Effects of Smart Goggles Used Before Bed on Objectively Measured Sleep and Self-Reported Anxiety, Stress, and Relaxation: A Pilot Study

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Abstract

Background: Insufficient sleep is a problem affecting millions. Poor sleep can instigate or worsen anxiety and, conversely, anxiety can lead to or exacerbate poor sleep. Advances in innovative consumer products designed to promote relaxation and support healthy sleep are emerging and their effectiveness can be evaluated accurately using sleep measurement technologies in the home environment.

Objective: This study examined the effects of smart goggles used before bed to deliver gentle, slow vibration to the eyes and temples. Objective sleep, perceived sleep, and self-reported stress, anxiety, and relaxation were measured at home by adults with subclinical threshold sleep problems.

Methods: A within-subjects, pre-post design was implemented. Healthy adults reporting suboptimal sleep (N=20) tracked their sleep nightly using a PSG-validated non-contact biomotion device and completed questionnaires daily and nightly for 6 weeks (3 weeks baseline, 3 weeks intervention). During the baseline period, participants slept at home as usual. During the intervention period, participants used Therabody SmartGoggles in Sleep mode before bed. This mode delivers gentle eye and temple massage through vibrating motors for relaxation.

Results: Multilevel regression analysis of 676 nights of objective data showed improvements during nights when using the goggles, relative to baseline, in sleep duration (+12 minutes, P=.014); deep sleep, measured in duration (+6 minutes, P=.002), proportion of the night (7% relative increase, P=.020), and BodyScore (4% increase, P=.002); number of nighttime awakenings (7% decrease, P=.021); total time awake at night after sleep onset (-6 minutes, P=.047); and SleepScore, a measure of overall sleep quality (3% increase, P=.020).

Questionnaire data showed that, compared to baseline, participants felt they had better sleep quality (P<.001) and felt more well-rested upon waking (P<.001). Furthermore, immediately after using the goggles each night, compared to immediately before, participants reported feeling sleepier, less stressed, less anxious, and more relaxed (all Ps<.05). A standardized inventory administered before and after the 3-week intervention period indicated reduced anxiety, confirming the nightly analysis (P=.03).

Conclusions: Objectively measured sleep quality and duration, as well as perceived sleep, improved when using the goggles before bed compared to baseline. Participants also reported increased feelings of relaxation along with reduced stress and anxiety. Future research expanding on this pilot study is warranted to confirm the preliminary evidence presented in this brief report.

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Conclusions. Objectively measured sleep quality and duration, as well as perceived sleep, improved when using the goggles before bed compared to baseline. Participants also reported increased feelings of relaxation along with reduced stress and anxiety. Future research expanding on this pilot study is warranted to confirm the preliminary evidence presented in this brief report.

Keywords: relaxation; stress; anxiety; sleep; health technology; intervention

Introduction

Insufficient sleep is a problem affecting approximately one-third of the population [1]. Poor sleep can instigate or worsen anxiety and, conversely, anxiety can lead to or exacerbate poor sleep [2]. Technological advances in unobtrusive sleep measurement technologies allow intervention studies to be conducted in the comfort of research participants' own bedrooms, yielding ecologically valid results while capturing accurate objective data [3,4]. Concomitantly, the development of innovative consumer products designed to promote relaxation and support healthy sleep are emerging and their effectiveness can be evaluated in field research using ambulatory measurement technologies [5].

Previous research suggests that vibration may be a useful non-pharmacological intervention for poor sleep [6]. In the current pilot study, presented as a short paper, the use of goggles delivering gentle, slow vibrations before bed was hypothesized to contribute to a reduction of sympathetic tone, measured as increased relaxation, reduced stress and anxiety, and better sleep in a sample with subclinical threshold sleep problems. This was measured across 676 nights of objective sleep data collected using a validated non-contact sleep biosensor, as well as by self-report.

Methods

Participants

The sample included 20 SleepScore technology users who reported difficulty falling asleep or staying asleep, but no sleep disorders or other medical issues affecting sleep, nor any lifestyle issues influencing their sleep such as shift work. Participants were 40% female, ranging from 26-75 years old (mean 50.41, SD 13.12). All provided written informed consent. The study protocol was approved by Sterling IRB (ID: 11012), and all procedures were conducted in accordance with the ethical standards of the Declaration of Helsinki.

