect of smartphone use on morning affect only marginally significant ($\beta = -0.26$, $SE = 0.14$, 95% CI $[-0.55, 0.02]$, standardized $\beta = -0.16$, $p = 0.064$). The indirect effect of smartphone use on morning affect through sleep debt was non-significant ($\beta = 0.004$, $p = 0.946$). However, the total effect of smartphone use on morning affect was marginally significant ($\beta = -0.26$, $p = 0.061$).

Discussion

This study examined the relationship between pre-sleep smartphone use, sleep debt, and morning affect in athletes. Frequent smartphone use was significantly associated with lower morning affect, even after adjusting for age, sex, MSF_{SC} , competitive level, employment/study status,

number of naps per week, sleep-medication use, and caffeine intake. Although smartphone use did not significantly contribute to greater sleep debt, sleep debt itself was negatively associated with morning affect and showed the strongest association among high smartphone users. This highlights pre-sleep smartphone use as a key modifiable factor linked to sleep and next-morning well-being. These results align with existing literature showing that insufficient sleep impairs mood and cognitive functioning, elements essential for athletic performance (Vhaduri and Poellabauer 2018). The absence of significant effects in the low/moderate smartphone use group may suggest that healthier sleep practices, such as reduced evening screen exposure, could help protect morning affect and enhance performance outcomes in athletes.

The analysis revealed that sleep debt showed a significant negative relationship with morning affect, indicating that larger discrepancies between work/schooldays and free-day sleep duration were associated with worse mood upon waking. Medication use also emerged as a significant negative experience lower

morning affect. This may reflect underlying health issues like a sleep disease (e.g. insomnia), pharmacological side effects, or disrupted sleep architecture linked to sleep medication use (Ujma and Bódizs 2024). A recent study of Swiss elite athletes using the Athlete Sleep Screening Questionnaire found that 5.5% reported using sleep medication >1x/week (with women over twice as likely as men), alongside high rates of short sleep (18%), sleep dissatisfaction (30%), and night awakenings (18%), all predicting poorer well-being highlighting medication as a marker for underlying sleep issues in athletes (Vorster et al. 2024).

Moreover, age and sex were included as covariates in the regression model but did not show significant associations with morning affect. Additionally, chronotype (MSF_{sc}) did not meaningfully change the associations between sleep debt, smartphone use, and mood, suggesting that, within this athletic sample, sleep debt emerged as the principal sleep-related correlate of next-morning affect beyond individual differences in circadian timing. Although chronotype is often a meaningful predictor in the literature, its role may depend on the extent to which biological timing conflicts with social schedules and context. For example, Reis et al. reported that later chronotype (MSF_{sc}) and social jetlag were associated with poorer workday sleep quality in healthy subjects and patients with sleep disorders, highlighting the relevance of circadian misalignment for sleep outcomes (Reis et al. 2020b). Similarly, Wills et al. (2021) found that greater eveningness was associated with higher depressive symptoms in university student athletes, with evidence that social support moderated this association (Wills et al. 2021). MSF_{sc} may not have been predictive in our sample because, in this athletic cohort, sleep timing likely reflected scheduling constraints and day-to-day sleep pressure more than stable circadian preference, so sleep debt, not MSF_{sc} , captured the variance most relevant to next-morning mood. Therefore, individual chronotype and habitual wake up time remain important and should be examined more thoroughly in future research.

Previous research has shown that screen time before bed can increase sleep latency (Grandner et al. 2025), disrupt circadian rhythms (Bauducco et al. 2024), and impair sleep quality (Vhaduri and Poellabauer 2018) thus affecting one's mood, cognition and (sleep) behaviour the next day (Fullagar et al. 2015). These effects are largely attributed to melatonin suppression and arousability caused by blue light emitted from screens (Heo et al. 2017). Younger individuals, including many athletes, may be particularly sensitive to evening light exposure, heightening this vulnerability (Crowley et al. 2015). In addition to light-based disruption, the

emotionally and cognitively stimulating nature of smartphone activities, such as social media, messaging, or gaming can increase arousal and further delay sleep onset (Almeida et al. 2023). Athletes may be especially susceptible following competition, when social media use could amplify emotional reactions to wins or losses, potentially affecting next-morning mood. While our study focused on use within the hour before sleep, broader evening phone use patterns and their impact on emotional state and sleep warrant further investigation. Combined with early wake times for training and competition, these behavioural habits likely contribute to sleep debt and mood disturbances, ultimately impairing recovery and performance. Given that athletic development depends on sufficient, high-quality sleep, evening screen exposure may be undermining the restorative potential of rest in this population.

