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Sleep Measurement and Health Management Using Fitness Trackers for Elderly People Living Alone: Targeting Elderly People in Areas Affected by the Great East Japan Earthquake (2011)

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ABSTRACT

This study examined the effects of wearable fitness trackers (Fitbit) on sleep monitoring and health awareness among elderly residents of Naraha Town, Fukushima Prefecture—an area affected by the 2011 Great East Japan Earthquake and subsequent nuclear disaster. Elderly individuals, both those living alone and those living with others, wore Fitbits for approximately two weeks, during which their daily sleep duration was recorded and analyzed. In addition, interviews were conducted to assess participants' experiences and perceived changes in health awareness. Results showed that all participants averaged around six hours of sleep per night, with no statistically significant difference in sleep duration between those living alone and those living with others. However, the visualization of sleep data encouraged self-reflection and health awareness, leading to behavioral changes such as improved sleep hygiene and proactive health consultations. Notably, in a region where prolonged stress and social isolation remain ongoing

challenges, daily sleep tracking proved to be a valuable tool for enhancing self-awareness and fostering reassurance among older adults.

Keywords: Elderly, Fitness Tracker, Sleep Measurement, Health Care, Great East Japan Earthquake.

INTRODUCTION

In Fukushima Prefecture, where the Great East Japan Earthquake struck in 2011, some residents resettled permanently in evacuation areas following the Fukushima Daiichi Nuclear Power Plant accident. However, after evacuation orders were lifted, many began returning to their original homes. A high proportion of these returnees are elderly, and many live alone, raising concerns about stress and social isolation. According to the *Fukushima Prefectural Health Survey's Mental Health and Lifestyle Survey*, complaints of sleep disorders and psychological distress have increased among elderly evacuees since the disaster [1]. Those living alone are particularly vulnerable to insomnia and depression.

Even after returning home, concerns about radiation, changes in living environments, and difficulties rebuilding communities remain potential risk factors. Insomnia in the elderly is influenced by multiple factors—age-related declines in sleep quality, post-disaster anxiety, altered living conditions, and social isolation. Understanding its current state and addressing it appropriately are critical.

This study, conducted in cooperation with the Naraha Town Health and Welfare Division, asked elderly residents to wear fitness trackers to monitor sleep quality (e.g., ease of falling asleep, nighttime awakenings) and sleep patterns (e.g., duration, timing, and sleep stage cycles such as REM and non-REM). Unlike traditional self-reports, this method provides objective, quantitative data. Among those living alone, the study aimed to visualize specific insomnia trends, such as shortened sleep or frequent awakenings, and to clarify the relationship between such disturbances and psychological stress or social isolation. Moreover, by enabling elderly participants to view and interpret their own sleep data, the study encouraged reflection on daily habits and supported improvements in quality of life (QOL).

This paper reports the results of sleep monitoring using fitness trackers in both elderly people living alone and those living with family members in Naraha Town, as well as the findings of interviews conducted with participants. Based on these results, we discuss potential forms of support to improve sleep quality for elderly residents in disaster-affected communities.

FITNESS TRACKERS

Characteristics of Fitness Trackers

In this study, we employed Fitbit Inspire 3 [2], a wearable device designed to objectively assess sleep in older adults. The Fitbit Inspire series belongs to the category of fitness trackers and records various biometric data in real time, including step count, heart rate, and sleep parameters. The Fitbit Inspire 3, released in 2022, is equipped with multiple sensors—an optical heart rate sensor, an accelerometer, and an electrodermal activity sensor—that enable the automatic estimation and recording of sleep onset, wake time, and sleep stages (light, deep, and REM).

Smartwatches share many of these functions but provide additional features, such as call and message notifications via connection with smartphones or tablets. However, smartwatches tend to be larger and heavier, and their battery life is limited to approximately 1–2 days, compared with 7–10 days for fitness trackers. Given the older age of our participants, we selected a lightweight device with minimal charging requirements to reduce participant burden.

Fitbit devices have been widely used in clinical and academic research, which further justified our selection of the Inspire 3. This device allows for the quantitative collection of sleep data in elderly participants without imposing significant strain. In addition, the ability to capture step count and heart rate data provides a foundation for examining sleep patterns, comparing solitary versus cohabiting participants, and analyzing correlations between physical activity and sleep quality.

