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Restricted use of electronic media, sleep, performance, and mood in high school athletes—a randomized trial

Anette Harris, PhD [a,*], Hilde Gundersen, PhD [b], Pia Mørk-Andreassen, MSc [c], Eirunn Thun, PsyD [a], Bjørn Bjorvatn, MD, PhD [d,e], Ståle Pallesen, PhD [a,e]

[a] Faculty of Psychology, University of Bergen, Norway
[b] Department of Sport and Physical Education, Bergen University College, Norway
[c] The Norwegian Elite Sport Centre Region West, Norway
[d] Faculty of Medicine and Dentistry, University of Bergen, Norway
[e] Norwegian Competence Center for Sleep Disorders, Haukeland University Hospital, Bergen, Norway

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Objectives: The study aims to evaluate whether 4 weeks with restricted use of electronic media after 22:00 affects sleep, athletic performance, cognitive performance, and mood in high school athletes.
Methods: Eighty-five athletes were randomized to either an intervention group ($n = 44$), who was instructed to not use any electronic media after 22:00, or a control condition ($n = 41$), where they could act as they preferred in terms of media use. Primary outcomes were sleep habits measured with a sleep diary. Secondary outcomes were (*a*) physical performance measured with a set of standardized tests (beep test, 20-m linear sprint, chin-up test, hanging sit-ups test, counter movement jump and sit-n-reach test); (*b*) cognitive performance (response time and response accuracy); and (*c*) positive and negative affect. Differences between groups were tested with mixed between-within subject analyses of variance.
Results and conclusions: Thirty-five and 40 of the athletes in the intervention and control group, respectively, completed the study. Results showed that restricted use of electronic media after 22:00 did not improve sleep habits, athletic performance, cognitive performance, or mood in a group of high school top athletes with already good sleep habits. However, these findings give us knowledge about sleep habits and performance in this population that is of importance when designing future studies.

Introduction

The process of sleep is regulated by an interaction between 3 main factors: a homeostatic factor, an endogenous circadian factor, and a behavioral factor.[1–3] The sleep homeostat reflects a gradual build-up of a sleep pressure/need, and the amount of previous wakefulness correlates positively with the depth of subsequent sleep.[2] The circadian factor affects mainly the timing and overall duration of sleep,[3] and is normally entrained by external "zeitgebers" or time givers to a 24-hour cycle,[4] with the environmental light-dark cycle considered the primary synchronizer.[5–7] Behavioral factors such as different types of activities and exposure to stimuli can override both the homeostatic and the circadian factors.[5] In particular, behaviors carried out close to sleep are considered as sleep disturbing. For example, increased arousal at bedtime and behaviors involving exposure to evening bright light are both associated with sleep disturbances.[8–10]

In terms of athletic performance, a recent systematic review investigating sleep, circadian rhythms, and athletic performance showed that both circadian rhythm and sleep are important factors for performance in sports.[11] However, it seems that the effect of sleep deprivation varies across athletic challenges.[11] Negative effects of sleep deprivation have been reported on explosive athletic tasks such as knee extension peak torque[12] and vertical jump height[13] in some studies, whereas others did not find any negative effects on explosive actions as assessed with the Wingate Anaerobic Power Test[14–16] and snatch, clean and jerk, and front squat.[17] Exercises demanding more endurance, like time to exhaustion on ergometer cycling[18] or treadmill walking,[19] are more strongly affected by sleep deprivation. Furthermore, extended sleep has been associated with improved performance of several parameters such as sprints and shooting accuracy in a basketball team.[20]

Many sports rely on intact cognitive functions, such as attention, strategic thinking, problem solving, and memory.[21] Impairment seen following sleep deprivation seems to be rather large on cognitive variables.[22,23] Mood is another factor that affects athletic performance[24] and is also negatively affected by sleep loss.[17,23] An

* Corresponding author at: Faculty of Psychology, University of Bergen, Christiesgt 13, 5020, Bergen, Norway.
E-mail address: anette.harris@uib.no (A. Harris).

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increased activity in amygdala and decreased connectivity between amygdala and the prefrontal cortex have been suggested as an explanation to the association between sleep deprivation and negative mood.[25]

In the past few decades, we have witnessed a sharp increase in the availability and use of electronic media such as mobile phones, video game consoles, DVD players, television, audio players, computers, and tablets.[26,27] As electronic media become more lightweight and portable, people may conveniently use these devices even in bed. Electronic media use before sleep has been related to delayed bedtimes and less time spent in bed,[28] reduction of sleep duration, and impaired school performance the next day[29] as well as insomnia.[30] Impaired sleep might also act as a mediator between electronic media use in bed before sleep and symptoms of depression[31] and between video gaming and sustained attention, but not working memory.[32] Furthermore, smartphone ownership is related to later bedtimes and more electronic media use in bed before sleep compared with ownership of a conventional mobile phone.[31] Frequent use of mobile phone after lights out also predicted tiredness 1 year later.[33] According to the National Sleep Foundation's "Sleep in America Poll" in 2011, 95% of the respondents used electronic media such as television, computer, video game, or cell phone at least a few nights a week within the hour before going to bed.[34]