To explore potential mechanisms, we used a structural equation model to assess whether sleep debt mediated the relationship between smartphone use and morning affect. Sleep debt was significantly associated with lower morning affect, but smartphone use was not significantly associated with sleep debt, and the indirect pathway was unsupported. The direct effect of smartphone use on morning affect approached significance ($\beta = -0.26$, $p = 0.064$), and the total effect was similarly marginal ($\beta = -0.26$, $p = 0.061$), consistent with a marginal negative association found in Spearman's analysis ($\rho = -0.15$, $p = 0.056$). These findings suggest that bedtime phone use may impair mood via immediate sleep disruptions such as delayed sleep onset, fragmented sleep, or emotional arousal, rather than through accumulated sleep debt. Objective sleep data in future studies could help clarify these pathways.

This study relied on self-reported measures of sleep and smartphone use, which may introduce recall bias. Its cross-sectional design limits causal inference, and generalizability is restricted to athletic populations. However, the findings likely reflect patterns in otherwise healthy individuals and may have even greater implications for those with clinical conditions. Moreover, our assessment of digital behaviour was confined to the frequency of smartphone use within the hour before bedtime and did not capture overall daily screen time, other evening devices, or the type of content consumed (e.g. social media, gaming, work-related tasks), which may differentially affect arousal, circadian timing, and sleep quality. In addition, the item assessing medication use captured only the frequency of "sleep medication" use and did not distinguish among specific medication types (e.g. benzodiazepines, non-benzodiazepines hypnotics (Z-drugs), melatonin, sedating anti-depressants, sedating antihistamines) nor did it

assess dose or purpose of use. This limits interpretation of the observed association. Future research and clinical assessments should include more detailed questions about the specific medications used, their intended purpose (e.g. to address travel-related circadian misalignment (jet lag) or to treat insomnia symptoms), and frequency of use. A further limitation was the dichotomization of pre-sleep smartphone use into High versus Low/Moderate groups. Although this decision was driven by the highly skewed empirical distribution in this athletic sample (with 77% reporting daily use and relatively few participants in the remaining three categories), collapsing categories inevitably reduces information and may introduce classification bias. Importantly, sensitivity analyses treating smartphone use as a 4-level ordinal variable produced comparable, small negative associations with morning affect and no association with sleep debt, indicating that our conclusions are not solely a consequence of the binary grouping. Future research should incorporate objective measures (e.g. actigraphy), non-parametric or transformation-based methods, other blue light emitting technology (e.g. TVs and computers) and detailed assessment of evening screen exposure across devices and content types, and interventions targeting digital curfews or screen filtering. Additional studies should investigate the bidirectional relationship between mood disorders (e.g. anxiety, depression), phone use, and next-morning affect by examining both how mood influences phone behaviour and how phone use may impact mood outcomes. Studies would also benefit from looking into how bedtime phone-use behaviour varies and influences sleep quality between different training cycles (i.e. training season, competition season and off-season). Finally, longitudinal designs are needed to clarify the temporal links between evening screen time, circadian disruption, and athletic performance.

Beyond these limitations, the findings also point toward some practical recommendations for healthier pre-sleep phone-use practices. In line with current research, it may be beneficial for athletes to avoid smartphone use 30–60 minutes before going to sleep (He et al. 2020; Schrempft et al. 2024), keep their phones out of arm's reach or outside the bedroom at night (Kheirinejad et al. 2023), and silence notifications too reduce nocturnal checking. If screens are in use before bedtime, choosing dimmed displays and the stage of blue light filters, and less emotionally or cognitively stimulating content, as well as using it outside of the bedroom, may help limit pre-sleep arousal and support better sleep quality and morning affect (Schrempft et al. 2024).

In conclusion, our findings suggest that frequent smartphone use in the hour before bedtime is associated

with worse morning affect in athletes, regardless of sleep debt. While we observed a trend toward greater sleep debt in high smartphone users, sleep debt did not significantly mediate the relationship between smartphone use and morning affect, suggesting no evidence for a mediation pathway in this cross-sectional sample. These results emphasize the potential direct associations between smartphone use, sleep and mood. Importantly, with more than 75% of our sample reporting daily smartphone use before bed, this behaviour appears to be highly prevalent among athletes. Given the link between evening screen time and reduced morning affect, our findings highlight the value of promoting healthier pre-sleep routines to support better sleep health, mental recovery, and athletic performance.

Author Contributions

CRedit: **Liza Rozman:** Formal analysis, Methodology, Software, Visualization, Writing – original draft; **João Barreira:** Visualization, Writing – review & editing; **João Brito:** Data curation, Resources, Writing – review & editing; **Júlio A. Costa:** Data curation, Project administration, Writing – review & editing; **Cátia Reis:** Conceptualization, Data curation, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Funding

João Barreira was supported by the Portuguese Foundation for Science and Technology through a doctoral grant [2022.09446.BD].

Data Availability Statement

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

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