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ACTIVITY TRACKERS IN SHORT-TERM SELF-MONITORING OF PATIENTS WITH SLEEP DISORDERS: PITFALLS AND BENEFITS

ABSTRACT

Wearable activity trackers are increasingly being used for the self-monitoring of well-being. Self-help devices are popular and there is a growing market for the monitoring of physical activity, sleep and other behaviour. However, evidence of their usefulness in relieving insomnia symptoms is scarce. This randomized clinical intervention study investigated the therapeutic significance of activity trackers among patients with sleep disorders that were referred to clinical sleep consultation. All the patients filled sleep logs for two weeks, while the intervention group also wore activity trackers as wristbands. Insomnia symptoms were significantly reduced in the group wearing activity trackers and their quality of life was significantly increased, whereas there were no significant changes in the control group. Subjective benefits of the activity tracking were reported by a majority of the patients, but a change in health behaviour during activity tracking was reported only by one third of the patients. The benefits were emphasized among those patients whose main problem was sleep related and whose psychiatric comorbidity was milder.

KEY WORDS: ACCELEROMETRY, ANXIETY, DEPRESSION, MENTAL WELL-BEING, MOBILE PHONE, 15D

INTRODUCTION

Insomnia, common with chronic somatic and psychiatric illnesses, is independently associated with poor quality of life (1). Long-term insomnia increases the risk of depression (2) and disability (3, 4). A shortened sleep period is associated with decreased cognitive function (5). Total sleep time and sleep efficiency are reduced among psychiatric patients (6).

Negative self-perception is typical of common mental disorders. Misperception of sleep is a typical feature of insomnia (7) and it is associated with hyperarousal (8). Insomnia with subjective underestimation of sleep is associated with depressive and anxious features (9, 10).

Studies about sleep misperception (8–10) and clinical observations have shown subjective monitoring of sleep by sleep logs may even emphasize the stress and worry about insomnia among psychiatric patients. Sleep log, the established assessment method and therapeutic tool in cognitive behavioural approach, may also have adverse effects (11).

According to cognitive behavioural theory, the focus of attention on sleep, excess worry about the consequences of insomnia, adverse behavioural coping, negative sleep perceptions, associations and conditioning are mechanisms behind the persistence of insomnia (12, 13). These maladaptive cognitive and behavioural patterns are targeted in cognitive behavioural interventions that are prioritized treatments with long-term evidence in insomnia (14).

An example of maladaptive coping is the avoidance of physical activity and an excess of rest in the daytime to compensate for poor sleep. The association between physical inactivity and insomnia symptoms is bidirectional: inactivity seems to predict insomnia symptoms, and vice versa. These associations may, to some extent, be explained by common mental disorders and lowered motivation for exercise due to tiredness (15).

Moderate physical exercise has been shown to have immediate effects on the following night's sleep (16) and regular exercise to have positive effects on stress management, well-being and symptom control in mental disorders (17, 18). Exercise as a sole intervention for insomnia is readily available and cost effective but not universally effective (19). Exercise is implicated in a range of physiological changes, including potential alterations of circadian rhythms. The current literature indicates that moderate amounts of exercise, which can be obtained through a variety of means such as brisk walking and resistance training, are sufficient to improve sleep quality (20).

Wearable activity trackers are increasingly used as self-help devices and are possibly useful because health behaviour improves when it is closely monitored. Sleep tracking devices provide an important opportunity for public health intervention, but research on the accuracy and effects of the various commercially available devices is sparse. However, with more research and technological improvement, self-monitoring devices may have an important role in managing sleep problems in patients with insomnia (19).

Ambulatory activity monitoring and sleep logs can be used as complementary monitoring methods, because there are remarkable discrepancies between objective and subjective assessments of physical activity and diurnal rhythms (21).

In this study we aimed to examine if there was any change in subjective insomnia symptoms and well-being during objective activity monitoring with a self-help device, a commonly used simple activity tracker.