Several mechanisms might be involved in the interrelationship between electronic media, insufficient sleep, and impairments of daytime functioning. First of all, time spent with electronic media may displace sleep, but sleep might also be disturbed as a result of incoming messages after sleep onset.[35,36] The light emission of the screens of electronic media is another factor that might suppress melatonin secretion, increase arousal, and delay the circadian rhythm.[37] Furthermore, electronic media, and especially playing video games in the evening, might lead to an increased arousal that might disturb sleep and daytime functioning.[9,38]

Whereas electronic media are associated with unfavorable sleep patterns, higher levels of both self-reported and objective physical activity are linked to favorable subjective and objective sleep in young people.[39] In contrast to general sleep hygiene recommendations, Brand and colleagues[40] also found an association between increased exercise exertions before bedtime and better sleep patterns. In line with this, adolescents engaging in high amounts of exercise (elite athletes) reported more favorable sleep patterns compared with healthy controls.[41,42]

In spite of this, interventions focusing on regulation of the use of electronic media to improve sleep are scarce. The same goes for sleep interventions aiming to improve elite athletes' performance. The present study aims to investigate the effects of an intervention focusing on restricting evening and night use of electronic media in high school athletes. The intervention lasted for 4 weeks and involved restricted use of electronic media after 22:00 in high school athletes. We expected that restricted use of electronic media would encourage the athletes to earlier bed times and less disturbed sleep due to incoming messages from mobile phones. The association between use of electronic media, athletic performance, cognitive performance, and mood was expected to be mediated through sleep. Primary outcome variables comprised parameters from the sleep diary (bedtime, total sleep time, sleep efficiency, sleep onset latency, wake after sleep onset, sleep quality, and daytime functioning). Secondary outcomes comprised: (1) athletic performance (endurance measured with a beep test, acceleration and speed measured with a 20-m sprint test, strength measured with a chin-ups test and a hanging sit-ups test, explosive strength using the counter movement jump (CMJ), and mobility of the muscles in the back of the body by the sit-n-reach test); (2) cognitive performance (reaction time and attention); and (3) mood (positive and negative affect).

Methods

Procedure

One hundred and eighty athletes at 2 different high schools for top athletes in Norway were invited to an information meeting regarding the study. Of those who attended the meeting (approximately 150 eligible participants were present), 106 agreed to participate. Of these, 16 withdrew before randomization and 5 were excluded (4 due to traveling across time zones during the intervention period, 1 due to use of sleep medication) (see flowchart in Fig. 1). To be included in the study, participants had to ensure (1) not to use any kind of medication that could affect sleep and (2) not to travel across time zones during the intervention period. After inclusion, they were randomized (stratified by sport) into 2 groups, an intervention group (n = 44) and a control group (n = 41), by use of a randomization calculator (www.randomizer.org). The participants in the intervention group were instructed not to use any electronic media after 22:00.[43,44] The participants in the control group could act as they preferred in terms of electronic media use. Participants in both groups decided their own bedtimes and rise times. Before and after the intervention, all participants completed a questionnaire and a visual attention test, kept a sleep diary for 1 week, and performed athletic performance tests. The intervention lasted for 4 weeks and was performed during fall of 2013. All tests were administered between 12:00 and 16:00 to control for the circadian influence on performance.[45] Personnel from the Norwegian Elite Sport Centre region west (trainers) conducted the athletic tests. The intervention group completed a compliance log, ticking off adherence to the regimen in terms of electronic media use every morning throughout the intervention. If adherence was violated, they were instructed to provide a short description of how they deviated from the instructions. Participants with deviations from the protocol for more than 4 days over the study period were excluded. The participants were not informed about the exclusion procedure. The compliance log showed that 36 of the 44 participants in the intervention group completed the intervention and were included in the analysis. The study was approved by the Regional Committee for Medical and Health Research Ethics, western Norway (2013/995). All participants provided a written informed consent and were informed about the right to withdraw from the study at any time.

Instruments

Questionnaire

Demographic variables include sex, age, height, weight, mean hours with training per week, hours with paid work per week, living condition, medication, and type of sport.

Chronotype was measured with the Horne-Östberg Morningness-Eveningness Questionnaire (MEQ).[46] The instrument consists of 19 items and measures several aspects of morningness, including sleep habits, times feeling sleepy, and preferred time for performing activities that require physical or mental alertness. The scores range from 16 to 86, with higher scores indicating a higher degree of morningness. The scale showed acceptable internal consistency ($\alpha = .744$).

Mood was measured with the Positive and Negative Affect Scale.[47] The instrument is a reliable and valid scale for measuring positive affect and negative affect.[47] The questions related to positive affect are meant to give a numeric expression of the subject's feelings of enthusiasm, pleasure, and engagement. A high score reflects a high degree of positive affect. The questions regarding negative affect reflect distress and other unpleasurable states such as nervousness and anger. A high score indicates a high degree of negative affect. There are 10 questions for positive and 10 for negative affect, respec-