Open Access

OBM Neurobiology

Original Research

The Effects of Subjective and Objective Sleep Monitoring on Sleep Patterns and Attitudes

Sarah Kölling [1, 2, †, *], Annika Hof zum Berge [1, †]

1. Faculty of Sport Science, Ruhr University Bochum, Bochum, Germany; E-Mails: sarah.koelling@rub.de; annika.hofzumberge@rub.de
2. Department of Sport Science, Stellenbosch University, Stellenbosch, South Africa

† These authors contributed equally to this work.

* **Correspondence:** Sarah Kölling; E-Mail: sarah.koelling@rub.de

Academic Editor: Grace E. Vincent

Special Issue: Sleep and Health

OBM Neurobiology
2020, volume 4, issue 1
doi:10.21926/obm.neurobiol.2001052

Received: November 22, 2019
Accepted: March 03, 2020
Published: March 11, 2020

Abstract

Self-reports and actigraphy are common methods of sleep monitoring. Portable polysomnography (p-PSG) may serve as a screening tool in natural environments. Common concerns with its use are that sleep and compliance might be affected. Further, dysfunctional beliefs of the subjects may contribute to sleep disturbances, which might manifest throughout sleep monitoring. This study examined the effect of monitoring sleep patterns and attitudes among healthy individuals. Sixty-eight physically active university students (26.6 ± 2.5 years) were assigned to the intervention (n = 35) or the control group (n = 33). Sleep monitoring consisted of 2-week online sleep logs and a 1-week actigraphy. Portable PSG was applied for the final two nights. Objective and subjective sleep parameters and ratings were compared between the baseline measurements and the first two nights of actigraphy and the two nights of p-PSG. The participants answered the Dysfunctional Beliefs and Attitudes about Sleep Scale (DBAS), pre- and post-monitoring. The groups did not display any interaction×time effect (p = 0.187) for DBAS. Also, there were no subjective insomnia complaints. Following the nights with p-PSG application, perceived restfulness of sleep was reduced between baseline measurement and the second p-PSG night ($p = 0.045$). In contrast, the objective parameters showed an increased sleep-efficiency ($p < 0.001$) and reduced wake after sleep-onset ($p = 0.002$) after both p-PSG nights. All other sleep parameters revealed no significant differences between actigraphy-only and p-PSG nights. Two-week sleep monitoring had no negative effect on the objective sleep patterns and attitudes about sleep. Yet, sleep with p-PSG led to reduced subjective sleep quality, which was not reflected in the objective sleep parameters. Contrarily, participants showed higher sleep efficiency and shorter waking phases, possibly due to changed bedtime routine. Hence, p-PSG may be applicable for field studies in sport science, provided the participants receive detailed information.

Keywords
Self-report; actigraphy; polysomnography; sleep monitoring; dysfunctional attitudes; sleep parameters

1. Introduction

Sleep is vital for health and psychological well-being. Especially in sport science, it is considered as the most essential and effective regeneration strategy for athletes [1, 2]. For instance, sleep correlates with better cardiovascular health and effective functioning of the immune system [3, 4]. However, insufficient and/or unrestful sleep is highly prevalent among young adults [5, 6]. Moreover, elite athletes are highly vulnerable to sleep disturbances and irregular sleep schedules [7-9]. According to a recent review and meta-analysis, athletes do not sleep ≥ 7 hours during training phases and on the night of competition [10]. Conditions of the sport too may exacerbate sleep quality and quantity, such as training schedules [11], competition [12], or travel-induced fatigue and jet lag [13]. Conversely, insufficient sleep may negatively affect domains of athletic performance, neurocognitive function, and physical health [14].

Persistent and recurrent periods of prolonged sleep-onset or nightly wakefulness may lead to clinically relevant sleep disorders [15, 16]. Insomnia is characterized by continuous problems in initiating and/or maintaining sleep, accompanied by dissatisfaction with sleep quality and performance as well as by daytime sleepiness [17]. Young adults are facing competing demands and dynamic changes in social and contextual factors, such as entering university, starting full-time jobs, or moving away from home. This population experiences high vulnerability to sleep deficiencies. According to a prospective study, young adults between 20 and 35 years of age bear an increased risk of developing insomnia compared to people of age 65 years and above. This is suggested to be due to higher demands from life and increased evaluation of the stressors [18]. Insomnia symptomatology is also prevalent among the athletic population as indicated by longer sleep latencies, greater sleep fragmentation, non-restorative sleep, and excessive daytime fatigue [9].

The severity or persistence of insomnia symptoms may be aggravated by dysfunctional attitudes and beliefs about sleep [19-21]. For instance, the assumption that one night of insufficient sleep has severe daytime consequences may raise the anxiety of sleeplessness when trying to fall asleep. This leads to an excessive negatively toned cognitive activity and increases arousal and distress [19]. Findings of a longitudinal study among the general population indicate that cognitive processes, such as worry and dysfunctional beliefs as well as dysfunctional safety behaviors, distinguish between normal sleepers and people with persistent insomnia [21]. Bidirectional effects between sleep problems and cognitive or emotional arousals are also possible, as recently revealed in undergraduate students [22]. The research group found that negative repetitive thoughts in the evening impair sleep quality, which then decreases positivity in the morning, leading to increased repetitive thoughts the following evening.