MATERIALS

The study population included outpatients referred to Helsinki University Hospital (HUS), Department of Psychiatry for clinical sleep consultation during 2017. The naturalistic sample consisted of patients with persistent sleep complaints (n=105). Among those, 81 who went through the routine clinical assessment with sleep log were included in the study. The rest (n=24) were excluded, because they were examined in a more restricted manner (by telephone, skype or patient file consultation).

All of the 81 patients who were asked to participate the study gave their informed consent. The study patients were aged between 19 and 68 years, mean 39 years. There were 36 males (44%) and 45 females (56%). Most of the patients (n=53) were referred to sleep consultation by the specialists responsible for their psychiatric treatment, and the rest were referred by general practitioners or by specialists from other fields. The patients from psychiatric outpatient units had several referral diagnoses. Some referrals from general practitioners had no definite diagnosis. The referral diagnoses are listed in *Table 1*.

There were no significant differences between the two groups in gender, age, educational level, working status, diagnoses or baseline symptom scores.

METHODS

The patients were randomized into the intervention group or the control group according to the date and time order of referrals, as they were registered by secretaries. The consultation began by an appointment with a nurse, who collected preliminary information and guided the patients in how to fill in questionnaires and sleep logs, while they also informed the patients about our study and asked for their informed consent. Both groups were asked to fill in sleep logs for two weeks before the medical examination, but the intervention group patients were also offered an activity tracker for the same fortnight. They were given instructions for using the activity tracker. The type of activity tracker was a simple, low-cost version of Polar Loop with activity goal setting and an alarm after prolonged immobility of 55 minutes. There was no heart rate monitoring (22).

The activity tracker is based on accelerometry that records all movements in three dimensions. The wearable activity trackers are not classified as medical devices like the actigraphy monitors that are used in clinical neurophysiological assessments, in sleep research and in clinical care of patients with sleep and circadian rhythm abnormalities.

The wearable activity trackers do, however, roughly estimate the amount of daytime activity, and they imprecisely measure the periods of rest, interpreting the most immobile periods as sleep. They are not adequate for comparison between individuals, but they can monitor changes in diurnal activity and rest of an individual over a course of time. The user can follow the activity data with a mobile phone.

At the beginning, all the patients filled in the same clinical questionnaires that were repeated at the end of the monitoring period of two weeks (*Table 2*). Higher scores in the symptom scales and the quality of life scale reflect more morbidity, thus a decrease of scores refers to a positive clinical change or a relief of symptoms. The scale of SWEMWBS makes an exception, as a higher score reflects a better mental well-being, thus a decrease of score refers to a weakening of mental well-being.

In addition, the intervention group was asked categorical questions about the experienced benefits and adverse effects of the activity trackers, and about the possible behavioural change. Furthermore, free comments were encouraged to obtain qualitative information (*Table 3*).

The quantitative data was processed by SPSS. As our sample was small and some of the variables were not normally distributed, we used nonparametric statistical tests with the Bonferroni correction for the statistical significances of the outcome measures. Wilcoxon test was used to analyse the difference between baseline and follow-up measures, and Mann-Whitney U test to detect the intergroup differences of the changes. For the comparison of baseline characteristics of the two groups, we used chi-squared test for categorized variables, t-test for age and Mann-Whitney U test for outcome variables.

REFERRAL DIAGNOSES

- F31-32 Mood disorders n=36 (44%)
- F51 Non-organic sleep disorders n=35 (43%)
- F40-49 Neurotic, stress-related and somatoform disorders n=16 (20%)
- G47 Organic sleep disorders n=6 (7%)
- F60-69 Personality disorders n=4 (5%)
- F80-98 Developmental neuropsychiatric disorders n=3 (4%)
- F20-29 Psychotic disorders n=2 (2%)

CONSULTATION DIAGNOSES

F51 Non-organic sleep disorders n=46 (57%)

- F51.0 Non-organic insomnia n=35 (43%)
- F51.5 Nightmares n=8 (10%)
- F51.4 Sleep terrors n=6 (7%)
- F51.3 Sleep walking n=2 (2%)
- F51.1 Non-organic hypersomnia n=1 (1%)
- F51.2 Non-organic disorders of sleep-wake schedule n=1 (1%)
- F51.8 Other non-organic sleep disorders n=1 (1%)