Data Acquisition and Visualization

Data from Fitbit Inspire 3 were retrieved and visualized via the Fitbit mobile application on smartphones or tablets. The application displays biometric information, such as sleep stages, step count, and heart rate, in graphical format to facilitate interpretation. Each device must be paired with a dedicated smartphone or tablet to enable data transfer. For this study, we prepared five Fitbit Inspire 3 devices, each paired with an individual smartphone or tablet, to ensure seamless data collection.

RESEARCH METHODS

Study Design

This study aimed to investigate the sleep status of elderly residents in Naraha Town. Participants were instructed to wear fitness trackers continuously to obtain objective sleep data, while subjective perceptions of health and sleep were collected through interviews. Prior to participation, the purpose and procedures of the study were explained in detail, along with information on consent, the right to withdraw, and compensation. After confirming their understanding, participants provided written informed consent and subsequently received the prescribed compensation.

Study Site: Naraha Town

Naraha Town, located in Futaba District, Fukushima Prefecture, is a coastal municipality situated approximately 20 km south of the Fukushima Daiichi Nuclear Power Plant. Following the Great East Japan Earthquake and subsequent nuclear accident in 2011, all residents were forced to evacuate. The evacuation order was fully lifted in September 2015, after which residents began to gradually return. As of April 30, 2025, the Basic Resident Register reported a population of approximately 6,400, although the actual number of residents was only around 4,500. The proportion of residents aged 65 years or older is approximately 36% [3].

Participants

With the cooperation of the Naraha Town Health and Welfare Division, we recruited 10 elderly residents aged 65 years or older who demonstrated normal cognitive function. The sample included both individuals living alone and those living with spouses. Participant characteristics are summarized in Table 1. These 10 participants were divided into two survey periods, with five participants in each period wearing fitness trackers continuously to measure sleep and daily activity. This design enabled a comparison of sleep quality and patterns between elderly individuals living alone and those living with spouses.

Table 1: Composition of Survey Subjects

Group	Participant	Age	Sex	Living Arrangement
1st group	A	68	Male	Living alone
	B	75	Female	Living with others (Married couple)
	C	76	Male	Living with others (Married couple)
	D	72	Male	Living with others (Married couple)
	E	71	Female	Living with others (Married couple)
2nd group	F	68	Female	Living alone
	G	65	Male	Living alone
	H	75	Male	Living alone
	I	77	Female	Living alone
	J	80	Female	Living with others

Survey Period

As noted above, the survey was conducted in two sessions (Table 1). The survey schedule is shown in Table 2.

Table 2: Survey Schedule

Group	Start Date	Charging Day	End Date	Duration
1st group	Jan. 8	Jan. 16	Jan. 22	15 days
2nd group	Feb. 10	Feb. 19	Feb. 28	19 days

On the first day of each session, participants gathered at a local facility, where the study procedures were explained and written consent was obtained. They were then asked to wear the fitness tracker continuously for approximately two weeks, including during bathing. As the device battery lasts for about 10 days and can store approximately one week of data, participants returned to the facility on a designated charging day. At that time, devices were recharged and data were transferred, after which participants continued wearing the device for the remainder of the study period.

Following completion of the two survey periods, individual sessions were held with each participant to provide explanations of the data collected.

Collected Data

The Fitbit Inspire 3 used in this study records multiple biometric parameters in addition to sleep data. We collected step count and heart rate, as well as physiological indicators including respiratory rate, heart rate variability, skin temperature variation, blood oxygen saturation, and resting heart rate.

Ethical Consideration

This study was conducted in accordance with the ethical standards of the Declaration of Helsinki. Ethical approval was obtained from the institutional review board of Tokyo Online University. Prior to participation, all subjects received both oral and written explanations of the study’s purpose, procedures, potential risks, and benefits. Participants were informed of their right to withdraw from the study at any time without penalty. Written informed consent was obtained from all participants before data collection. To ensure confidentiality, all collected data were anonymized, securely stored, and used solely for research purposes.

SURVEY RESULTS

Sleep Data

Figure 1 shows a boxplot of total sleep duration. Participants B, C, D, E, and J lived with a spouse or family member, while the remaining participants lived alone. Across all participants, the average sleep duration was approximately six hours per night. No significant differences in sleep duration were observed between those living alone and those living with family members.

