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SHORT REPORT

A useful tool or a new challenge? Hand-wrist-worn sleep trackers in patients with insomnia

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Summary

Consumer sleep wearables are increasingly popular, even among patients with sleep problems. However, the daily feedback provided by these devices could exacerbate sleep-related worry. To investigate this issue, 14 patients received a self-help guide booklet to improve sleep and wore the sleep tracker Fitbit Inspire 2 on their non-dominant hand for 4 weeks, while a control group of 12 patients only kept a hand-written sleep diary. All patients completed questionnaires at a primary care centre's first and final visit to assess general anxiety, sleep quality, sleep reactivity to stress, and quality of life. Our analysis showed that sleep quality, sleep reactivity to stress, and quality of life improved significantly for all patients between the first and final visit ($p < 0.05$). However, there were no significant differences between the Fitbit and control groups. Using sleep diary-derived estimates from the first and last week, we found that the control group but not the Fitbit group, increased their average time asleep each night and sleep efficiency ($p < 0.05$). However, these differences were primarily driven by baseline differences between the two groups. Our findings suggest that using wearables does not necessarily exacerbate sleep worries among people with insomnia.

KEYWORDS
anxiety, insomnia, orthosomnia, patients, sleep, sleep-wearable technology

1 | INTRODUCTION

In 2020, there were 31 million active users of Fitbit products who used their devices at least once a week. Using photoplethysmography measuring interbeat intervals and actigraphy, the wrist-worn Fitbit tracker provides insights into various health estimates, including sleep timing, duration, and quality (Chinoy et al., 2022). Given that a considerable proportion of patients with insomnia have sleep misperception (Rezaie et al., 2018), using wearables may provide patients with a more objective and less subjective insight into their sleep than commonly used sleep diaries. For example, a study involving 128 participants with insomnia found that integration of the wearable device with a digital insomnia therapy enhanced user engagement and led to improvements in sleep parameters compared to digital insomnia therapy alone (Aji et al., 2022). On the other hand, the results of sleep tracker data may exacerbate sleep-related anxiety and worry among patients, as suggested by previous case reports (Baron et al., 2017).

In the present study, we examined sleep quality, general sleep reactivity to psychological stress, general anxiety, and quality of life in 27 consumer sleep wearable-naive patients with insomnia between two primary care visits four weeks apart. About half of the group used a Fitbit device and handwritten diaries to track their sleep during the study period. In contrast, the remaining patients only used sleep diaries to document daily bed and rise times.

2 | METHODS

2.1 | Patients

One of the authors, general practitioner D.O., screened 34 adult patients who met insomnia *International Classification of Diseases*, 10th Revision (ICD-10) criteria during their visit to one of two healthcare centres in Visby, Sweden. To minimise the risk of secondary insomnia, D.O. conducted an anamnestic interview. He also reviewed the patient's medical records and performed a physical examination to eliminate possible somatic causes of sleep difficulties. After the screening session, one patient was excluded due to excessive anxiety, two because of clinical signs of obstructive sleep apnea, and two others were not included due to chronic pain issues. Furthermore, one subject refused to participate, and another patient did not attend the follow-up visits. Therefore, 27 patients were randomly assigned to treatment arms on a one-to-one basis, regardless of their baseline characteristics (i.e., D.O. allocated the first patient to the Fitbit group, the second to the control group, and so on). After the initial visit, one patient from the Fitbit group reported having an obsessive–compulsive disorder and was therefore not considered eligible for analysis. As a result, the Fitbit group comprised 14 patients and the control group 12 patients.

The study protocol was pre-registered (https://doi.org/10.17605/OSF.IO/UG68H), approved by the Regional Ethical Review Board in Stockholm, Sweden (Dnr 2022-00059-01), and was conducted following the Declaration of Helsinki. Participants provided informed consent before the study. No compensation was paid for study participation.

2.2 | Study protocol and measures

Following written and verbal consent, each patient completed the following questionnaires at the initial visit: (a) General Anxiety Disorder seven-item (GAD-7; range of 0–21 points; higher scores indicating higher general anxiety) (Plummer et al., 2016), (b) the Pittsburgh Sleep Quality Index (PSQI) assessing sleep quality and disturbances over 1 month (range of 0–21 points; score >5 indicating a 'poor' sleeper) (Buysse et al., 1989), and (c) the Ford Insomnia Response to Stress Test (FIRST) measuring vulnerability to experience situational insomnia under stressful conditions (total score ranges from 9 to 36; higher scores indicating higher vulnerability) (Drake al., 2004). Patients also indicated their quality of life using a 100-mm visual analogue scale (VAS; with 0 indicating very low and 100 very high perceived quality of life).

