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Portable polysomnography for sleep monitoring in elite youth rowing: An athlete's gain or the sleep's thief?

Annika Hof zum Berge[1] | **Alexander Ferrauti**[1] | **Tim Meyer**[2] | **Mark Pfeiffer**[3] | **Michael Kellmann**[1,4]

[1]Faculty of Sport Science, Ruhr University Bochum, Bochum, Germany

[2]Institute of Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany

[3]Institute of Sport Science, Johannes-Gutenberg University, Mainz, Germany

[4]School of Human Movement and Nutrition Sciences, The University of Queensland, Brisbane, Australia

Correspondence
Annika Hof zum Berge, Faculty of Sport Science, Ruhr University Bochum, Gesundheitscampus Nord 10, 44801 Bochum, Germany.
Email: annika.hofzumberge@rub.de

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Abstract

Portable polysomnography (PSG) is a promising tool to assess sleep architecture and stages in athletes, yet there are hardly any research findings concerning comfort and practicability within the applied field. Thus, aim of this study was to examine to what extent self-applied portable PSG has an influence on objective (measured via actigraphy) and subjective (measured via sleep log) sleep parameters. Consequently, it should be assessed in how far the use of a portable PSG in sport-scientific field investigations is reasonable. The study sample included thirteen elite youth rowers (M_{age} = 16.31 ± 0.63 years; M_{height} = 187.23 ± 5.3 cm; M_{weight} = 81.92 ± 7.59 kg) of the German Rowing Federation. During a preparational training camp with standardized sleeping conditions, athletes engaged in a supervised sleep monitoring. Participants kept a sleep log (for subjective evaluation of sleep) and wore an actigraphy bracelet (for objective evaluation of sleep) on four consecutive days. Further, athletes applied a portable PSG device on two consecutive nights in randomized order. Results indicate no significant differences between nights with and without the application of portable PSG for all objective and subjective sleep parameters. Its use seems to be reasonable without affecting sleep quality significantly. Hence, portable PSG may be installed whenever the assessment of sleep architecture seems desirable and information cannot be adequately attained by actigraphy.

KEYWORDS

exercise, health, physical activity

1 | INTRODUCTION

Sleep is identified as a reoccurring behavioral state of reduced movement and responsiveness, allowing rest from prior periods of wakefulness, and is considered a precious resource for both, psychological and physiological well-being.[1,2] It follows a specific architecture within a circadian and ultra-circadian rhythm, and is divided into five stages, with three sleep stages (N1-N3), rapid eye movement (REM) sleep, and the waking state. Sleep stages split into light (N1-N2) and slow-wave (N3) sleep. A healthy sleeper starts a sleep cycle with N1, followed by more robust sleep (N2) and deep sleep (N3). REM as the last stage completes one sleep cycle. Ideally, a sleep cycle repeats three to seven times during a night. With each repetition, deep sleep is continuously reduced, while REM episodes increase in the last cycles of a night.[3] The exact functions of sleep are not fully researched yet, but some general assumptions about the function of different sleep stages can be generated regarding occurring symptoms of disturbed or deprived sleep. While REM sleep seems to be vital for memory and procedural learning, as well as brain stimulation and localized recuperation processes, non-REM sleep is essential for recovery and somatic function.[1,4,5]

Elite athletes, who constantly need to perform on the highest level, have an especially high demand in both, physiological and cognitive functioning.[6,7] Hence, covering the demand of all sleep stages seems to be of high importance to ensure an athlete's overall performance capability and health.[8,9] Deficiency in sleep, contrarily, is negatively linked to athletic performance (eg, speed and endurance), neurocognitive function (eg, attention and memory), and physical health (eg, illness, injury risk, and weight maintenance).[10] Further, sleep disturbances are allegedly a key symptom of non-functional overreaching/overtraining and hence a direct result of increased training load or indirect adjustments to training scheduling. Nevertheless, a large number of athletes reports sleep issues, as well as a variety of non-medical explanations.[1,9] Some of these can be tackled through appropriate education and behavior change strategies, and others mostly relate to the overall elite athlete's lifestyle and are influenced by the elite sports system itself.[11] Thus, to efficiently intervene against athlete's sleep disturbances, there is substantial need for intra-individual sleep monitoring in elite sports in order to identify the specific areas of concern.[6,9,12,13]

