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DOI
10.5812/asjsm.25678

Publication date
2015

Document Version
Final published version

Published in
Asian Journal of Sports Medicine

Asian J Sports Med. 2015 December; 6(4): e25678. doi: 10.5812/asjsm.25678
Published online 2015 December 1. **Brief Report**

Extreme Violation of Sleep Hygiene: Sleeping Against the Biological Clock During a Multiday Relay Event

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Received 2014 November 28; **Revised** 2015 February 9; **Accepted** 2015 February 21

Abstract

Background: Sleep hygiene is important for sleep quality and optimal performance during the day. However, it is not always possible to follow sleep hygiene requirements. In multiday relay events, athletes have to sleep immediately after physical exertion and sometimes against their biological clock.
Objectives: In this pilot study we investigated the effect of having to sleep at an abnormal circadian time on sleep duration.
Patients and Methods: Eight runners and two cyclists performing a 500 km relay race were followed. They were divided into two groups that took turns in running and resting. Each group ran four times for approximately five hours while the other group slept. As a result, sleep times varied between normal and abnormal times. All athletes wore actigraphs to record the duration and onset of sleep.
Results: Linear mixed model analyses showed that athletes slept on average 43 minutes longer when they slept during usual (night) times than during abnormal (day) times. In general, sleep duration decreased during the race with on average 18 minutes per period.
Conclusions: This pilot study shows that, even under extreme violation of sleep hygiene rules, there still is an apparent effect of circadian rhythm on sleep duration in relay race athletes.

Keywords: Athletes, Sleep, Circadian Rhythm

1. Background

Sleep quality is crucial for optimal physical and mental performance (1-4). For optimal sleep quality, bed times should be in accordance with the circadian rhythm, which determines the periods within the 24 hour cycle when melatonin secretion rises and when it is easiest to fall asleep (5). In addition, sleep hygiene (conditions and practices that promote continuous and effective sleep) is important (6). Examples of proper sleep hygiene include avoidance of mental and physical effort during two hours before the desired sleep onset and keeping regular sleep times (7-9).

However, several reasons may exist why these basic sleep hygiene rules cannot be practiced, e.g. due to shift work or jetlag. Also in athletes, these requirements cannot always be accomplished, because training times or matches may conflict with optimal sleep hygiene. Especially during multiday events, athletes are physically very active before they have to sleep, do not have enough time to sleep, and are forced to sleep during non-optimal circadian times.

2. Objectives

The aim of this pilot study was to explore sleep duration during extreme violation of sleep hygiene rules. In particular, it was investigated if, even under tough sleep hygiene conditions, a circadian rhythm effect on sleep duration would still be present.

3. Patients and Methods

3.1. Subjects and Procedures

To examine sleep duration and the circadian effect on sleep duration in athletes performing under extreme circumstances, a team of Roparun athletes was studied. The Roparun is a 500 kilometres relay race from Paris or Hamburg to Rotterdam. The Roparun team participating in the study consisted of ten athletes (9 men, 1 woman): two groups of four runners and one cyclist. The two groups alternated in about five hours running and five hours resting. During running, batons were passed on between the same four runners who ran two kilometres each for 60 consecutive kilometres, accompanied by one supporting cyclist. After 60 kilometres the other group of four runners and one cyclist took over. While one group performed, the other group was able to rest, eat, and sleep. So athletes could not sleep for long continuous periods and they had to perform shortly before going to sleep.