Several factors, such as psychological, behavioral, or external influences, may affect sleep. Hence, the assessment and monitoring of sleep patterns may be useful in different settings. For instance, the effect of sleep interventions can be evaluated. In competitive athletes, it is recommended to monitor sleep along with general training routines to analyze the response to training [23]. Different methods are available depending on the specific research question. In general, a combination of subjective and objective monitoring methods is recommended to get a comprehensive understanding of an individual's sleep pattern [1, 23]. Sleep is defined as the changes in brain activity, determined using electroencephalography (EEG) and additional sensors, e.g., detecting eye movements and muscle tone [24]. Polysomnography (PSG) is the gold standard to assess sleep. It is typically used in the laboratory and requires high expertise and medical assistance [23]. However, it is impractical for long-term monitoring and measurements in the natural environment. In order to address the latter, portable PSG (p-PSG) was developed to serve as a screening tool for the examination of healthy individuals in applied research settings [25, 26]. For longitudinal assessments, activity monitors are practical devices as they are incorporated with algorithms to discriminate sleep from wakefulness, providing reasonable estimations of sleep parameters [27]. In order to assess the individual's perception of sleep, several psychometric instruments are available, such as sleep logs and diaries [28, 29] as well as specific questionnaires to target issues like sleep disorders and dysfunctional attitudes toward sleep [15, 20]. Each method has its advantages and limitations that need to be considered depending on the aim of the study.

However, a typical concern could be that the assessment of sleep itself negatively affects the sleep, instead of supporting training adaptation and modification. Especially, the application of multiple sensors, as is the case with p-PSG, may be considered rather obtrusive. Individuals could become inevitably aware of being analyzed. At the same time, the objectives of sleep questionnaires and diaries, which assess concrete behavior, are usually transparent to the respondents as well. Thus, the question arises whether the observation of sleep causes changes in sleep behavior or the attitude toward sleep. Regarding the sleep log, Hoffmann et al. suggested that self-observation could lead to an improvement of symptoms in people having insomnia [29]. Presumably, this becomes obvious in the decreased discrepancies between the subjectively perceived sleep parameters, e.g., sleep-onset latency, and those of the PSG. In this case, the researchers speak of a therapeutic effect.

Contrary to this, Weeß recommended to be cautious in analyzing the first seven days as increased self-observation can lead to irritations and secondary adjustment disturbances [30]. Riemann et al. also suggested that an increased focus on sleep or the absence of sleep is problematic for the affected people [31]. This reflects Harvey's assumption that focused monitoring of sleep can aggravate insomnia symptoms [19]. Overall, these considerations are ambiguous about the negative or positive influence of sleep logs on subjective sleep behavior in people without diagnosed insomnia, especially in young adults or students. It can be assumed that sleep monitoring is an intervention that causes a change in sleep behavior or attitude toward sleep. This phenomenon is also called Mere-Measurement Effect in psychology and is widely known in other topics of behavior and attitude research [32]. The effect of protocolling sleep constitutes a desirable effect in therapeutic settings. However, in controlled intervention studies, a distortion of the results should be eliminated, as far as possible. This is of further importance in control group designs and even more so if the participants are sleep-healthy persons without previous sleep difficulties.

Previous studies have not addressed the aspect of 'intervention' by protocolling sleep in a sleep log. Therefore, we aimed to analyze the effect of a two-week sleep monitoring program in physically active university students on their beliefs and attitudes about sleep. Several studies have reported prevalent insomnia symptoms and dysfunctional attitudes among women [6, 33-35]. Hence, we also included gender as a possible covariate. Moreover, athletes' compliance regarding the application of monitoring devices could be affected, if they would anticipate disturbed sleep as a consequence of the application. Therefore, our second aim was to compare subjective and objective sleep parameters and perceived sleep quality between nights without p-PSG and with p-PSG as well as actigraphy, to analyze if sleep is particularly affected by the application of a monitoring system.

2. Materials and Methods

2.1 Participants

The sample population consisted of 68 university students (n = 28 female, n = 40 male), aged 19 to 33 years, with an average of 26.6 ± 2.5 years. Criteria of inclusion were the age of majority, no neurological restrictions, and no use of sleep-influencing medication for the duration of the study. Moreover, the participants were encouraged to have an athletic background or to regularly engage in sports or exercise, for at least 5 hours per week. On average, the level of weekly physical activity was 6.7 ± 2.6 hours, and 24 athletes reported to participate in competitions regularly. The intervention group consisted of 33 participants (n = 14 female, n = 19 male, 24.4 ± 2.6 years),who completed the two-week sleep monitoring program. The control group consisted of 35 participants (n = 14 female, n = 21 male, 24.9 ± 2.4 years), who only answered the questionnaires at pre- and post-measurements. Age (t (65) = -0.862, p = 0.392), gender (X^2 = 0.041, df = 1, p = 0.839), and the number of competitive athletes (X^2 = 0.472, df = 1, p = 0.492) were equally distributed between the two groups.

We obtained written informed consent from the participants before the beginning of the study. All participants received personal feedback about their sleep behavior. Ethical approval was obtained by the faculty's local ethics committee, in advance of the study (Faculty of Sport Science, Ruhr University Bochum, Germany, "EKS21032017").