In clinical and research settings, in-laboratory polysomnography (PSG) is the gold standard diagnostic test.[11] Within PSG, three physiological parameters are derived by means of electroencephalography (EEG; brain activity), electrooculogram (EOG; eye movement), and electromyography (EMG; muscle tonus), with EEG measures being the most important parameter for determining level of consciousness and allowing determination of sleep stages.[2] Yet, in-laboratory PSG is not feasible in sport-scientific field studies; hence, most of the sleep data in a population of athletes is obtained by using subjective questionnaires or wrist actigraphy as they are portable, non-invasive, and no specialist is needed to secure the recording.[11,14-16] However, as no EEG measures are recorded, it is not possible to score sleep stages with these methods. Thus, they cannot measure physiological aspects of sleep.[2] Considering that different sleep stages have different functions, the question needs to be raised if actigraphy can display sleep quality and therefore can be used to evaluate whether an athlete effectively meets his or her very own requirements of sleep. Nonetheless, sleep monitoring in a sleep laboratory is financially and time effectively almost impossible in elite sports.[14,17]

Prospectively, first smartphone applications promise to monitor sleep stages via acceleration and microphone, but do not result sufficiently reliable in sleep-wake detection compared with polysomnography and exhibit significant differences in sleep stages' identification when compared with gold standard devices.[18] As one example, a study by Fino and colleagues indicated a high sensitivity in detecting sleep (range 91%-97.4%) but a low specificity in detecting wakefulness (range 0%–48%), and an overall accuracy of 92.8% (range 85%-95%). Further, the smartphone application underestimated wake and sleep efficiency, while overestimating deep sleep and total sleep time compared with the PSG.[19] To overcome this hurdle, first studies indicate portable PSG to be an advisable and promising tool to assess sleep architecture and stages in athletes, prospectively, leading to a new approach in monitoring sleep.[20,21] Portable PSG may ensure locational independence and improve overall comfort and compliance, while assessing sleep stages and possibly identifying sleep irregularities or even disorders early on.[20,22] With a 97.79% sensitivity and accuracy of 97.06% of the epochs being correctly identified, the SOMNOwatch plus EEG may serve as a reliable tool for sleep specialists that are looking for a more reliable, long-term recorded total sleep time evaluation.[21] Yet, correct positioning of scalp electrodes requires a trained sleep nurse or researcher. Thus, the reduction of electrodes and modification to forehead EEG electrodes could serve as a suitable option.[23,24] A first study by Hof zum Berge and colleagues advocates the SOMNOwatch plus EEG device to be a suitable and self-applicable device whenever information cannot be sufficiently achieved by actigraphy.[20] Yet, there are only restricted findings for its use in sport-relevant settings. First investigations suggest that sleeping with this kind of setup may lead to reduced subjective sleep quality, but not to objectively measurable reduction of sleep.[22] Hence, the device seems to be applicable in sport-scientific field studies without significantly affecting sleep quality, on condition that participants receive detailed information prior the assessment.[22] However, it must be taken into consideration that findings were conducted with sportive students, rather than elite athletes. Therefore, the acceptance and willingness of coaches and athletes to apply the device remain unknown.[25]

As the application of EEG electrodes is more invasive than the use of actigraphy, a widespread concern might be that athletes' sleep quality is reduced while wearing a portable PSG device which means usage is not possible in high-intensity training and competition phases. Moreover, the unfamiliar sleeping situation may have a retroactive effect on the perception of sleep itself.[22] This is of additional importance, as an athlete's perception of sleep is associated with deviations in well-being measures.[26] Further, these worries may lead to a mere-measurement effect possibly causing a change in sleep behavior or attitude toward sleep.[22,27] Thus, subsequent studies need to investigate to which extent the usage affects overall comfort and sleep quality during the night to determine whether its use is reasonable in immediate competition preparation.[20] Especially for sports with early morning practices, studies advocate that early morning sessions severely restrict the amount of sleep obtained by elite athletes.[28] Thus, sleep plays an important role and sleep architecture may be influenced by early rising times.[29] For this reason, the present study's aim is to examine to what extent the self-applied portable PSG has an influence on objective (measured via actigraphy) and subjective (measured via sleep log) sleep parameters in elite junior rowing.