Design and Procedures

A within-subjects, pre-post design was implemented. Following a 3-week baseline period during which participants measured their sleep at home without intervention, participants used Therabody SmartGoggles before bed for 15 minutes (within 30 minutes of their intended sleep time) for 3 weeks. Participants were instructed to use Sleep mode, which delivers slow, gentle massage to the eye and temple area through vibrating motors. The other modes (SmartRelax and Focus) were not used in the current study.

During the entire 6-week study, objective sleep was measured nightly, and online questionnaires were completed each morning and evening. Data were collected during the same time period across all participants to account for weekday/weekend variation.

Measurement

Objective sleep was measured with *SleepScore Max*, a non-contact monitoring device using respiratory signal and motion sensing to detect sleep. The sensor is placed next to the bed and controlled using a companion app. It uses ultra-low power radiofrequency waves to monitor body movement when in bed; measurement is unaffected by bedding or nightwear. High resolution magnitude and duration data of gross movements, micro-movements, and full breathing cycles are captured and transformed into 30-second epoch sleep stage data (Wake, Light, Deep, REM) using proprietary algorithms. Studies have shown good agreement with gold-standard polysomnography [7,8], exceeding the agreement typically reported for actigraphy-based devices [9].

Using the 30-second epoch data, standard sleep metrics were calculated. In addition, 3 SleepScore technology proprietary sleep measures reflecting sleep quality were calculated, all ranging from 0-100 and normalized for age and sex using reference values from the meta-analysis of quantitative sleep parameters by Ohayon and colleagues [10]: SleepScore is an overall sleep quality metric that includes objectively-measured total sleep time, sleep onset latency, and sleep stage durations; BodyScore reflects the age and sex normalized amount of deep (NREM-3) sleep; and MindScore reflects the age and sex normalized amount of REM sleep.

Daily self-report items, completed in the morning, were 100-point visual analog scales measuring perceived sleep quality and feeling well-rested upon waking. At night, 100-point visual analog scales assessed relaxation, stress, and anxiety, immediately before and after using the goggles at bedtime. A 6-item form of the state scale of the Spielberger State-Trait Anxiety Inventory (STAI) [11] was administered once before and once after the intervention period.

Statistical Analyses

Nightly objective sleep data and daily self-report data were analyzed using multilevel regression with random intercept, accounting for nights nested within participants, comparing nights during the baseline period to nights during the intervention period for each outcome. The regression model was $SleepMeasure_{ij} = Const_{0ij} + B*TestPeriod_{ij}$; TestPeriod, coded as 0 for observations during baseline and 1 for nights during the intervention period. Nightly self-report data used the same model but comparing immediately before using the goggles to immediately after using them each night. A 2-tailed paired-samples *t*-test was used to analyze the 6-item STAI.

Discrepancies in sample sizes (*n*=20 for objective and self-reported sleep, *n*=17 for 6-item STAI) were due to incompletion of the data sources. Participants tracked their sleep at home, and at times were not fully compliant with using the objective measurement tool or completing surveys online. All results reported reflect the largest sample available for each set of analyses.

Results

Objective Sleep

Night-to-night objective measurement of sleep (*N*=676 nights nested within 20 participants) revealed that when using the goggles before bed, participants experienced multiple improvements: increased sleep duration (+12 minutes, *P*=.014); increased deep sleep, measured in duration (+6 minutes, *P*=.002), proportion of the night (7% relative increase, *P*=.020), and BodyScore (+4%, *p*=.002); fewer nighttime awakenings (-7%, *P*=.021); decreased total amount of time awake at night after sleep onset (-6 minutes, *P*=.047); and improved SleepScore, indicating overall sleep quality (+3%, *P*=.020). Detailed objective sleep metrics are displayed in Table 1.

Table 1. Multilevel regression results for objective sleep (676 nights), comparing the baseline to the intervention period.