2.2 Instruments

2.2.1 Dysfunctional Beliefs and Attitudes about Sleep Scale (DBAS)

For the pre- and post-assessment, we used the German version of the Dysfunctional Beliefs and Attitudes about Sleep Scale (DBAS) [36]. This is an adaptation of the English DBAS, with 16 items to identify sleep/insomnia-related cognitions, such as beliefs, attitudes, expectations, appraisals, or attributions [37]. Each statement (e.g., *I am worried that I may lose control over my abilities to sleep*) is rated on a scale, ranging from 0 (*strongly disagree*) to 10 (*strongly agree*). Higher values correspond with dysfunctional beliefs. In accordance with the recommendation of Hiller et al., the total score was used for analyses [20]. Psychometric quality criteria were reasonably fulfilled for the German DBAS, with a good homogeneity of the total score (Cronbach's $\alpha = 0.87$) and a three-factor solution [36]. In particular, the three factors distinguished between beliefs about long-term consequences, biological conditionality of insomnia, and effects on next-day performance. Further, people with insomnia and those without sleep complaints could be reliably differentiated with this scale [36]. Using the mean score of the English DBAS, Carney et al. identified a cut-off value of 3.8, which we also applied in the present study [38]. While the sum score was used to evaluate the German version (ranging 0–160), a mean value (ranging 0–10) was calculated to apply the cut-off to the current sample. Accordingly, mean scores of 3.8 and below were graded as normal, while mean scores from 3.9 to 10 were considered as an unhelpful degree of sleep-related beliefs.

2.2.2 Sleep Log

Sleep behavior was documented over a course of two weeks every evening and morning, with a modified sleep log, according to the German standard assessment tool [29]. Participants reported the times of going to bed, waking up, and rising. They rated the time to initiate sleep (sleep-onset latency; SOL) as well as wake periods and the total amount of waking up after falling asleep (wake after sleep-onset; WASO). Final wake time (FWT) was the duration of wakefulness between sleep-offset and rising. These reports were used to calculate the sleep parameters—time in bed (TIB), total sleep time (TST), and sleep efficiency (SE) as TST:TIB ratio in percent. Sleep quality was assessed in terms of perceived restfulness on a Likert-type rating scale ranging from 1 (*very*) to 5 (*not at all*), with lower values indicating most restful sleep. Mood was rated on a Likert-type rating scale ranging from 1 (*relaxed*) to 6 (*tensed*), with lower values indicating a positive mood state.

2.2.3 Actigraphy

For objective sleep assessment, the SenseWear MF Armband™ (SWA; BodyMedia, Pittsburg, USA) was applied in the second week of the study. It was worn on the triceps of the non-dominant arm. Wakefulness is distinguished from sleep state through the processing data of the dual-axis accelerometer and sensors for skin conductance, heat flow, skin and ambient temperatures, based on the proprietary algorithms. Raw data were exported to Excel sheets with the SenseWear Professional Software 8.1. We calculated the sleep parameters described above, following the procedure reported by Kölling et al. [39]. Several studies have demonstrated the practicability and validity of the SWA in comparison to the gold standard PSG [40-42].

2.3 Procedure

Over the course of two weeks, participants of the intervention group answered a sleep protocol via an online platform (SoSciSurvey), two times during the day—immediately before going to bed and every morning no later than 30 min after getting up [29]. Figure 1 provides an overview of the experimental set-up. The first week served as a baseline measurement; in the second week, the SWA recorded the nocturnal sleep behavior. Furthermore, a p-PSG device, SOMNOwatch™ Plus EEG (SOMNOmedics, Randesacker, Germany), was used during the last two nights. The participants positioned ten self-adhesive electrodes in their home environment, after receiving information and personal briefings about the handling, as recommended by Hof zum Berge et al. [26]. As the aim of the present study was to analyze the effect of the application of that device only, data of those recordings are not reported in this manuscript. The DBAS was answered at the beginning and at the end of the monitoring phase, while the control group did not receive any instructions in that interval. Participants of both groups could freely choose their times of lights-off and lights-on.

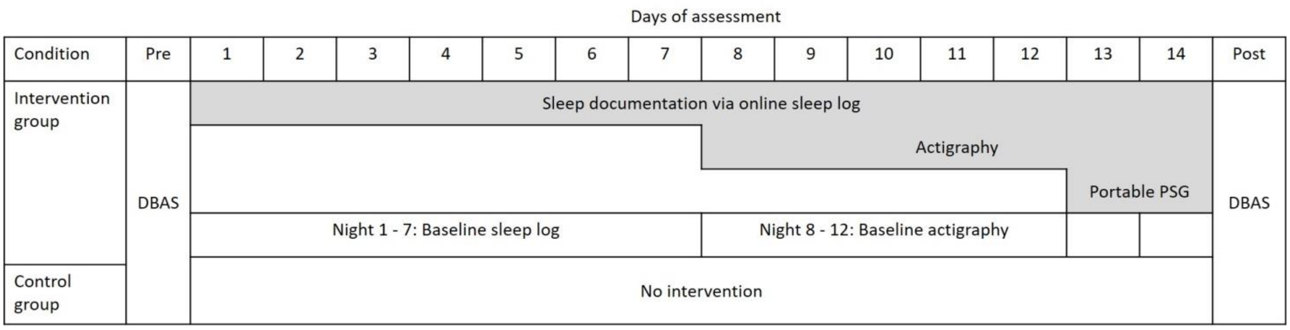

Figure 1 Overview of the experimental set-up. Note: DBAS = Dysfunctional Beliefs and Attitudes about Sleep Scale; p-PSG = Portable polysomnography.