At the end of the baseline visit, D.O. handed the patient a Swedish booklet released by the Stockholm County Council for patients. This booklet discusses various measures that patients with insomnia can apply. For example, patients should avoid sleeping during the day and clock-watching during the night. They are also advised to use the bed only for sleep, be physically active during the day, spend time outdoors, and abstain from coffee, alcohol, and nicotine in the evening. The booklet also discusses common misbeliefs (e.g., everyone must sleep for 8 h). Notably, it does not raise the potential of sleep tracking to amplify sleep worries.

Under the supervision of D.O., patients in the Fitbit group downloaded the Fitbit app on their smartphones. After that, D.O. informed them on how to charge the device, connect it to their smartphones, and track their sleep. D.O. encouraged the patient to reflect on their sleep daily using the Fitbit app. Both the Fitbit and control patients kept a handwritten sleep diary specifying daily bed and rise times. At 2 weeks after the first visit, a second visit to the healthcare centre was scheduled to ensure that patients of both groups continued tracking their sleep (i.e., either by Fitbit, sleep diaries, or both). After an additional 2 weeks, patients met D.O. at the healthcare centre for the final visit. They again completed the GAD-7, PSQI, and FIRST, and estimated their quality of life. Patients also returned the Fitbit device and handed in the sleep diaries. Two patients in each group did not specify bed and rise times and subjective sleep onset latency in the sleep diaries time at the final visit. Finally, for one patient in the Fitbit group, no sleep data were successfully uploaded to the cloud.

2.3 | Statistical analyses

All data were analysed using the IBM Statistical Package for the Social Sciences (SPSS) version 26 (IBM Corp., Armonk, NY, USA) and shown as mean (± SD) unless otherwise stated. For sleep diary-derived total time in bed, total time asleep, and sleep efficiency (total time asleep/total time in bed × 100), we determined the average for the week after baseline consultation and the fourth week, that is, the week before the final consultation. To account for possible baseline group differences, we calculated the difference in the outcome scores between the first and last visit to compare changes within the whole group and between the Fitbit and control groups. We used *t* tests for within- and between-group comparisons unless otherwise stated. A $p < 0.05$ was considered statistically significant.

3 | RESULTS

The patients' characteristics can be found in Table 1. Compared to baseline scores, after 4 weeks, patients reported significantly better sleep quality and lower sleep reactivity to stress. This improvement was observed in both the Fitbit and control patient groups (Table 2). Sleep diary-derived total time in bed dropped by ∼18 min between the two visits in the entire group ($p = 0.05$); however, the change over time was statistically comparable between the Fitbit and control patient groups (−24 versus −10 min, $p = 0.44$). In contrast, sleep diary-derived total time asleep and sleep efficiency significantly increased in the control (+45 min and +10%, respectively) but not Fitbit (−17 min and +1%) patient group between the baseline and final visits (Table 2).

When analysing sleep parameters from the Fitbit device, we found that patients in the Fitbit group spent ∼28 min less in bed and slept 26 min less in the week before the final visit than they did in the

TABLE 1 Baseline cohort characteristics.

Outcome	Fitbit patients	Control patients	*p* for Fitbit versus control
Number of patients	14	12	–
Women, *n*	9	9	0.56[a]
Age, years, mean (SD)	46.1 (16.4)	59.4 (19.0)	0.07[b]
BMI, kg/m^2, mean (SD)	25.5 (3.9)	27.5 (4.0)	0.22[b]
Use of sleep medication, *n*	11	8	0.50[a]

[a]Derived from a chi-square test.
[b]Derived from Student's *t* tests.

TABLE 2 Sleep scores at baseline and after 4 weeks.