2 | METHODS

The study sample included 13 youth athletes (six females, seven males; $M_{age} = 16.31 \pm 0.63$ years) from the perspective squad (NK2) of the German Rowing Federation. Athletes were recruited for a 4-day sleep monitoring during a preparational training camp in Vaires-sur-Marne, France. Before starting the monitoring phase, all participants were briefed about the aims of the study, questioned about possible exclusion criteria (ie, neurological disorders and use of sleep-influencing medication), and athletes as well as their legal guardians signed an informed written consent. Further, the study was approved by the local ethics committee. At study completion, participants received a verbal and written individual interpretation of their sleep data constructed by a sleep medicine expert. Descriptive data and performance parameters of the sample group are displayed in Table 1.

Within the week of the training camp, study participants were provided with a standardized sleep protocol designed by the German Sleep Society, the morning-evening protocol,[30] which was completed on four consecutive days (for subjective evaluation of sleep), both in the morning after waking up and at night before going to bed. Time in bed (TIB; bed time until rising time), wake and rising time, estimated Sleep Onset Latency (SOL; duration of falling asleep, in minutes), and Wake After Sleep Onset (WASO; amount of time being awake after falling asleep, in minutes) were noted in the sleep log. Further, Likert scales were presented to rank mood before bedtime on a scale 1 (*tensed*) to 6 (*relaxed*), exhaustion on a scale 0 (*not exhausted*) to 3 (*very exhausted*), and average performance capability on a scale from 1 (*good*) to 6 (*bad*) prior to sleeping. In the morning, the same ranking system was used to evaluate restfulness of sleep (1 = *very*, 5 = *not at all*) and relaxation in the morning (1 = *tensed*, 6 = *relaxed*). Further, athletes were given space to name possible reasons for poor sleep.[30]

The morning-evening protocol is a sleep log developed to reflect the subjective dimension of sleep-wake disorders in German-speaking countries and in order to distinguish between normo- and insomniacs,[30] but also has been used in various studies with German athletes.[22,29,31] Its statistical evaluation shows good discrimination values between clinical and non-clinical populations with satisfactory reliability and validity. Yet, this survey instrument does not solve the problem of inadequate agreement between sleep parameters recorded using polysomnography and sleep diaries in general and only serves as an additional source for the assessment of subjective perception.[30]

Hence, for objectively measurable results, athletes additionally wore an actigraphy armband (SenseWear MF Armband™, BodyMedia) on the non-dominant triceps head for all four nights of the study (for objective evaluation of sleep) and, as independent variable, a portable PSG system (SOMNOwatch plus EEG, SOMNOmedics GmbH) for two nights. The SenseWear MF Armband™ (SWA) includes a dual-axis accelerometer and sensors for skin conductance, heat flow, skin, and ambient temperature. Aside from physical activity and energy expenditure, the data from these sensors are calculated by proprietary algorithms to distinguish wakefulness from sleep. The following sleep parameters were defined for this purpose: SOL, WASO, TIB, Total Sleep Time (TST), and Sleep Efficiency (SE; TST divided by TIB and multiplied with 100). Overall, the validity of SWA has been demonstrated in several publications.[32,33] While Sharif and BaHammam[34] reported strong agreement rates between SWA and PSG for a clinical as well as

TABLE 1 Descriptive group data

	Gender (n)		Age (in years)	Height (in cm)	Weight (in kg)	Ergo 2000 (in min:sec)	Average training hours per week
	m	f	M ± SD	M ± SD	M ± SD	M ± SD	M ± SD
Total (N = 13)	7	6	16.31 ± 0.63	187.23 ± 5.34	81.92 ± 7.59	6.20 ± 0.53	16.92 ± 3.50
Group 1 (n = 7)	4	3	16.29 ± 0.76	187.71 ± 5.22	82.57 ± 6.55	6.08 ± 0.39	16.43 ± 3.70
Group 2 (n = 6)	3	3	16.33 ± 0.52	186.67 ± 5.92	81.17 ± 9.24	6.35 ± 1.08	17.50 ± 3.51

Abbreviations: cm = centimeter; Ergo 2000 = time to row 2000 m on an ergometer; f = female; kg = kilogram; m = male; M = mean; min = minutes; n = number of participants per group; SD = standard deviation; sec = seconds.