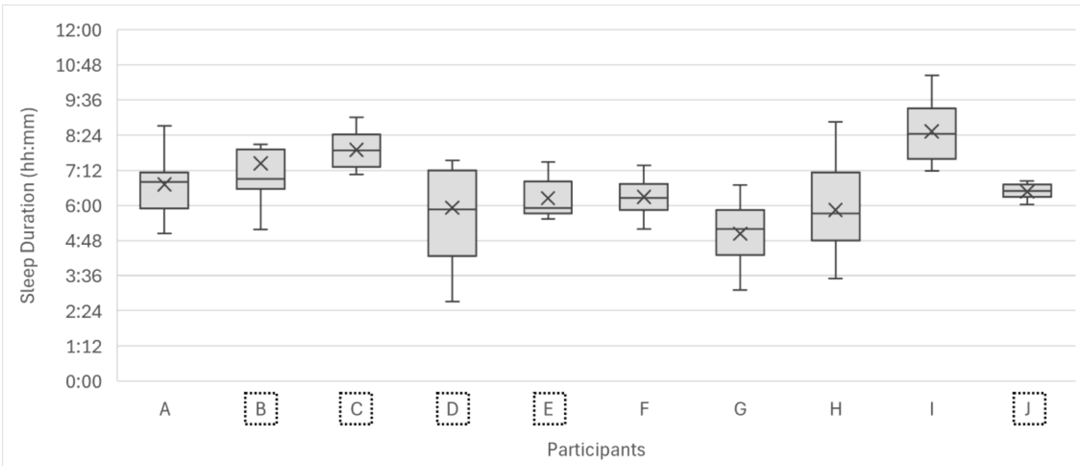

Figure 1: Boxplot of Total Sleep Duration (the frame indicates participants living together)

Figure 2 illustrates the relative proportions of sleep stages—deep sleep, light sleep, and REM sleep—expressed as percentages of total sleep time. Similar to sleep duration, no notable differences were observed between solitary participants and those living with others.

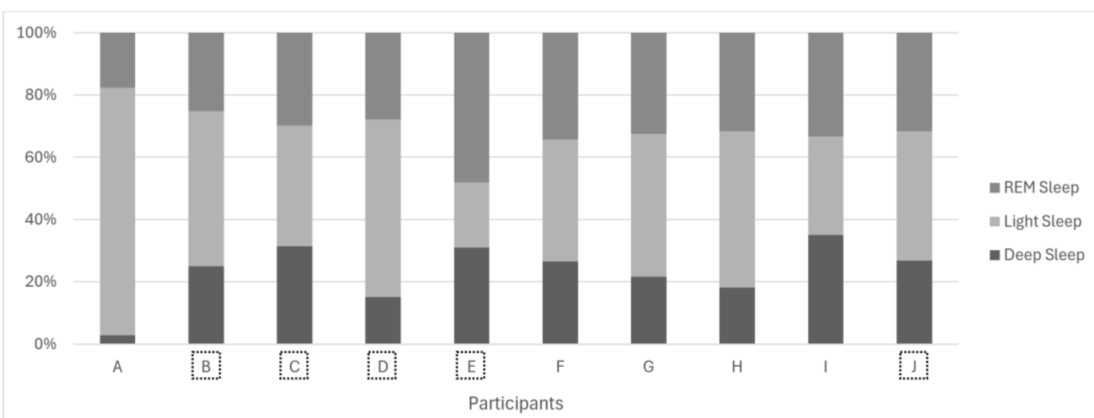

Figure 2: Percentage of Sleep Stages (the frame indicates participants living together)

Step Count Data

Figure 3 presents the average daily step counts of participants. On particularly active days, some individuals exceeded 10,000 steps. According to the *Physical Activity and Exercise Guide for Health Promotion 2023* issued by the Ministry of Health, Labor and Welfare [4], the recommended daily step target for adults aged 65 years and older is at least 6,000 steps. Considering the average age of participants in this study (76.5 years), their step counts were found to be generally close to this guideline.