2.4 Statistical Analyses

Statistical analyses were performed with IBM SPSS 25. A mixed analysis of variance (ANOVA) was conducted with the group as a between-subject factor to compare the monitoring group and the control group, regarding the DBAS ratings from pre-monitoring (t1) to post-monitoring (t2). In a second step, gender was integrated into the analysis.

To analyze the effect of applying actigraphy and the p-PSG device, subjective and objective sleep parameters were analyzed via ANOVA for repeated measurements. For this purpose, the first week of monitoring, with sleep log only, was aggregated to a baseline score (subjective baseline), while the five nights of the actigraphy-only application were aggregated to the objective baseline (Figure 1). Thus, subjective sleep parameters were compared with the time variables of subjective baseline, first and second night of actigraphy, and first and second night of p-PSG application. Objective sleep parameters were compared between the actigraphy baseline and the first and second night of p-PSG application. Degrees of freedom were adjusted via Greenhouse–Geisser procedure, if the assumption of sphericity was violated. The level of significance was set to $p < 0.05$ and effect sizes were determined as *small* (i.e., η_p^2 = 0.10 – 0.039), *intermediate* (i.e., η_p^2 = 0.060 – 0.110), and *large* (i.e., $\eta_p^2 \geq 0.140$) following Cohen's categorization [43]. Bonferroni-corrected post-hoc tests were performed, when significant time effects were found.

Missing data occurred among selected variables either because participants did not complete the second DBAS assessment or because participants or SWA did not record single nights. Thus, varying sample sizes were reported for specific analyses.

3. Results

3.1 DBAS

The descriptive statistics of the DBAS scores are shown in Table 1. On a descriptive level, the sleep monitoring group showed a slight increase in the DBAS scores, while the control group slightly decreased. However, there was no significant time effect (F (1, 56) = 0.109, p = 0.742, η_p^2 = 0.002), nor a significant group×time interaction (F (1, 56) = 1.781, p = 0.187, η_p^2 = 0.031). In addition, there was no group effect either at t1 (F (1, 56) = 0.423, p = 0.518, η_p^2 = 0.008) or at t2 (F (1, 56) = 0.080, p = 0.779, η_p^2 = 0.001). Moreover, gender was not a significant covariate (F (1, 55) = 1.781, p = 0.809, η_p^2 = 0.001). At t1, 35.3% (n = 24) of the participants identified with an unhelpful degree of sleep-related beliefs, with 36.4% (n = 12) of the monitoring group and 34.3% (n = 12) of the control group. A comparable classification was present for the total sample at t2, with 36.2% showing an unhelpful degree. The distribution decreased in the monitoring group (28.0%) and increased in the control group (42.4%) at t2. Despite this, the groups did not differ significantly after the monitoring phase (X^2 = 1.281, df = 1, p = 0.258). In addition, comparing the cut-off values from t1 to t2, no change was observed for 70.6% (n = 48) of the total sample, 76% (n = 19) of the monitoring group, and 87.9% (n = 29) of the control group. Two participants from the monitoring group and three from the control group developed an unhelpful degree of sleep-related beliefs. At the same time, four participants from the monitoring group and one from the control group changed from unhelpful to normal DBAS scores.

Table 1 Scores of the DBAS at pre (t1) and post (t2) monitoring.

	Sleep monitoring group (n = 25)		Control group (n = 33)	
	M	*SD*	*M*	*SD*
DBAS total score t1	52.4	18.1	56.4	26.6
DBAS total score t2	54.5	18.2	52.9	23.7

Note: DBAS = Dysfunctional Beliefs and Attitudes about Sleep Scale.

3.2 Sleep Parameters

The participants were asked to specify the location and whether they were sleeping alone each night. Table 2 shows the frequency of responses for the first two nights of actigraphy and the two nights of p-PSG application. The majority of the participants (73-91%) spent the nights at home when they applied the actigraphy and p-PSG devices, and most of them (58-70%) slept alone each night. In an open response format in the sleep log, participants could comment on reasons for unrestful sleep. One participant reported discomfort with the SWA on the first night. Twelve participants reported discomfort with the p-PSG device on the first night, and nine on the second night. In terms of insomnia-related sleep parameters (i.e., SOL ≥ 30 min, WASO and/or FWT ≥ 30 min, wake periods ≥ 3 times [21, 44, 45]), 55% of the monitoring group experienced the symptoms three or more times in the sleep log for week 1 and week 2. At the same time, dissatisfaction with their sleep (i.e., values of 4 [*barely*] or 5 [*not at all*] for restfulness) was not present in week 1, and present for only two participants in week 2.

Table 2 Frequency (*n* [%]) of sleeping conditions in the first two nights with actigraphy and portable PSG of the sleep monitoring group (*n* = 33).

	Night spent at home	Night spent outside home	Night spent alone	Night spent with other person in the room	Night spent with other person in same bed
1. Night actigraphy	27 (82%)	2 (6%)	19 (58%)	-/-	10 (30%)
2. Night actigraphy	24 (73%)	6 (18%)	22 (67%)	1 (3%)	7 (21%)
1. Night p-PSG	27 (82%)	4 (12%)	19 (58%)	-/-	12 (36%)
2. Night p-PSG	30 (91%)	3 (9%)	23 (70%)	-/-	10 (30%)

Note: p-PSG = Portable polysomnography.