G47 Sleep disorders n=39 (48%)

- G47.2 Disorders of the sleep-wake schedule n=19 (23%)
- G47.3 Sleep apnoea n=18 (22%)
- G47.1 Hypersomnias n=1 (1%)
- G47.4 Narcolepsy and cataplexy n=1 (1%)

G25 Other extrapyramidal and movement disorders n=18 (22%)

- G25.8 Restless legs syndrome n=18 (22%)

Table 1. Diagnoses of sleep consultation patients (n=81), both primary and secondary diagnoses reported.

Name of the questionnaire, abbreviation and reference		**Scale**	**Study sample:** Range	Mean	Median	SD
Insomnia severity index ISI	(32)	0-28	8-28	18.4	19.0	5.16
Dysfunctional beliefs and attitudes about sleep DBAS-16	(33)	0-10	2.6-9.1	6.2	6.1	1.56
Overall anxiety severity and impairment scale OASIS	(34)	0-20	0-19	8.8	10.0	5.48
Beck's Depression Inventory BDI	(35)	0-63	0-51	20.3	18.0	12.2
The Short Warwick-Edinburgh Mental Well-being Scale SWEMWBS	(36)	7-35	11-35	21.4	21.0	5.40
Health-related quality of life instrument 15D	(37)	15-75	17-46	30.6	30.0	6.96

Table 2. The questionnaires and their baseline scores (range, mean, median and SD) in the whole sample.

	Significance of change in scores (Wilcoxon test)		**Intergroup difference of the change** (Mann-Whitney U test)
	Activity tracker group	Controls	
ISI	p<0.0005; **p<0.003**	p=0.887	p=0.005; **p=0.030**
DBAS	p=0.743	p=0.666	p=0.857
OASIS	p=0.991	p=0.196	p=0.479
BDI	p=0.007; **p=0.042**	p=0.641	p=0.193
SWEMWBS	p=0.991	p=0.009; **p=0.054**	p=0.078
15D	p=0.020; **p=0.120**	p=0.420	p=0.045; **p=0.270**

Table 3. Results. Comparison of baseline and follow-up scores in both groups (activity tracker wearers and controls) and intergroup comparison of the score changes with the controls. Statistically significant p-values are corrected with the Bonferroni correction (bolded font).

RESULTS

CHANGE OF SYMPTOMS, MENTAL WELL-BEING AND QUALITY OF LIFE

The patients with activity trackers showed a significant reduction of insomnia and depression symptoms as measured by ISI and BDI. The differences remained significant after the Bonferroni correction. Their quality of life as measured by 15D increased significantly, but after the Bonferroni correction the increase was non-significant.

The controls showed no significant changes in any scores except that the mental well-being measured by SWEMWBS was reduced, but the decrease of well-being scores became non-significant after the Bonferroni correction.

When the changes of clinical scores were compared between intervention group and controls, a significant intergroup difference was detected in insomnia symptoms measured by ISI and quality of life measured by 15D, but the latter became non-significant after the Bonferroni correction.

The statistical values are presented in Table 3, and the comparison of changes in scores between the two groups are illustrated in *Figures 1–6*.

THE EXPERIENCES OF THE PATIENTS

Most of the patients with activity trackers (35 out of 38, 92%) responded to the feedback questionnaire. The activity tracker was reported to be useful by a majority of the respondents (22 patients, 62%). It was reported to be harmful by 3 of the patients (9%), and the rest (10 patients, 29%) did not report harm nor benefit. The descriptive comments of the patients are categorized and reported in *Table 4*.

The patients that reported benefit from the activity trackers (n=22) were compared to the rest (n=13) because of the small sample size. The gender made no difference (chi-squared p=0.268). The male to female ratio was 10:12 among those with positive experiences and 7:6 among the others. The mean age was not significantly different between those who experienced benefit and those who did not (t-test p=0.336), although the mean age of the former group was higher (44.8 years) than that of the latter (40.6 years).