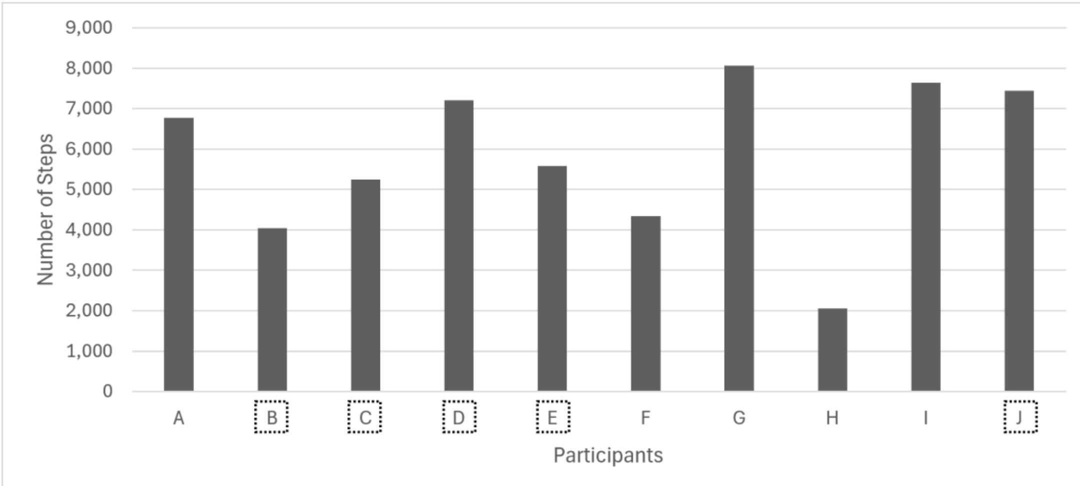

Figure 3: Step Count Data (the frame indicates participants living together)

Interview Results

Following each survey period, interviews were conducted individually with participants or jointly with couples. The interview guide included the following items:

1. Impressions of wearing the fitness tracker
2. Ease of use
3. Problems encountered
4. Perceptions of the survey period
5. Perceived sleep quality during the survey period
6. Additional comments

The responses are summarized in Table 3 and grouped by theme as follows:

Table 3: Summary of Interview Results

Category	Representative Responses from Participants
Impressions of wearing the device	- Initially inconvenient for those unaccustomed to wearing a watch, but most adapted within a few days. - Some expressed interest in owning the device, noting it became a habit. - Concerns about wearing it while bathing, though participants became accustomed over time.
Ease of use	- Reported as easy to use. - No major difficulties operating the device.
Problems encountered	- Display was difficult to read. - Step counts sometimes perceived as overestimated. - Required removal during swimming.
Perceptions of the survey period	- Two weeks was considered sufficient by some, though others desired more detailed results. - Several participants wished for a longer period and expressed interest in continuing.

Perceived sleep quality	- Some realized they were waking frequently to use the bathroom after viewing the graphs. - Others felt reassured that they were indeed sleeping well. - Reported persistent issues such as late bedtime, difficulty falling asleep, or frequent awakenings. - Reluctance to use sleeping pills despite poor sleep initiation.
Additional comments	- Appreciated viewing pulse rate and step counts. - Valued the opportunity to monitor and reflect on sleep data. - Became more conscious of sleep and lifestyle habits after seeing the data. - One participant noted life had stabilized since returning to the area after the earthquake.

CONSIDERATION

Sleep Data and Community Support

All participants achieved approximately six hours of sleep per night. Aging is typically associated with changes in sleep duration, depth, and rhythm, as well as decreased physical activity due to reduced strength and social interaction. These factors often contribute to shorter nighttime sleep; nevertheless, the present study demonstrated that participants in Naraha Town maintained a relatively stable sleep duration.

In disaster-affected communities, local support systems and community ties may exert an influence on sleep quality. Naraha Town provides a variety of health promotion activities, including walking events, yoga, and exercise classes. Notably, the yoga program integrates medical components and is conducted by a licensed physical therapist, who adapts the exercises to accommodate individual conditions such as knee or back pain. For those not attending organized programs, the town provides a "Naraha Town Walking Map," which estimates calories burned along different routes, thereby encouraging personal exercise. Participation in these activities is especially common among women, reflecting a broader national trend of higher female involvement in social activities. In addition, members of the town's social welfare council visit elderly households regularly in cooperation with the community comprehensive support center to reduce isolation. These initiatives may help promote healthier sleep among older residents.

Regional Psychological Trends and Post-Disaster Recovery

The Fukushima Prefecture "Mental Health and Lifestyle Survey (Kokoro Survey)" has documented improvements in psychological responses to radiation risk among residents of designated evacuation zones, including Naraha Town. Dissatisfaction with sleep has also declined over time [1]. For example, a survey conducted in Naraha Town and Iwaki City found that while roughly 20% of respondents expressed strong concerns about radiation exposure seven to eight years ago, this figure dropped to less than 5% in recent data. These findings suggest decreasing anxiety not only for individuals themselves but also for future generations. However, evacuees who have not returned were excluded, and ongoing fear of radiation remains one reason for non-return [5].