The results of the comparison of subjective sleep parameters between subjective baseline nights and the first two nights with actigraphy and p-PSG application are shown in Table 3. TIB had an *intermediate* effect, while post-hoc tests did not reveal significant differences among the different nights. On a descriptive level, subjective baseline nights presented the longest duration. TST had a *large* effect, whereas the pairwise comparison between subjective baseline and the first night of actigraphy-only indicated a trend (p = 0.053). The remaining subjective sleep parameters did not reveal significant changes. Regarding the participants' evaluation of their sleep, restfulness had an *intermediate* effect. Specifically, the second night with p-PSG was rated significantly less restful than the subjective baseline nights.

Regarding actigraphy, the participants recorded 209 out of 231 nights in total, with an average of 6.3 nights per participant in the intervention group. Table 4 provides an overview of the analyses for the objective sleep parameters of the SWA. SE had a *large* effect, with both nights of p-PSG showing higher scores compared to the actigraphy baseline. Among the other sleep parameters, WASO also had a *large* effect, where longer duration was recorded in the actigraphy baseline nights compared to both nights with p-PSG.

Table 3 Comparison of subjective sleep parameters of the monitoring group between baseline and the first two nights with actigraphy and portable PSG.

	Subjective baseline		1. Night actigraphy		2. Night actigraphy		1. Night p-PSG		2. Night p-PSG			Statistical analysis		
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*n*	*F* (df)	*p*	η_p^2
Restfulness	2.3	0.6	2.6	0.9	2.3	0.9	2.8	1.1	2.7	0.7	25	3.089 (4, 96)	0.019	0.114
Mood	4.2	0.6	4.4	1.3	4.4	1.1	4.2	1.0	4.2	0.8	21	0.448 (4, 80)	0.773	0.022
SE	92.6	4.0	87.6	13.2	92.5	5.0	88.6	10.5	89.7	10.1	21	1.676 (2.9, 59.0)	0.183	0.077
SOL	17.3	12.0	18.0	20.3	16.5	14.9	26.1	40.9	19.1	14.5	25	0.840 (1.7, 40.7)	0.422	0.034
TIB	519.0	45.8	458.0	82.8	509.2	81.2	488.4	83.4	465.0	88.7	21	3.038 (2.8, 56.0)	0.040	0.132
TST	480.5	50.0	404.9	101.9	471.3	82.3	432.9	92.3	419.6	99.4	21	3.643 (2.8, 56.0)	0.020	0.154
Wake periods	2.4	0.8	2.2	1.0	2.9	2.0	2.8	1.6	2.9	1.1	9	0.595 (4, 32)	0.669	0.069
WASO	15.9	13.5	18.0	21.2	22.2	27.4	12.8	9.1	16.3	13.8	9	0.418 (1.8, 14.3)	0.644	0.050
FWT	13.7	8.9	18.3	32.3	15.2	15.7	21.4	20.8	18.7	26.4	21	0.527 (2.6, 52.3)	0.641	0.026

Note: Baseline refers to nights 1-7 of sleep log; p-PSG = portable polysomnography; SE = sleep efficiency (in %); SOL = sleep-onset latency (in min); TIB = time in bed (in min); TST = total sleep time (in min), WASO = wake after sleep-onset (in min); FWT = final wake time (in min), Restfulness = 1 (*not at all*) – 5 (*very*), Mood = 1 (*relaxed*) – 6 (*tensed*).

Table 4 Comparison of objective sleep parameters of the monitoring group between actigraphy baseline and the first two nights with portable PSG

	Actigraphy baseline		1. Night p-PSG		2. Night p-PSG		Statistical analysis			
	M	*SD*	*M*	*SD*	*M*	*SD*	*n*	*F* (df)	*p*	η_p^2
SE	85.0	6.6	89.0	5.2	87.9	7.2	27	7.493 (2, 52)	0.001	0.224
SOL	11.2	7.3	8.3	8.8	9.4	5.6	27	1.313 (2, 52)	0.278	0.048
TIB	452.8	56.7	430.6	69.3	413.1	98.1	27	2.728 (2, 52)	0.075	0.095
TST	384.8	53.7	383.3	65.3	363.2	90.9	27	1.293 (2, 52)	0.283	0.047
Wake periods	12.5	5.4	9.1	5.5	13.6	15.6	27	1.510 (1.2, 31.3)	0.233	0.055
WASO	47.6	28.4	27.2	24.4	31.1	31.3	27	7.084 (2, 52)	0.002	0.214
FWT	11.6	3.6	12.0	8.0	8.9	6.9	27	2.478 (2, 52)	0.094	0.087

Note: Baseline refers to nights 8-12 with actigraphy; p-PSG = portable polysomnography; SE = sleep efficiency (in %); SOL = sleep-onset latency (in min); TIB = time in bed (in min); TST = total sleep time (in min), WASO = wake after sleep-onset (in min); FWT = final wake time (in min).

4. Discussion

The aim of the present study was to analyze the effects of a two-week sleep monitoring program among physically active university students. The results revealed that the program had no significant effect on dysfunctional beliefs and attitudes about sleep, as neither the monitoring nor the control group presented any substantial changes. Thus, it seems that two-weeks is too short a period to meet all the requirements of a systematic intervention. The results rather underline the stable nature of (dysfunctional) beliefs, reinforcing the conclusions by Morin et al. [37]. Another intervention study supports this assumption, where they studied insomniacs with a waiting list control group [46]. A reduction in DBAS scores was observed only in the intervention group, which received treatment via cognitive behavior therapy for insomnia. Although that type of therapy is generally established, Schlarb et al. argue that dysfunctional attitudes and beliefs still persist [47].