The patients, who reported benefit from activity trackers, had more sleep disorders (n=9, 41% vs n=3, 23%) and less mood disorder diagnoses (n=8, 36% vs n=6, 46%) as a main diagnosis, whereas anxiety disorders were as common in both groups (n=5, 23% vs n=3, 23%). Among patients with either non-organic or organic sleep disorders, there were more benefits than among patients without sleep disorder as main diagnosis, but the differences (chi-squared p-values, consequently p=0.088 and p=0.060) were, however, non-significant. Among patients with no benefits, there was one psychotic main diagnosis, substance abuse disorder and generally more psychiatric comorbidity.

Figure 1.
Change in ISI scores, comparison between the groups. Decrease of scores (a change below zero) reflects relief of symptoms. There is more symptom relief in the intervention group (p=0.005), even after the Bonferroni correction (p=0.030).

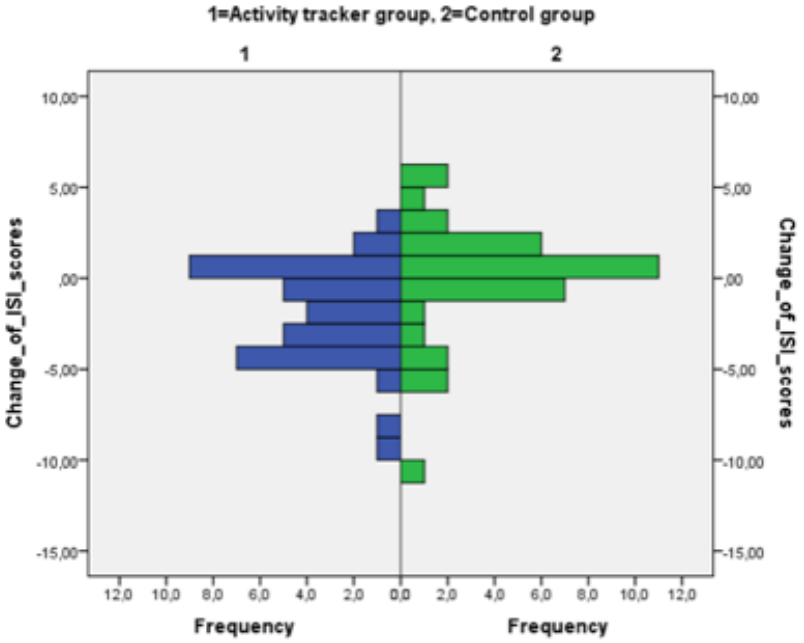


Figure 2.
Change in DBAS scores, comparison between the groups. Decrease of scores (a change below zero) reflects relief of symptoms. No significant difference between the groups was detected (p=0.857).

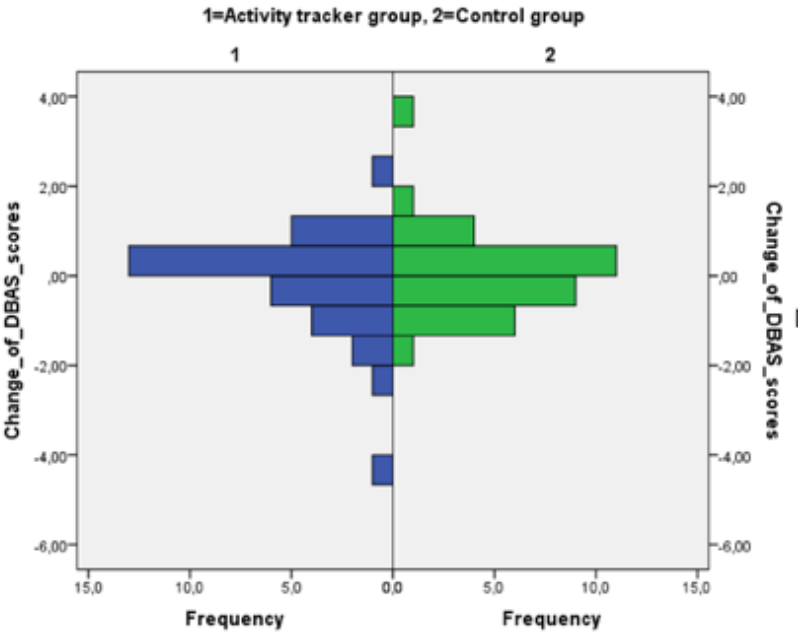


Figure 3.
Change in OASIS scores, comparison between the groups. Decrease of scores (a change below zero) reflects relief of symptoms. No significant difference between the groups was detected (p=0.479).