Outcome	All patients	Fitbit patients	Control patients	*p*[a] for Fitbit versus control
Pittsburgh Sleep Quality Index, total score (range 0–21)[b], mean (SD)				
Baseline visit	12.9 (2.8)	12.3 (2.9)	13.6 (2.7)	0.25
4-week follow-up visit	10.2 (4.3)	9.7 (3.8)	10.8 (5.0)	0.56
Within-group change	−2.7 (3.5)	−2.6 (3.3)	−2.8 (4.0)	0.86
p for within-group change	<0.001	0.01	0.03	
Ford Insomnia Response to Stress Test, score (range 9–36)[c], mean (SD)				
Baseline visit	21.4 (6.3)	23.1 (6.7)	19.3 (5.3)	0.13
4-week follow-up visit	17.7 (4.7)	19.9 (3.3)	15.0 (4.7)	0.01
Within-group change	−3.7 (4.8)	−3.2 (4.7)	−4.3 (5.1)	0.57
p for within-group change	<0.001	0.02	0.01	
Sleep diary – total time in bed, min, mean (SD)				
1st week	513 (64)	512 (65)	515 (65)	0.92
4th week	495 (64)	488 (62)	505 (69)	0.56
Within-group change	−18 (41)	−24 (50)	−10 (28)	0.44
p for within-group change	0.05	0.12	0.28	
Sleep diary – total time asleep, min, mean (SD)				
1st week	440 (72)	470 (51)	405 (80)	0.03
4th week	452 (61)	453 (52)	450 (74)	0.89
Within-group change	11 (63)	−17 (51)	45 (62)	0.02
p for within-group change	0.40	0.28	0.05	
Sleep diary – sleep efficiency, %, mean (SD)				
1st week	86.2 (12.8)	92.2 (6.5)	79.1 (15.1)	0.01
4th week	91.5 (7.5)	93.3 (6.2)	89.3 (8.7)	0.23
Within-group change	5.2 (9.4)	1.1 (4.6)	10.1 (11.4)	0.02
p for within-group change	0.02	0.46	0.02	

[a]Derived from Student's *t* tests.
[b]The lower the score, the better the sleep quality.
[c]The higher the score, the greater the vulnerability to experience situational insomnia under stressful conditions.

week after the baseline visit (mean [SD] time in bed per night: 476 [57] versus 448 [54] min; and average time asleep per night: 420 [54] versus 394 [51] min); however, these differences were not below the significance criterion ($p \geq 0.052$ as derived from a paired Student's *t* test). Finally, no differences in Fitbit-derived sleep efficiency were found between the first and last visit (mean [SD] 88.1% [2.1%] versus 87.9% [2.3%], $p = 0.656$ as derived from a paired Student's *t* test). Individual changes in Fitbit-derived time in bed, time asleep, and sleep efficiency are shown in Figure 1.

As insomnia is characterised by common worries about the ability to fall and stay asleep and is not necessarily accompanied by objectively insufficient sleep (Castelnovo et al., 2019), patients were also asked whether their subjective sleep experience had improved from the baseline to the final visit. In all, 16 of the 26 patients stated that their sleep had improved since the first visit (10/14 in the Fitbit group and 6/12 in the control group; $p = 0.383$, as derived from a Pearson chi-square test), and two patients of 10 Fitbit patients discontinued hypnotic medication.

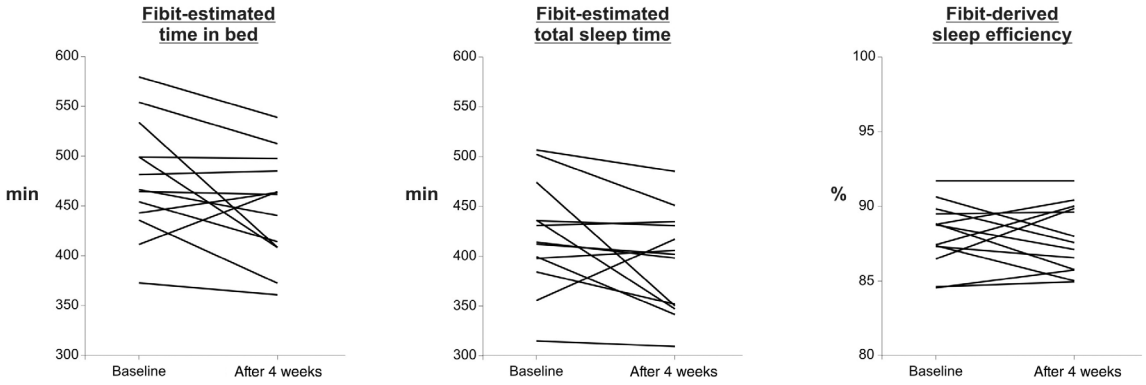

FIGURE 1 Individual changes in Fitbit-derived time in bed, time asleep, and sleep efficiency.

TABLE 3 General anxiety and quality of life at baseline and after 4 weeks.

Outcome	All patients	Fitbit patients	Control patients	*p* for Fitbit versus control
Generalised Anxiety Disorder seven-items assessment, score (range 0–21)[a], mean (SD)				
Baseline visit	5.8 (4.1)	7.7 (4.2)	3.5 (2.6)	0.01
4-week follow-up visit	4.5 (4.4)	6.3 (4.6)	2.3 (3.2)	0.02
Within-group change	−1.3 (3.3)	−1.4 (3.9)	−1.2 (2.6)	0.84
p for within-group change	0.05	0.19	0.15	
Estimated quality of life VAS, score (range 0–100)[b], mean (SD)				
Baseline visit	69.5 (14.8)	65.7 (16.2)	74.0 (12.4)	0.17
4-week follow-up visit	74.1 (12.1)	71.6 (13.8)	77.1 (9.4)	0.26
Within-group change	4.7 (11.0)	5.9 (12.5)	3.2 (9.2)	0.53
p for within-group change	0.04	0.10	0.26	

Note: *p* values derived from Student's *t* tests.
Abbreviation: VAS, visual analogue scale.
[a]The higher the score, the greater general anxiety.
[b]The higher the score, the higher the level of perceived quality of life.