The monitoring of sleep and the use of p-PSG system affected the sleep patterns and perception of sleep of the participants. The movement-based assessment indicated that participants spent less time in bed when they applied the p-PSG system. But, in contrast to prior assumptions, those nights revealed better sleep patterns in terms of reduced wake duration and higher sleep efficiency. We hypothesize that sleep monitoring led participants to perform certain sleep hygiene practices, either consciously or subconsciously. The application of the electrodes requires time and preparation. This could have led to a change in their bedtime routine and an intentional focus on the sleep period. The participants may have refrained from distracting behaviors, thus being more aware of going to sleep. In addition, they may have chosen a convenient time frame without external disturbances to reduce any distractions. Another explanation for reduced WASO could be that the participants were limited in their range of movement, with the armband registering less arousal in terms of movement in bed. We expected participants to report difficulties initiating sleep or having lighter, disrupted sleep due to the use of p-PSG. However, subjective sleep parameters did not change significantly for those specific nights. Only sleep-onset latency (SOL) increased on a descriptive level, but there was also higher variability for the nights with p-PSG. Yet, subjectively perceived sleep quality was indeed affected negatively. The degree of the restfulness was significantly reduced, and several participants reported discomfort sleeping with p-PSG. The application of actigraphy, on the other hand, did not have negative effects on the sleep parameters; although, it remains unclear why the first night with the armband was the shortest. Unfortunately, analyses of the wake periods and wake duration had to be interpreted very cautiously due to the reduced sample size. Missing responses in the sleep log were not coded as zero, as it could only be speculated whether the participants did not perceive any wake phases. It is possible that these participants could not remember the exact number, and thus did not report reliable estimations. Based on these results, practitioners may address any possible reservations the participants may have. They may emphasize that perception of disturbed sleep does not necessarily come along with measurable effects on sleep, to increase athletes' compliance.

The National Sleep Foundation recommends at least 7 to 9 h of sleep [48]. The participants did not meet this required amount, according to the average value of actigraphy recordings. Therefore, the reduced wake time could be attributed to accumulated fatigue and need for sleep, resulting in overcompensation by quickly falling and staying asleep.

While the present study was not specifically targeted at students with insomnia, more than half of the monitoring group revealed certain symptoms of insomnia during the study. These symptoms were categorized following the criteria that are commonly reported in insomnia research [21, 44, 45]. However, these symptoms only applied for the sleep pattern and not for subjective complaints. Taylor et al. reported a similar finding, identifying 26.9% of 1039 university students with problematic sleep patterns but without insomnia complaints [49]. This underlines the vulnerability of that population dealing with challenging sleep issues. According to a systematic review, prevalence rates are higher among university students than the general population [5]. It needs to be critically remarked, though, that there was no clinical diagnosis of sleep disorders in our study. Moreover, a time frame of two weeks is too short to identify insomnia, as symptomology needs to be manifested over at least one month according to the International Classification of Mental and Behavioral Disorders [50], or for at least three months according to the International Classification of Sleep Disorders [51].

Further limitations of this study need to be taken into consideration. As the sample size was quite small in each group, the results have to be interpreted cautiously. Unfortunately, several participants of the monitoring group failed to answer the post-questionnaire, and single nights were missed or single items were omitted. Future studies may address these issues to apply advanced statistical approaches, such as multilevel modeling [52]. In addition, we could not control the compliance of the participants with regards to the completion of the morning sleep log within 30 min after waking. Therefore, the present study rather serves as a pilot to examine the effects of monitoring sleep and using complex devices in the natural environment of physically active and healthy participants. This set-up needs to be replicated in the setting of elite sports to verify the present findings. In addition, a thorough anamnesis of sleep-related issues may be done in advance to exclude any occurrence of insomnia in the past. Future research could also consider a longer time frame of monitoring and focus on other constructs than the beliefs and attitudes about sleep.

5. Conclusions

Overall, the present study did not identify any measurable effects in terms of changed attitudes toward sleep. Nevertheless, anecdotal reports of some participants revealed that they gained an increased awareness of their sleep and sleep behavior. According to objective assessments, the p-PSG device did not negatively affect sleep. Thus, these results have two implications — (1) in field-based research or intervention studies, documentation of sleep via online logs does not have negative effects on the participants, and (2) the stability of objective sleep parameters should pacify the concerns of potential participants and practitioners regarding any confounding effects of sleep monitors. However, the likely discomfort with the electrodes needs to be communicated. Therefore, p-PSG may be applicable for field studies in sport science without significantly affecting the sleep quality, on the condition that participants receive detailed information ahead of the assessments.

Acknowledgments

We would like to thank the participants for their valuable contribution to this study. Special thanks go to the student assistants for their support in the provision of the individual feedback.

Author Contributions

Both authors contributed equally to the conceptualisation of the study, the data collection, analyses and the preparation of the manuscript.

Funding

There was no funding for this research.

Competing Interests

The authors have declared that no competing interests exist.

References

1. Kölling S, Duffield R, Erlacher D, Venter R, Halson SL. Sleep-related issues for recovery and performance in athletes. Int J Sports Physiol Perform. 2019; 14: 144-148.
2. Halson SL. Sleep and the elite athlete. Sports Sci Exc. 2013; 26: 1-4.
3. Bryant PA, Trinder J, Curtis N. Sick and tired: Does sleep have a vital role in the immune system? Nat Rev Immunol. 2004; 4: 457-467.