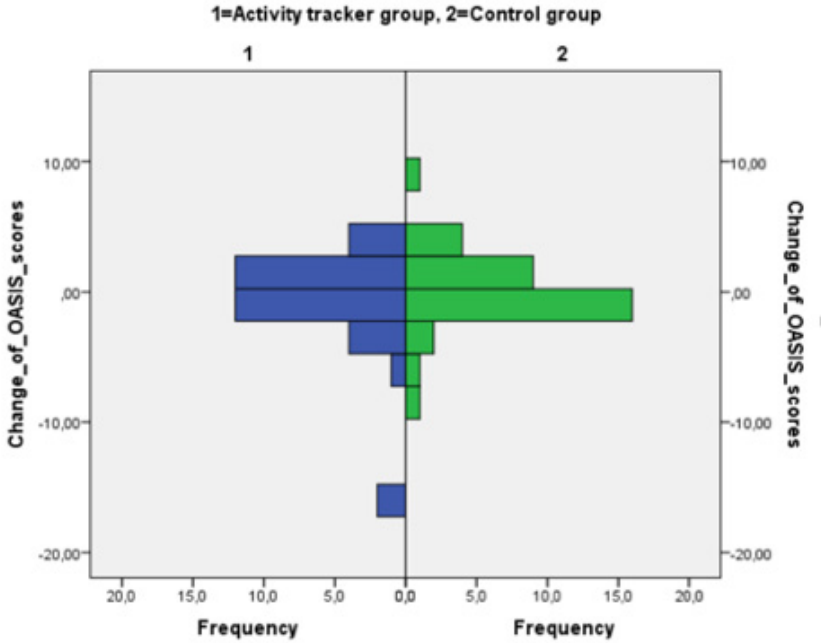


Figure 4.
Change in BDI scores, comparison between the groups. Decrease of scores (a change below zero) reflects relief of symptoms. No significant difference in symptom change between the groups was detected (p=0.193).

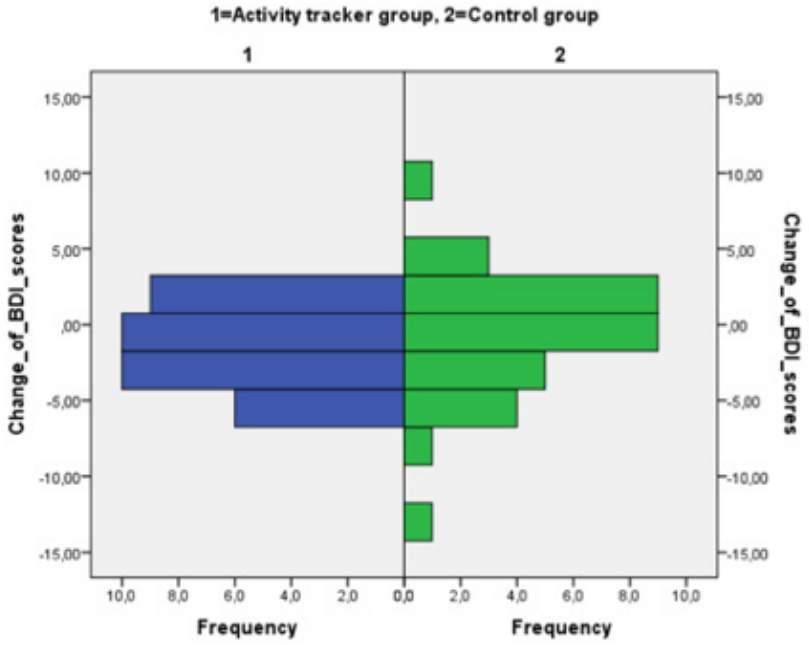


Figure 5.
Change in SWEMWBS scores, comparison between the groups. In contrast to other scales, an increase of scores reflects a positive change, referring to an increase of well-being. No significant difference in symptom change between the groups was detected (p=0.078).