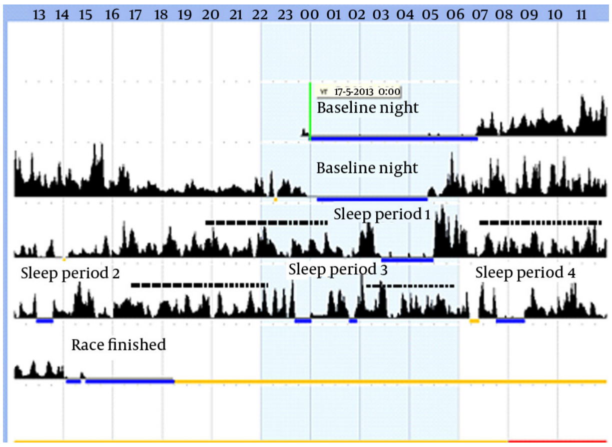
One week before the start of the Roparun, all athletes received basic information on optimal sleep hygiene, including the advice to extend sleep time in the week before the competition by trying to go to bed one hour earlier than usual, to prevent excitement in the time between finishing the individual run and sleep onset, and to sleep at a place as quiet and comfortable possible.

Informed consent was obtained from all study participants. The study conforms to the ethical guidelines of the 1975 Declaration of Helsinki.

3.2. Outcome Measures

Sleep duration was assessed using actigraphy (Vivago Ultra Watch, Zoetermeer, The Netherlands). Actigraphy is considered a reasonable valid and reliable method for objectively assessing sleep in comparison to polysomnography (10). The athletes wore the actigraphs two days before the start of the run to investigate possible effects of sleep duration before the race on sleep duration during the race. They kept wearing the actigraphs until the last run. See Figure 1 for an example of the actigraph output of one of the runners.

Figure 1. Example Activity Curve for One Athlete



The black spikes indicate wrist movements. When there is no wrist movement the runner is considered to be asleep, indicated by a horizontal bar. The running periods are indicated in the graph by dotted lines.

If the run was finished between 22:00 - 3:00 hours, we considered this as "favourable", in view of what would be the best time to fall asleep according to the circadian rhythm. Bed times outside this time window were considered "unfavourable". The window of optimal bed times was determined on the basis of the circadian process of sleep, which states that it is easiest to fall asleep at times when melatonin secretion is high and increasing (5). Exact times vary between individuals, but as all participants held daytime jobs, we chose this time window as, on average, persons who have 23:00 hour as a regular bedtime, have their highest melatonin secretion between 22:00 hour and 3:00 hour (11).

3.3. Analysis

Data were analyzed using a linear mixed model (computer program IBM SPSS Statistics version 20, Armonk NY, United States of America), with a compound symmetry covariance structure to account for the dependency of repeated observations (12). The mixed model enables the analysis of data that are a combination of independent observations (two groups of five subjects) and dependent observations (repeated measurements), simultaneously testing both within-subject and between-subject effects of falling asleep within or outside the window of favourable bed times.

The dependent variable was sleep duration in each of the four sleep periods during the race. Independent variables were bed time (inside or outside the favourable time window) and control variables sleep period (first, second, third, fourth), relay group (1 or 2), and the amount of sleep prior to the race (total hours of sleep during the two nights before the race). Regression coefficients indicate the change in the dependent variable (sleep duration during the race) when the independent variable increases with one unit.

4. Results

The race took place from 18^{th} - 20^{th} May 2013. In general, the weather conditions were good. Temperature varied between 7 - 16°C and there was not much wind. However, it rained heavily during the second race period of the second group.

Characteristics of the athletes and clock times of the end of the runs and sleep duration in the four sleep periods during the race are given in Table 1.

Sleep duration during the different periods of the race varied from 0 minutes to 2 hours and 36 minutes. Mean (SD) sleep duration was 1 : 28 hours (0 : 43). The mixed models analyses showed that there was a significant effect of favourable/unfavourable sleep time ($\beta = 0.72$, se = 0.19, $P < 0.01$), while controlling for group ($\beta = -0.10$, se = 0.23, $P = 0.67$), sleep period (first, second, third, fourth) ($\beta = -0.31$, se = 0.08, $P < 0.01$), and sleep duration prior to the race ($\beta = 0.02$, se = 0.03, $P = 0.44$). This indicates that sleep duration was on average 43 minutes longer when athletes could sleep during favorable sleep times. In general, sleep duration decreased during the race, with on average 18 minutes after each consecutive run. Group and sleep duration prior to the race did not have significant effects on sleep duration during the race.