4. Tobaldini E, Costantino G, Solbiati M, Gogliati C, Kara T, Nobili L, et al. Sleep, sleep deprivation, autonomic nervous systems and cardiovascular diseases. Neurosci Biobehav Rev. 2017; 74: 321-329.
5. Jiang XL, Zheng XY, Yang J, Ye CP, Chen YY, Zhang ZG, et al. A systematic review of studies on the prevalence of insomnia in university students. Public Health. 2015; 129: 1579-1584.
6. Schlarb AA, Claßen M, Grünwald J, Vögele C. Sleep disturbances and mental strain in university students: Results from an online survey in Luxembourg and Germany. Int J Ment Health Syst. 2017; 11: 24.
7. Lastella M, Roach GD, Halson SL, Sargent C. Sleep/wake behaviours of elite athletes from individual and team sports. Eur J Sport Sci. 2015; 15: 94-100.
8. Erlacher D, Ehrlenspiel F, Adegbesan OA, El-Din HG. Sleep habits in German athletes before important competitions or games. J Sports Sci. 2011; 29: 859-866.
9. Gupta L, Morgan K, Gilchrist S. Does elite sport degrade sleep quality? A systematic review. Sports Med. 2017; 47: 1317-1333.
10. Roberts SSH, Teo WP, Warmington SA. Effects of training and competition on the sleep of elite athletes: A systematic review and meta-analysis. Brit J Sports Med. 2019; 53: 513-522.
11. Sargent C, Lastella M, Halson SL, Roach GD. The impact of training schedules on the sleep and fatigue of elite athletes. Chronobiolog Int. 2014; 31: 1160-1168.
12. Lastella M, Roach GD, Halson SL, Martin DT, West NP, Sargent C. Sleep/wake behaviour of endurance cyclists before and during competition. J Sports Sci. 2015; 33: 293-299.
13. Kölling S, Ferrauti A, Meyer T, Pfeiffer M, Kellmann M. Sleep in Sports: A short summary of alterations in sleep/wake patterns and the effects of sleep loss and jet-lag. Dtsch Z Sportmed. 2016; 67: 35-38.
14. Simpson NS, Gibbs EL, Matheson GO. Optimizing sleep to maximize performance: Implications and recommendations for elite athletes. Scand J Med Sci Sports. 2017; 27: 266-274.
15. Buysse DJ, Ancoli-Israel S, Edinger JD, Lichtstein KL, Morin CM. Recommendations for a standard research assessment of insomnia. Sleep. 2006; 29: 1155-1173.
16. Chung KF, Yeung WF, Ho FYY, Yung KP, Yu YM, Kwok CW. Cross-cultural and comparative epidemiology of insomnia: The Diagnostic and Statistical Manual (DSM), International Classification of Diseases (ICD) and International Classification of Sleep Disorders (ICSD). Sleep Med. 2015; 16: 477-482.
17. Ohayon MM. Epidemiology of insomnia: What we know and what we still need to learn. Sleep Med Rev. 2002; 6: 97-111.
18. Singareddy R, Vgontzas AN, Fernandez-Mendoza J, Liao D, Calhoun S, Shaffer ML, et al. Risk factors for incident chronic insomnia: A general population prospective study. Sleep Med. 2012; 13: 346-353.
19. Harvey AG. A cognitive model of insomnia. Behav Res Ther. 2002; 40: 869-893.
20. Hiller RM, Johnston A, Dohnt H, Lovato N, Gradisar M. Assessing cognitive processes related to insomnia: A review and measurment guide for Harvey's cognitive model for the maintenance of insomnia. Sleep Med Rev. 2015; 23: 46-33.
21. Norell-Clarke A, Jansson-Fröjmark M, Tillfors M, Harvey AG, Linton SJ. Cognitive processes and their association with persistence and remission of insomnia: Findings from a longitudinal study in the general population. Behav Res Ther. 2014; 54: 38-48.