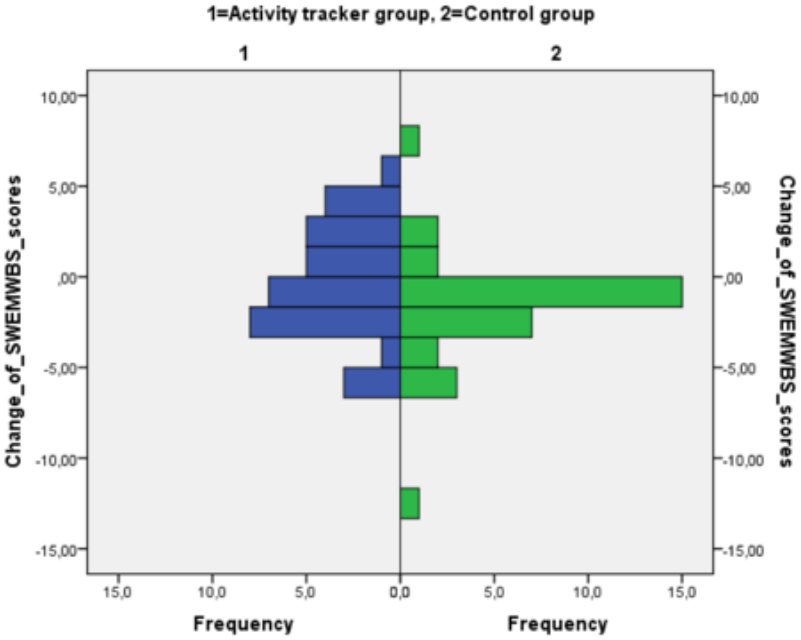
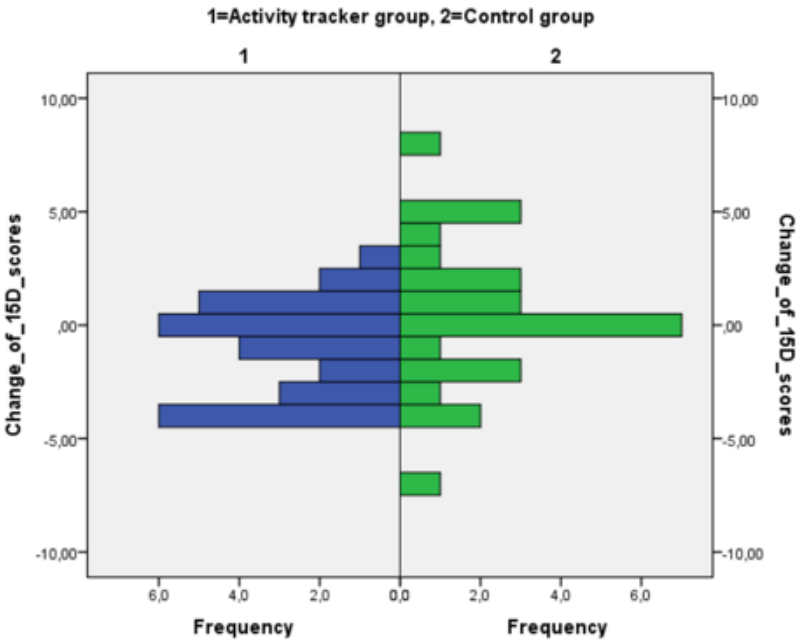


Figure 6.
Change in 15D scores, comparison between the groups. Decrease of scores (a change below zero) reflects amelioration of life quality. The difference between the groups was significant (p=0.045) referring to positive change in life quality in the intervention group, but after the Bonferroni correction the difference was non-significant (p=0.270).