Table 1. Characteristics of the Roparun Athletes

Athlete Characteristics	Values
Age, y [a]	42.9 ± 8.0
Average sleep duration prior to race, h [a]	7.7 ± 2.0
Race characteristics	
Group 1, hh: mm	
End of run 1	19 : 43
End of run 2	06 : 40
End of run 3	16 : 44
End of run 4	02 : 11
Group 2, hh:mm	
End of run 1	00 : 40
End of run 2	11 : 40
End of run 3	22 : 13
End of run 4	05 : 40
Group 1, h [a]	
Sleep duration after run 1	1.58 ± 0.47
Sleep duration after run 2	1.35 ± 0.65
Sleep duration after run 3	0.63 ± 0.73
Sleep duration after run 4	1.82 ± 0.62
Group 2, h [a]	
Sleep duration after run 1	2.60 ± 0.47
Sleep duration after run 2	1.43 ± 0.55
Sleep duration after run 3	1.30 ± 0.18
Sleep duration after run 4	1.00 ± 0.33

[a] The values are presented as mean ± SD.

5. Discussion

The present pilot study showed that, even under extreme violation of sleep hygiene rules, athletes slept longer when they were able to fall asleep at usual bed times (at night) than when they had to fall asleep during abnormal bed times (during daytime). This is in accordance with the circadian aspect of sleep (5), but interestingly this effect is persistent even under these extreme circumstances, when athletes are tired from physical exertion and sleep deprived because of limited sleep time.

There was no effect of sleep prior to the race on sleep during the race. We did not investigate the effect of sleep on performance as this was outside the scope of our study, but previous research has shown that such an effect exists (13).

In general, sleep duration decreased during the race. A possible explanation for this finding is that the physical activity increases physical excitement, which hampers sleep (6). It might be that in longer events in which athletes have to sleep at varying, unusual, and short time periods, sleep duration would increase with time as sleep debt builds up.

Unfortunately, other measures of sleep variables (e.g. sleep latency) and circumstances (e.g. nutrition, mental preparation) were not available. We therefore did not take into account the quality of the beds, noise during sleep times, and other factors that may have influenced sleep duration. In addition, our sample is too small to generalize the results to all endurance athletes in multi-day events.

Still, our results show that the circadian rhythm has such a strong impact that it is still apparent under extreme circumstances. This means that whenever possible, athletes should either attune their activities as much as possible to their circadian rhythm, or try to adjust their circadian rhythm to the requirements of the event in which they participate. In events such as the Roparun, neither is possible. But in longer events, athletes should keep 24 hour sleep-wake rhythms as much as possible and shift their rhythms as infrequent as possible. Unavoidable shifts may be facilitated by administering exogenous melatonin (14, 15). The role of melatonin in promoting sleep in circumstances produced by events such as the Roparun needs further investigation.

In spite of its explorative character and small sample size, we believe that this pilot study yields valuable information about the effect of sleeping at abnormal times in athletes performing under extreme circumstances, giving rise to further research in this area.

Acknowledgments

We thank Van Dorp Zorg en Welzijn for providing the actigraphs.

Footnote

Authors' Contributions: Study concept and design: Marcel Smits, Maarten Moen, Peter Vergouwen. Analysis and interpretation of data: Bas Roest, Marcel Smits, Frans Oort, Annette van Maanen. Drafting of the manuscript: Annette van Maanen, Marcel Smits, Frans Oort, Maarten Moen, Peter Vergouwen. Critical revision of the manuscript for important intellectual content: Annette van Maanen, Marcel Smits, Frans Oort, Maarten Moen, Peter Vergouwen, Bas Roest, Ingrid Paul, Petra Groenenboom. Statistical analysis: Frans Oort, Annette van Maanen.

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