Between baseline and the final visit, anxiety dropped by ∼1.3 points on the GAD-7 scale, and self-reported quality of life significantly increased by +4.7 mm on a 100-mm VAS in the entire patient group. However, the changes did not significantly differ between the patient groups (Table 3).

Baseline differences in age and anxiety between the Fitbit and control groups may have masked possible differences in primary outcomes (i.e., change in PSQI, FIRST, GAD-7, and quality of life between the first and last visit). Thus, we ran Pearson correlational analyses in the entire patient group ($n = 26$). However, neither patients' age nor baseline GAD-7 scores significantly correlated with primary outcomes ($p \geq 0.278$ for correlations with age; $p \geq 0.122$ for correlations with baseline GAD-7 score).

4 | DISCUSSION

Our study included patients consulting primary care because of insomnia. We found that providing general recommendations on succeeding with sleep and increasing awareness of common sleep misconceptions improved sleep quality, reduced sleep reactivity to stress and general anxiety, and increased quality of life within 4 weeks. Notably, these improvements did not differ between patients who used a sleep-tracking Fitbit device and those who only kept a sleep diary during the study period. Previous studies have revealed similar outcomes (Kang et al., 2017; Luik et al., 2018). For example, improvements in insomnia after digital cognitive behavioural therapy have been reported for patients using a wearable sleep tracker (Luik et al., 2018). In addition, another study of 19 patients with insomnia disorder found that digital cognitive behavioural therapy for insomnia improved sleep metrics, such as sleep efficiency, latency, and quality, regardless of whether patients used a sleep-tracking device (Kang et al., 2017). In conjunction with our findings, current evidence suggests that using sleep-tracking technology may not necessarily reinforce sleep-related anxiety and worries among patients with insomnia.

We found apparent differences in sleep diary-derived estimates between Fitbit and control patients. Control patients extended their time asleep from baseline to the final visit by ∼45 min each night and improved their sleep efficiency from 79% to 89%. In contrast, these sleep diary-derived metrics did not significantly change over time in Fitbit patients. At first glance, these findings could be interpreted as a hint that Fitbit may negatively affect reported time asleep and sleep efficiency. However, the patient control group reported significantly

lower total time asleep and sleep efficiency at the baseline. Consequently, the improvement suggests that the control group caught up with the difference in total sleep time and sleep efficiency rather than that the Fitbit patients spent less time asleep due to worries related to the use of the wearable device.

There are several limitations to our study. First, we used sleep quality and sleep reactivity to stress questionnaires to evaluate patients' sleep between the initial and final visits. Thus, it is unclear whether similar findings would have been obtained using other sleep instruments (e.g., the Insomnia Severity Index [ISI] scale; Morin et al., 2011). However, total ISI scores correlate positively with PSQI scores, indicating good convergent validity (Morin et al., 2011). Despite being significant, the observed improvements in sleep, anxiety, and quality of life over the 4 weeks were relatively small. One explanation could be that the primary sleep intervention of our study was to hand out a booklet containing various sleep advice and elements of cognitive behavioural therapy for insomnia. On the other hand, primary care is often limited by economic resources and a relatively short consultation time, emphasising the ecological validity of the chosen intervention. Another critical point to consider is that although Fitbit use did not adversely impact sleep at the group level in our study, it does not preclude that certain individuals may start worrying about sleep when regularly using a Fitbit device. Finally, the study groups differed in age and baseline general anxiety. While both were unrelated to the primary outcomes (i.e., change in PSQI, FIRST, GAD-7, and quality of life between the first and last visit), residual confounding due to these baseline differences cannot be ruled out.

5 | CONCLUSIONS

Our study findings indicate it should not be assumed that people with insomnia who use wearables will per se develop orthosomnia (Baron et al., 2017). However, we cannot rule out that the lack of such a response may have been due to the limited sample size, setting, and instructions.

AUTHOR CONTRIBUTIONS

Dávid Ojalvo, André Pekkola Pacheco, and Christian Benedict conceived and designed the project. Dávid Ojalvo and André Pekkola Pacheco collected the data. All wrote the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest related to the manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available for researchers affiliated with universities on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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