A. For those, who reported benefits: What kind of benefits did you experience?

- Informs about one's activity (9 comments)
- Motivates to physical activity (6)
- Informs about one's rest or sleep (6)
- Gives objective information (3)
- Interesting, new experience (2)
- Informs about one's diurnal rhythms (1)
- Weight loss (1)

B. For those, who reported adverse effects: What kind of adverse effects did you experience?

- Stress (2)
- Mechanical disturbance (2)
- Motivated to exercise too much (1)

C. For those, who reported to have obtained new information: What kind of new information did you get?

Amount of activity (15)

- Surprised by one's low activity (3) / high activity (1)
- Recognition of the need to move more (2)
- How much and what kind of exercise is needed (1)

Sleep amount and quality (9)

- Better than expected (2)

Table 4. Free responses of the patients to questions about activity trackers.

DISCUSSION

In this study, the insomnia symptoms of clinical sleep consultation patients were significantly relieved while wearing activity trackers. The comparison of the change with controls demonstrates a specific effect with the activity trackers, which cannot be explained by the simultaneous use of sleep logs and initial nurse interviews, which were similar procedures for both groups.

Most of the patients wearing activity trackers (62%) reported benefits, while 29% reported no effects and 9% reported adverse effects. The most frequent subjective benefits were the knowledge about activity and the encouragement to increase activity. Follow-up information about sleep was also found useful. The negative experiences (9%) were related to increased stress and mechanical disturbance, including skin irritation.

Spontaneous comments of the patients included critiques about the limitations of the activity trackers: the underestimation of the activity counts in certain activities (swimming and cycling) and the inability to accurately differentiate between sleep and wake. Many patients, however, were enthusiastic about the activity trackers: five of them reported having bought their own activity tracker to continue with, and three of the patients asked to borrow an activity tracker for some extra time after their follow-up had ended. They were given the activity trackers for an extra month outside of the study, because there were enough trackers available. According to spontaneous comments after the study, one month, at least, would be more suitable for attaining behavioural changes.

The relatively short follow-up period of two weeks is a clear limitation of the study. The length was defined by the clinical process to avoid any delay in consultation: before medical examination at the doctor's appointment, all the sleep consultation patients filled in sleep logs for two weeks to obtain current information about their sleeping habits, sleep rhythm, and subjective perceptions about the quantity and quality of sleep. Thus, the activity tracker period was integrated with the sleep log follow-up for those randomized to the intervention group to keep the clinical process standardized.

Another important limitation of this naturalistic study is that the small sample size weakens the statistical power of our results. The small sample size does not allow exclusion other possible associations that were not detected here and the diagnosis-related differences in patient reported benefits could not be statistically confirmed due to the sample size.

Limitations of the study also include the lack of objective measurements. The subjective distress of insomnia, however, is one of the core phenomena in functional insomnia, thus measuring subjective change is adequate. The objective change in sleep and amount of activity would have been interesting to measure with clinical actigraphy, but then there would also have to be wristband devices for controls, and even two wristband devices for the intervention group patients. This would have been another type of study setting, less naturalistic, but it would have allowed comparison of the sleep reports between clinical actigraphy monitors and wearable activity trackers, in addition to offering objective information about the changes in diurnal activity.

In this study sample, comorbid psychiatric diagnoses were common, reducing the generalizability of the results. The results might have been better in non-psychiatric samples, because motivational problems and persisting maladaptive health behaviour are common in mental disorders. In this sample, those patients with more depressive symptoms and more serious psychiatric disorders reported less benefit from the activity trackers. After the study follow-up, those patients who experienced obstacles (like pain, fatigue, anxiety) for increasing physical activity were referred to a physiotherapist for psychophysiological therapy.

According to later clinical follow-up and patient feedback, it seemed that the patients, who could not benefit from the activity trackers were, however, able to benefit from some sensitively guided psychophysiological methods to increase body awareness to encourage individually suitable bodily rehearsals. Physiotherapeutic interventions may be needed for insomnia patients with dysfunctional body awareness, typical of somatoform and eating disorders, also sometimes present in anxiety and depressive disorders.