a healthy sample with an overall intraclass coefficient >0.8 for TST, >0.6 for WASO and >0.5 for SE, and O'Driscoll and colleagues[32] found epoch-by-epoch estimations of 79.9%. Further, systematic bias and significant differences could be excluded for TST, WASO, and SE.[32,33] Consequently, the SWA appears to be a practical and promising tool in sleep research and has been applied in different field settings.[31]

Prior to monitoring, athletes were randomly assigned to one of two study groups to rule out time and habituation effect, with group one wearing the portable system on the first two nights and group two on the third and fourth night of the study. Both actigraphy armband and portable PSG were self-applied by the participants after they had been informed about the handling in a short and personal group briefing of approximately 10 minutes and had received picture-based instructions as a further guideline. For application of the SOMNOwatch plus EEG devices, ten self-adhesive silver chloride (Ag/AgCl) electrodes (Fiab) were placed (F3, F4, A1, A2, two EOGs, two EMGs, aFz, and FCZ) and digitized with a sampling frequency of 256 Hz.

All participants stayed at the same accommodation within close distance to the training facilities. Rooms were shared with French athletes who were not taking part in the study, in prearranged pairs of two. Time in bed and wake-up time in the morning were delimited, as mandatory breakfast time and nighttime curfew were predetermined by the staff. Overall, athletes objectively spend an average of 7:46 (±0:24) hours in bed, of which they slept 6:36 (±0:29) hours. Subjectively perceived TIB was 8:21 (±0:13) hours, with a TST of 7:40 (±0:37) hours. Intake of caffeine was protocolled in the sleep log, and athletes were encouraged to keep nutrition and sleep routine habits stable over the course of the time of sleep monitoring. Yet, athletes did not have to follow a specific nutrition protocol. Training protocols were predetermined by the coaches, targeting equal training loads over the course of the 4-day sleep monitoring.

Statistical analysis was performed using SPSS V.25 (IBM Corporation). Descriptive statistics are consistently presented as means ± standard deviation. For the interpretation of actigraphy data, SWA raw data were exported with SenseWear Professional software version 8.1 (BodyMedia, Inc) and Excel spreadsheets were analyzed with an objective software program. This software was a self-designed and implemented JAVA program that imports the Excel spreadsheets, calculates the parameters for every night individually, and exports the results night by night in an Excel spreadsheet again.[31] For this cause, SOL was defined as the time in minutes from the beginning of lying until the first 10 consecutive minutes of sleeping.[35] The calculated parameters were afterward transferred to IBM SPSS 25 for further analyses.

Total sleep time and SE were calculated prior to further analysis. Further, mean values for nights with portable PSG and actigraphy (group 1 = night 1 and 2; group 2 = night 3 and 4) and nights with actigraphy only (group 1 = night 3 and 4; group 2 = night 1 and 2) were calculated (objective and subjective time) and then tested for significant differences with paired t tests. Statistical significance was set to $P < .05$. Cohen's effect sizes (d) were calculated and interpreted using thresholds of 0.2, 0.5, 0.8 for small, moderate, and large, correspondingly.[36] For further examination of effect sizes, TOST equivalence tests were run using an Excel spreadsheet[37] as suggested by Lakens, Scheel, and Isager.[38]

3 | RESULTS

Results indicate no significant differences between nights with or without the application of portable PSG for all objective and subjective sleep parameters (Table 2). Yet, when comparing descriptive data, objective and subjective sleep data do vary. Most notably, subjective perception of TST indicated less sleep in nights with portable PSG (T [11] = 1.96, P = .76, d = 0.57) with moderate effect sizes. Yet, the TOST procedure indicated that the observed effect size was not significantly within the equivalent bounds of dz = −0.57 and dz = 0.57, or in raw scores: −37.25 and 37.25, T [11) = 0.01, P = .495.

TABLE 2 Comparison of nights with and without portable PSG.

	Subjective				Objective			
	T	*df*	*P*	*d*	*T*	*df*	*P*	*d*
TIB	1.63	11	.131	0.47	0.82	12	.426	0.23
TST	1.96	11	.076	0.57	0.55	12	.591	0.16
SOL	−1.31	12	.213	−0.36	0.76	12	.463	0.21
WASO	−0.31	12	.761	−0.09	0.85	12	.414	0.23
SE	1.61	11	.135	0.47	−0.73	12	.481	0.20

Note: Objective values represent data measured with actigraphy; subjective values were accumulated via sleep log.Abbreviations: d = Cohen's effect size; df = degrees of freedom; P = probability value; SE = Sleep Efficiency; SOL = Sleep Onset Latency; T = Student's t value (ratio between the difference between the two groups and the difference within the groups); TIB = Time in Bed; TST = Total Sleep Time; WASO = Wake After Sleep Onset.