Fourteen years after the Great East Japan Earthquake, reconstruction has progressed unevenly across the Tohoku region. In municipalities severely affected by the nuclear accident, such as

Namie Town, the return rate remains low, the population is aging, and large areas remain designated as "difficult-to-return zones" [6]. Research indicates that returnees often report higher stress and depressive symptoms than those who resettled elsewhere, possibly due to weakened social ties and changes in their hometown environment. Thus, recovery cannot be viewed uniformly, and revitalization of community life and economic activity remains essential. Although annual news coverage on March 11 often highlights municipalities where return is still difficult, towns like Naraha, where reconstruction has advanced considerably, are rarely featured. Disseminating such progress may inform evacuees across Japan and contribute to their decision-making about returning.

Comparison Between Those Living Alone and With Others

No significant differences were observed in sleep duration or sleep stage proportions between participants living alone and those living with family members. While cohabitation is often assumed to promote psychological security and regular daily routines conducive to sleep, the quality of interpersonal relationships and the living environment may also generate stress, complicating the effect of cohabitation. Thus, living arrangement alone could not explain differences in sleep outcomes. Future research should integrate additional factors such as transitions in living environment (e.g., from temporary housing to rebuilt homes), age-related sleep changes, and the role of community and social support in disaster-affected areas.

Consideration of Interview Results

Interviews with participants highlighted several important trends. Although initial discomfort was reported, most participants quickly adapted to wearing the device. They found it easy to use, even among the elderly population, and many noted that the experience increased their awareness of sleep quality.

Previous research [7] has reported that elderly individuals, even those familiar with digital devices, often struggle with independently operating smartwatches. For this reason, in our study researchers and assistants managed device operations, while participants were only required to wear the fitness tracker continuously. This simplified approach likely contributed to favorable participant responses. When participants were later shown their own sleep data, subjective concerns (e.g., difficulty falling asleep, frequent nocturnal awakenings) often matched the tracker data. This visualization provided reassurance and prompted reflection on their health. For example, one participant (Mr. A), who typically used sleep aids after waking during the night, noted that his data showed 34 minutes of deep sleep after medication use, despite subjective dizziness upon waking. A physician consulted on this case explained that dizziness suggested the medication was ineffective and recommended discussing alternative treatment options. This case illustrates how sleep data can serve as a practical tool for patient–physician dialogue.

Implications and Future Directions

This study demonstrated that fitness trackers can effectively visualize sleep data among elderly individuals in Naraha Town, thereby enhancing health awareness and encouraging behavioral changes. Participants became more conscious of their sleep and health, with some reporting lifestyle adjustments or seeking medical consultation as a result of reviewing their own data.

Given the risks of prolonged stress and social isolation following disasters, the findings highlight the importance of integrating objective health data into community health initiatives. Combining wearable technology with town-level programs such as exercise classes and walking support may help elderly residents feel more secure and empowered to manage their health.

Future efforts should focus on developing sustainable sleep and health support systems that consider multiple factors, including living environments, daily rhythms, and community engagement. Furthermore, the knowledge gained here may be applied to other disaster-affected areas and inform broader approaches in elderly welfare.

CONCLUSION

This study examined sleep patterns and health awareness among elderly residents of Naraha Town, an area affected by the Great East Japan Earthquake, using fitness trackers. Participants achieved an average of approximately six hours of sleep per night, with no significant differences between those living alone and those living with family members. Although aging is generally associated with shorter and more fragmented sleep, the relatively stable sleep durations observed here may reflect the influence of local health programs, social participation, and community support in Naraha Town.

Interviews revealed that while participants initially felt some discomfort wearing the device, they quickly adapted and found it easy to use. Importantly, reviewing their own sleep data increased awareness of sleep quality and, in some cases, prompted behavioral changes such as reconsidering lifestyle habits or consulting physicians. Objective data visualization thus appeared to bridge the gap between subjective perceptions and actual sleep patterns, contributing to improved self-understanding and health motivation.

The findings also suggest broader implications for post-disaster health management. In disaster-affected communities, long-term stress and social isolation remain serious concerns, yet linking wearable technology with community-level initiatives—such as exercise classes, walking programs, and regular visits by welfare staff—may help foster psychological security and encourage proactive health behaviors.

Overall, this study demonstrated the feasibility and value of using fitness trackers to support elderly residents' health awareness in a disaster-affected area. Future work should focus on refining sustainable support systems that integrate objective data with community resources, while also considering environmental, social, and psychological factors. Insights gained from Naraha Town may be applied not only to other disaster-stricken regions but also to broader approaches in elderly welfare and community health promotion.

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