Most of the study patients were diagnosed with non-organic sleep disorders and the most common diagnosis was insomnia. There were also parasomnias, organic sleep disorders and psychiatric disorders as main diagnoses, but even among them functional insomnia symptoms were common. Cognitive behavioural therapy (CBT) is the primary evidence-based treatment for insomnia, abbreviated as CBT-i (14). CBT-i is safe and effective in the long term (13,14). After the study procedure, all patients with functional insomnia, who were motivated enough, were offered either group or individual CBT. Beyond the study observations, it looks like the activity trackers gave a good start for the behavioural modifications that are elements of CBT. This study did not find out if the response to CBT could be enhanced by activity trackers, used in parallel with the traditional sleep logs.

Morin et al (2004) suggested using sleep hygiene instructions as a starting point in CBT-i (23). Sleep hygiene refers to things about lifestyle that can be changed to improve sleep pattern. Exercise is one of the main lifestyle factors that have effects of sleep. Physically fit people have a better quality of sleep. A good way to promote sleep might be to encourage patients to exercise three times a week for 20-30 minutes and to build up their aerobic fitness level (23).

In addition to the relief of insomnia symptoms, the patients wearing activity trackers also showed a small, but significant reduction of depressive symptoms, which was related to reported increase of physical exercise. The reduction of insomnia symptoms, however, was not related to reported increase of activity. Among the activity tracker patients that gave feedback (n=35), there were 13 who reported increased physical exercise. A small sample size may not find associations and so not allow further conclusions. The subjectively reported change in health behaviour was in line with the change of activity counts.

The increasing use of activity trackers brings great potential for public health (15). Lack of physical activity is a remarkable challenge to well-being for the prevention and treatment of common diseases in society, like diabetes, joint and muscular diseases, hypertension, ischaemic heart disease, sleep apnoea, depression and insomnia. According to a recent clinical study in Finland (24), pedometers, a simple type of activity tracker, seemed to be useful for patients with chronic obstructive pulmonary disease in motivating them to physical exercise. Similarly, self-guided activity monitoring could be increasingly used to motivate patients toward behavioural change and to encourage their own active and responsible role in carrying out and monitoring the changes.

Setting goals and monitoring the progress by self-help devices can motivate some patients for optimal exercise. Yet, some individuals and clinical patient groups have special obstacles related to daytime tiredness and dysfunctional beliefs, which are common in insomnia. Patients with depression have even more challenges for behavioural change, including the lack of motivation, reward, initiative and energy. In our study, untreated depression presumably formed some obstacle for experiencing the benefits of activity tracking. The activity trackers were most useful for those patients whose insomnia was the main clinical problem, and other psychiatric symptoms were adequately under control.

Established behaviour change techniques include goal setting, feedback, rewards, social support, coaching, identifying barriers/problem solving and action planning (25-29). Increasing physical activity and subsequent weight loss are more successful with interventions that include established behaviour change techniques than those without. Specifically, self-regulatory behaviour change techniques such as goal setting, self-monitoring and social support are associated with better outcomes (30). Most of the commercially available activity trackers (Jawbone UP24, Nike Fuelband, Polar Loop, Misfit Shine, Withings Pulse, Fitbit Zip and Spark) are equipped with goal setting, feedback, rewards, self-monitoring and social support (29).

There are, however, other strategies not typically included in fitness technologies that are promising for engaging inactive vulnerable populations. These include action planning, restructuring negative attitudes, enhancing environmental conditions, and identifying other barriers to regular physical activity (31). In our study sample, there were patients that would probably have needed these more advanced technologies for behavioural change and more favourable clinical outcomes.

CONCLUSIONS

Wearable activity trackers help to relieve insomnia symptoms according to this naturalistic pilot study. They can be used as a complementary self-help method to offer the patient some follow-up data about diurnal activity and rest, and to motivate insomnia patients to physical exercise.

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