Further, differences in TIB (T [11] = 1.63, P = .131, d = 0.47) and SE (T [11] = 1.61, P = .135, d = 0.47) with small effect sizes were found subjectively, while SOL appears to be perceived higher for nights with portable PSG (T [12] = −1.31, P = .213, d = −0.36). However, no observed effect size was significantly within the equivalent bounds ($TOST_{TIB}$: T [11] = −0,01, P = .502; $TOST_{SE}$: T [11] = 0,02, P = .494; $TOST_{SOL}$: T [12] = 0,02, P = .506).

In contrast, objectively measured values indicated fewer SOL (T [12] = 0.76, P = .463, d = 0.21) and less WASO (T [12] = 0.85, P = .414, d = 0.23), as well as higher SE (T [12] = −0.73, P = .481, d = 0.20). Once again, the TOST procedure signaled that the observed effect sizes were not significantly within the equivalent bounds ($TOST_{SOL}$: T [12] = 0, P = 0,501; $TOST_{WASO}$: T [12] = −0,02, P = 0,507; $TOST_{SE}$: T [12] = 0,01, P = 0,503). An overview of means and standard deviations for objective and subjective sleep parameters is visualized in Figure 1.

Further, perception of restfulness (T [12] = −0.039, P = .891, d = −0.04) did not vary between nights with or without PSG application alongside mean relaxation values were perceived similarly under both conditions ($M_{actigraphy}$ = 4.73 ± 0.75; M_{PSG} = 4.73 ± 0.73). Two participants in the first night and one athlete in the second night named applicated electrodes as be a possible reason for poorer sleep. Other more frequently named reasons were trouble with breathing (n = 3), urinary urgency (n = 3), heat (n = 6), and unfamiliar sleep environment (n = 7). As presented in Figure 2, one athlete subjectively suffered from a night of extremely restricted sleep (subjective SE = 12.5%; objective SE = 83.2%) while wearing the portable PSG device on the third night but did not give any possible explanation for lack of sleep. Subjective SE increased in the following night, again wearing portable PSG, to an excellent value of 97.85%. Two further participants noted SE below 80% on the first night of PSG application (73.58%; 75.81%). Yet, on the second night of portable PSG application, no subjective SE values were assessed beneath 87.01%. Perceived SE on nights with actigraphy only were 87.63% or higher for night 1 and 87.50% or higher for night 2 (Figure 2).

On an objective level, three participants indicated SE under 80% on the first night wearing the SOMNOwatch plus EEG (66.4%; 71.0%; 72.38%) and two athletes on the second night of wearing the system (64.3%; 77.5%). On nights without the portable PSG device, four athletes reported SE values under 80% on night one (62.3%; 75.5%; 76.7%; 79,6%) and three athletes on night two (70.7%; 71.7%; 77.0%).

4 | DISCUSSION

The aim of the study was to observe whether self-applied portable PSG has an influence on objective and subjective sleep parameters and whether its usage is reasonable in elite sports. Outcomes imply no significant differences between nights with or without the application of portable PSG neither for objective nor for subjective sleep parameters. In fact, sleep disturbances rather seem to be highly individual and, congruent with previous research, their occurrence may be due to a variety of different factors.[9] Yet, nights with portable PSG were perceived as slightly more challenging and overall individual differences were made visible. Henceforth, especially the suitability of the sleep environment needs to be considered. For an optimal sleep environment, room temperature should preferably be rather cool than warm, since exposure to warm environments may