22. Takano K, Sakamoto S, Tanno Y. Repetitive thought impairs sleep quality: An experience sampling study. Behav Ther. 2014; 45: 67-82.
23. Halson SL. Sleep monitoring in athletes: Motivation, methods, miscalculations and why it matters. Sports Med. 2019; 49: 1487-1497.
24. Carskadon MA, Dement WC. Monitoring and staging human sleep. In: Kryger MH, Roth T, Dement WC, editors. Principles and practice of sleep medicine. 5th ed. St. Louis, MO: Elsevier Saunders. 2011: 16-26.
25. Voinescu BI, Wislowska M, Schabus M. Assessment of SOMNOwatch plus EEG for sleep monitoring in healthy individuals. Physiol Behav. 2014; 132: 73-78.
26. Hof zum Berge A, Kellmann M, Kallweit U, Mir S, Geiselmann A, Meyer T, et al. Portable PSG for sleep stage monitoring in sports: Assessment of SOMNOwatch pluss EEG. Eur J Sport Sci. 2019: E-pub ahead of print.
27. Sadeh A. The role and validity of actigraphy in sleep medicine: An update. Sleep Med Rev. 2011; 15: 259-267.
28. Carney CE, Buysse DJ, Ancoli-Israel S, Edinger JD, Krystal AD, Lichtstein KL, et al. The consensus sleep diary: Standardizing prospective sleep self-monitoring. Sleep. 2012; 35: 387-302.
29. Hoffmann RM, Müller T, Hajak G, Cassel W. Abend-Morgenprotokolle in Schlafforschung und Schlafmedizin - Ein Standardinstrument für den deutschsprachigen Raum. Somnologie. 1997; 1: 103-109.
30. Weeß H-G. Diagnostische Methoden. In: Stuck BA, Maurer JT, Schredl M, Weeß H-G, editors. Praxis der Schlafmedizin. 2 ed. Heidelberg: Springer. 2013: 21-82.
31. Riemann D, Spiegelhalder K, Voderholzer U, Kaufmann R, Seer N, Klöpfer C, et al. Primäre Insomnien: Neue Aspekte der Diagnostik und Differentialdiagnostik, Ätiologie und Pathophysiologie sowie Psychotherapie. Somnologie. 2007; 11: 57-71.
32. French DP, Sutton S. Reactivity to measurement in health psychology: How much of a problem is it? What can be done about it? Brit J Health Psychol. 2010; 15: 453-468.
33. Brand S, Gerber M, Pühse U, Holsboer-Trachsler E. Depression, hypomania, and dysfunctional sleep-related cognitions as mediators between stress and insomnia: The best advice is not always found on the pillow! Int J Stress Manag. 2010; 17: 114-134.
34. Gaultney JF. The prevalence of sleep disorders in college students: Impact on academic performance. J Am Coll Health. 2010; 59: 91-97.
35. Lang C, Brand S, Holsboer-Trachsler E, Pühse U, Colledge F, Gerber M. Validation of the German version of the short form of the Dysfunctional Beliefs and Attitudes about Sleep Scale (DBAS-16). Neurol Sci. 2017; 38: 1047-1058.
36. Weingartz S, Pillmann F. Meinungen-zum-Schlaf-Fragebogen. Deutsche Version der DBAS-16 zur Erfassung dysfunktionaler Überzeugungen und Einstellungen zum Schlaf. Somnologie. 2009; 13: 29-36.
37. Morin CM, Vallières A, Ivers H. Dysfunctional Beliefs and Attitudes about Sleep (DBAS): Validation of a brief version (DBAS-16). Sleep. 2007; 30: 1547-1554.
38. Carney CE, Edinger JD, Morin CM, Manber R, Rybarczyk B, Stepanski EJ, et al. Examining maladaptive beliefs about sleep across insomnia patient groups. J Psychosom Res. 2010; 68: 57-65.

39. Kölling S, Endler S, Ferrauti A, Meyer T, Kellmann M. Comparing subjective with objective sleep parameters via multi-sensory actigraphy in German Physical Education students. Behav Sleep Med. 2016; 14: 389-405.
40. Al Otair H, Al-shamiri M, Bahobail M, Sharif MM, BaHammam AS. Assessment of sleep patterns, energy expenditure and circadian rhythms of skin temperature in patients with acute coronary syndrome. Med Sci Monit. 2011; 17: 397-403.
41. Sharif MM, BaHammam AS. Sleep estimation using BodyMedia's SenseWear™ armband in patients with obstructive sleep apnea. Ann Thorac Med. 2013; 8: 53-57.
42. Soric M, Turkalj M, Kucic D, Marusic I, Plavec D, Misigoj-Durakovic M. Validation of a multi-sensor activity monitor for assessing sleep in children and adolescents. Sleep Med. 2013; 14: 201-205.
43. Cohen J. Statistical power analysis for the behavioral sciences. New York: Erlbaum; 1988.
44. Eidelman P, Talbot L, Ivers H, Bélanger L, Morin CM, Harvey AG. Change in dysfunctional beliefs about sleep in behavior therapy, cognitive therapy, and cognitive-behavioral therapy for insomnia. Behav Ther. 2016; 47: 102-115.
45. Woodley J, Smith S. Safety behvaiors and dysfunctional beliefs about sleep: Testing a cognitive model of the maintenance of insomnia. J Psychosom Res. 2006; 60: 551-557.
46. Taylor DJ, Zimmermann MR, Gardner CE, Williams JM, Grieser EA, Tatum JI, et al. A pilot randomized controlled trial of the effects of cognitive-behavioral therapy for insomnia on sleep and daytime functioning in college students. Behav Ther. 2014; 45: 376-389.
47. Schlarb AA, Friedrich A, Claßen M. Sleep problems in university students – an intervention. Neuropsychiatr Dis Treat. 2017; 13: 1989-2001.
48. Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, et al. National Sleep Foundation's updated sleep duration recommendations: Final report. Sleep Health. 2015; 1: 233-243.
49. Taylor DJ, Bramoweth AD, Grieser EA, Tatum JI, Roane BM. Epidemiology of insomnia in college students: Relationship with mental health, quality of life, and substance use difficulties. Behav Ther. 2013; 44: 339-348.
50. WHO, editor. The ICD-10 classification of mental and behavioural disorders. Clinical descriptions and diagnostic guidelines. Genf: WHO. 1992.
51. AASM, editor. International classification of sleep disorders. 3rd ed. Darien, IL: Am Acad Sleep Med. 2014.
52. Quené H, van den Bergh H. On multi-level modeling of data from repeated measures designs: A tutorial. Speech Commun. 2004; 43: 103-121.