Outcomes	Observed mean (SD)[a]		Estimated marginal means[b]		
	Baseline period	Intervention period	Intercept (SE)	β[c]	*P* value
Total sleep time in minutes	331.55	343.48	331.52	12.04	0.014
Sleep onset latency in minutes	23.34	23.20	23.28	-0.13	0.935
Number of awakenings	5.51	5.14	5.51	-0.38	0.021
Time spent awake after sleep onset in minutes	60.50	54.32	60.17	-5.39	0.047
Light sleep in minutes	215.36	219.86	215.47	4.54	0.255
Deep sleep in minutes	57.52	63.19	57.66	5.58	0.002
REM[d] sleep in minutes	58.67	60.44	58.52	1.94	0.316
Percentage of time spent awake after sleep onset	16%	14%	15.36	-1.02	0.081
Percentage of time in light sleep	54%	55%	54.50	0.02	0.971
Percentage of time in deep sleep	15%	16%	15.10	1.14	0.020
Percentage of time in REM[d] sleep	15%	15%	14.92	-0.12	0.799
SleepScore[e]	69.57	71.65	69.61	2.02	0.020
BodyScore[e]	73.14	76.13	73.42	2.64	0.002
MindScore[e]	69.30	69.68	69.18	0.55	0.624

[a]For the baseline and intervention periods, each mean was calculated by averaging nights across participants, then averaging those participants' averages to a single simple average

[b]These are the outcomes of separate multilevel regression analyses. Each row shows results from a different single-predictor, single-outcome model.

[c]The beta values are unstandardized and can therefore be interpreted on the same scale as the original data.

[d]REM: rapid eye movement.

[e]These scores range from 0 to 100.

Self-Reported Sleep Quality and Well-Restedness

Multilevel regression analyses of daily self-report sleep data (*N*=723 nights nested within 20 participants) showed that participants perceived better sleep quality (β=12.37, *P*<.001) and felt more rested in the morning (β=12.13, *P*<.001) when using the goggles before bed compared to baseline, rated on 0-100 scales.

Anxiety, Stress, and Relaxation

Across 668 nights, immediately after using the goggles compared to immediately before, multilevel regression results showed that participants felt sleepier (β=9.98, *P*<.001), less stressed (β=-10.38, *P*<.001), less anxious (β=-12.87, *P*<.001), and more relaxed (β=11.76, *P*<.001), rated on 0-

100 scales.

At the end of intervention period, compared to at the end of baseline period, participants' scores on the 6-item STAI showed reduced anxiety (t_{16}=2.31, *P*=.03; 10% decrease), confirming the nightly analysis.

Discussion

Non-pharmacological techniques for promoting relaxation and improving sleep have the potential to help millions of individuals who experience suboptimal sleep. This study tested smart goggles designed to induce relaxation and support healthy sleep. Outcomes were measured both by self-report and a polysomnography-validated, non-contact biomotion device. The nonclinical sample included adults reporting poor sleep but the absence of sleep disorders.

When using the goggles before bed, compared to baseline, objective sleep improved, both in quality and duration. Although total sleep time remained less than 6 hours per night on average, objective improvement was seen in sleep duration; deep sleep, both in duration and proportion of the night; number of nighttime awakenings; amount of time spent awake at night after initially falling asleep; and two sleep quality metrics. Aligning with these objective results, questionnaire data showed that participants perceived improvement in their sleep quality and felt more well-rested in the morning. Additionally, immediately after using the goggles, participants felt sleepier, less stressed, less anxious, and more relaxed, compared to how they felt immediately before using the goggles. A standardized inventory administered before and after the 3-week intervention period also indicated reduced anxiety, confirming the nightly analysis.

The sleep improvements observed in the objective and self-report sleep data likely were driven by increased relaxation resulting from use of the product before bed, as vibration is known to be able to induce physiological relaxation [12]. This interpretation is supported by the changes in perceived relaxation, stress, and anxiety. However, objective parameters of physiological relaxation prior to sleep were not assessed. This would be an interesting addition for future research.

Another opportunity for further investigation would be a controlled trial. The current study assessed change from baseline to intervention while using the product at home, resembling how it is used outside of a research setting. This within-subjects design with long-term use of the product, following a baseline period absent of product use, provides confidence that significant effects are due to the intervention itself. Although this type of design has limitations, it reflects the real-life experience of introducing an intervention into the home environment while also accounting for night-to-night variations in sleep.

It is promising that a device delivering gentle vibrations to the eye and temple area appears to promote relaxation, decrease anxiety, and support healthy sleep in a nonclinical sample of adults reporting suboptimal sleep. Not only did sleep quality and sleep duration increase relative to baseline, but also wake decreased, both in the number of awakenings and the duration of time spent awake in the night. Furthermore, improvement was seen in multiple metrics of deep sleep, which is vital for brain health and physical recovery. Future research expanding on this pilot study is warranted to confirm the preliminary evidence presented in this short paper.

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Conflicts of Interest

The authors are employed by SleepScore Labs.

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