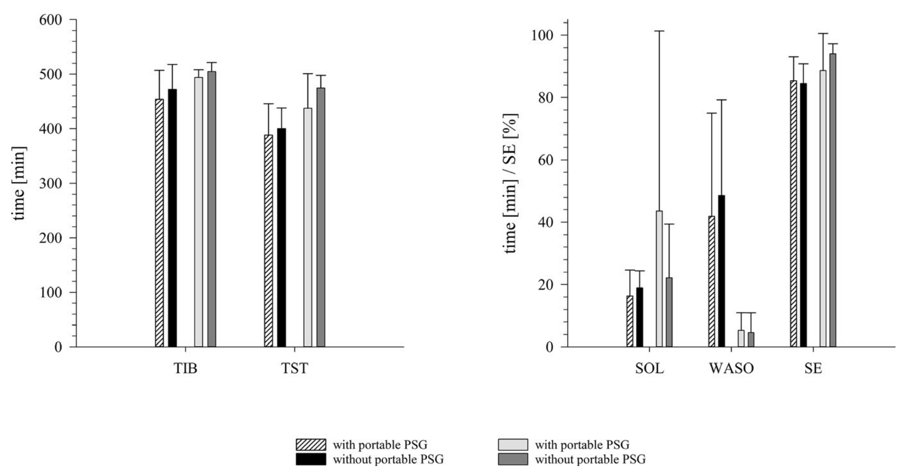

FIGURE 1 *Means and standard deviations for objective (left bar chart) and subjective sleep parameters (right bar chart).*
Annotation. Bar charts represent mean values of each sleep parameter assessed both, objectively via actigraphy (left bar chart) and subjectively via sleep log (right bar chart). For each mean value, standard deviation is represented in the according error bar. Abbreviations for the sleep parameters are used as following: TIB = Time in Bed (in minutes); TST = Total Sleep Time (in minutes); SOL = Sleep Onset Latency (in minutes); WASO = Wake After Sleep Onset (in minutes); SE = Sleep Efficiency (in percent); PSG = polysomnography.

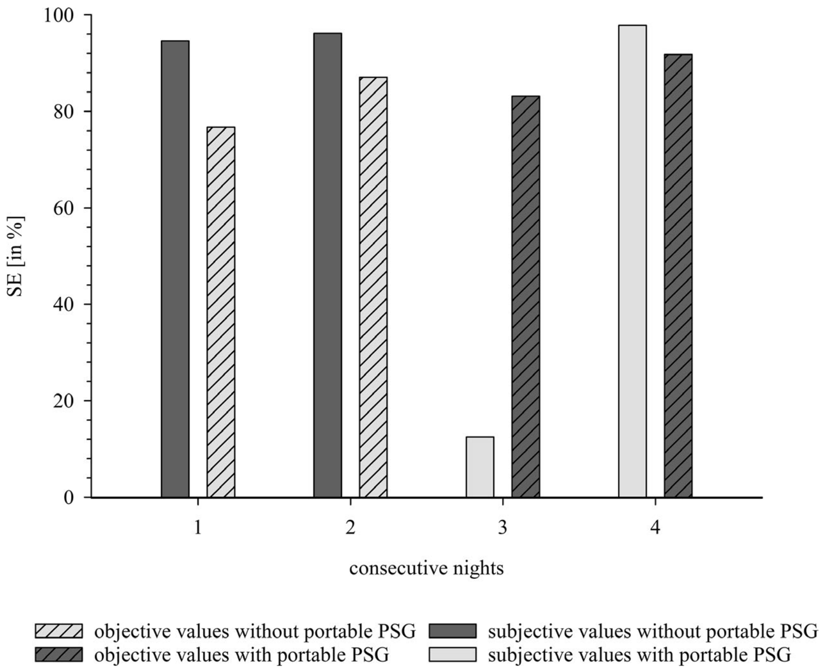

FIGURE 2 Individual case data *Rower X*: Subjectively and objectively measured Sleep Efficiency over the course of the four consecutive nights.
Annotation. Bar charts represent calculated Sleep Efficiency assessed both, objectively via actigraphy and subjectively via sleep log. *Rower X* slept on night one and two without portable polysomnography and on days three and four with additional portable polysomnography. SE = Sleep Efficiency (in percent), PSG = polysomnography.

lead to increased wakefulness and decreased REM and deep sleep.[9,39] The application of self-adhesive electrodes within a room that is already too hot might augment sweating and therefore not only restrict sleep but also reduce quality of data and durability of the adhesiveness of electrodes. To minimize confounding factors, an appropriate sleep environment for PSG assessment should be targeted whenever possible. Further, all devices were programmed in advance and there was no immediate data transferal. Consequently, it was not possible to intervene once the measurement had started even when technical problems (eg, wrong application, signal failure, and loss of electrodes throughout the night) appeared, which may have endangered the quality of the night's measurement.[20] Moreover, quality of sleep data relies on the correct positioning by each individual athlete. Thus, the importance of detailed briefings and instructions needs to be stressed with the objective to obtain interpretable data.

Alongside, there are some limitations to the study that need to be discussed to put results into context. With only four nights of sleep monitoring and thirteen athletes included in the study sample, both longitudinal and latitudinal sample size are rather small. In this matter, it was not possible to evaluate whether sleep parameters during the training camp somewhat represent regular sleep measured at home. Further, athletes did not have to follow a specific nutritional protocol and, thus, sleep also may have been affected by inconsistent diet or caffeine intake. Likewise, individually perceived intensity of training was not controlled within this study. As training load could further affect sleep, this must be stressed as a limitation to the study.[15] However, elite athletes often face training camp or competition phases in which they do not sleep at home, have inconsistent food intake, and do not have perfectly controllable training and sleeping environment. Consequently, it is of great interest to examine whether portable PSG is reasonable in these particularly high demanding situations as diagnostics will often be applied in these circumstances.

As a further limitation, the equation used to calculate sleep efficiency does not reflect non-sleep-related activities in bed in its construct. By using duration of the sleep episode (DSE; SOL + TST +WASO + time attempting to sleep after final awakening) as an alternate denominator for the calculation of SE (SE = TST/DSE × 100) in future studies, an even more precise idea of actual sleep patterns may be drawn.[40] In this particular study, however, comfort and space within the bedrooms were limited anyway, and hence, participants only spend time within their rooms during nighttime. Therefore, changes related to adaptation of the equation may only be marginal in this specific case.

Further, the small sample size may have influenced the power of statistical analysis. Thus, equivalent testing was used to interpret effect sizes. Overall, TOST procedure revealed that all observed effect sizes were not significantly within their according equivalent bounds. Additionally, there was not a single athlete suffering from sleep restriction on either night of PSG application. Yet, standard deviation within nights of portable PSG was of higher variance, and thus, future studies should investigate whether a first night effect may appear in this kind of setup.

Moreover, the inconsistency between objective and subjective perception of sleep may raise further questions. The discrepancy between SWA and sleep log parameters has already been evident in past research.[29,31] Nevertheless, it need to be kept in mind that actigraphy and sleep logs determine separate characteristics of sleep. While SWA assesses movements among different physical components during sleep, sleep logs ask participants to recollect relevant episodes of the prior night. Therefore, one of the most credible reasons for the difference between actigraphy and sleep logs might be established on the detection of wake episodes. While the movement-based device records each minute of waking independently, even with only 1 minute asleep in-between, participants might perceive this event as one single awakening.[29] Thus, in order to allow correct interpretation of data, practitioners should be aware of the differences between devices and know how to translate data or give explanations to the individual in order to not place disproportionate importance on smaller aspects of their data.[11] Therefore, educating athletes on discrepancies that may occur between perceived and measured sleep quality may help to reduce worries or rumination and lead to a higher compliance within the athletes. Yet, sleep is highly individual, and an athlete's voice should always be taken into consideration when deciding on the kind of measurement to use regularly.

5 | PERSPECTIVE

Previous research highly recommends further identification and treatment of common sleep disorders in elite athletes,[10,41] and underlines the importance of educating coaches and athletes regarding sleep to reduce the risk of injury in elite athletes.[42] As for sleep assessment, portable PSG is considered a promising tool in assessing athletes' sleep architecture out of the sleep laboratory and within applied settings,[20] but no studies have focused on possible negative effects of sleep quality assessment itself. In this manner, the study results did not identify nights with the application of portable PSG to be significantly different to nights without its application. For this reason, portable PSG may be installed whenever the assessment of sleep architecture seems desirable and information cannot be adequately attained by actigraphy.

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ORCID

Annika Hof zum Berge https://orcid.org/0000-0002-7019-8652
Alexander Ferrauti https://orcid.org/0000-0001-9807-2755
Tim Meyer https://orcid.org/0000-0003-3425-4546
Mark Pfeiffer https://orcid.org/0000-0002-9287-5343
Michael Kellmann https://orcid.org/0000-0003-1699-9624

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