Performance of Xiaomi Mi Band 5 Against Polysomnography in Measuring Sleep

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Abstract: This study sought to compare the effectiveness of one of the top-selling activity wristbands, the Xiaomi Mi Band 5, with polysomnography in the measurement of sleep stages. Conducted at a hospital in A Coruña, Spain, this study recruited individuals already participating in a polysomnography study at a sleep unit. The study encompassed a total of 45 adults.The Xiaomi Mi Band 5 demonstrated an overall accuracy. Notably, it tended to overestimate total sleep time, light sleep, and deep sleep compared to polysomnography. Conversely, it underestimated wake after sleep onset and REM sleep measured by polysomnography. The Xiaomi Mi Band 5 holds potential as a tool for monitoring sleep and identifying alterations in sleep patterns, especially among individuals without sleep disorders. However, further research is warranted to evaluate its efficacy when used with individuals suffering from various types of sleep disorders.

1 Introduction

Wearable devices have marked a milestone in the revolution of participatory population health by providing unprecedented access to health data with the potential to transform health promotion and well-being (Nieto-Riveiro et al., 2018). These devices are shaping a culture of participatory health, empowering individuals to actively manage and control their own health. Among these devices, wristbands and activity watches have emerged as leaders in this revolution by offering real-time information that enhances awareness and understanding of crucial biomedical parameters, such as sleep (Concheiro-Moscoso et al., 2023).

Sleep has gained increasing recognition in society in terms of its importance and implications for health (Sadek et al., 2019). This growing awareness has spurred interest in monitoring and measuring various aspects and parameters of sleep (de Zambotti et al., 2019). Sleep assessment can be subjective or objective, with subjective tools reflecting the user's or professional's perception of sleep quality and quantity, while objective measurements have sought more practical and cost-effective alternatives to polysomnography (PSG), which has been the gold standard for measuring sleep patterns (Kubala et al., 2020).

This paradigm shift has led to intense research on the validity and applicability of wearable devices in monitoring sleep and related biomedical parameters in diverse populations (Sadek et al., 2019). The technology industry has responded to this ever-growing demand by improving the accuracy and reliability of sleep stage detection, such as light sleep, deep sleep, and REM sleep, as well as the accessibility and comprehension of sleep, activity, and heart rate data for consumers (de Zambotti et al., 2019).

The benefits and positive impact of these devices on the population are becoming increasingly evident as they promote awareness of the importance of sleep and encourage the management of healthy sleep habits and lifestyles (Chong et al., 2020). As society embraces these devices, their influence on the healthcare and research domains becomes more prominent. Healthcare professionals and healthcare systems have begun integrating these devices into clinical practice, enabling more comprehensive user assessments and more accurate monitoring of sleep and other biomedical parameters (Concheiro-Moscoso et al., 2021).

Moreover, large companies and healthcare organizations have shown interest in using these devices to monitor and enhance the health of their employees and customers (Chong et al., 2020). The validation of sleep data quality provided by these devices has become a necessity to ensure their reliable use in daily life, clinical practice, and research (Concheiro-Moscoso et al., 2022). Despite the growing adoption of wearables, there are few validation studies comparing sleep data to standard methods, such as PSG (de Zambotti et al., 2019).

Therefore, this study aimed to assess the quality of sleep data from the Xiaomi Mi Band 5 wearable device. The findings of this research contribute to our understanding of the reliability and accuracy of sleep data provided by wearable technology, further emphasizing the potential impact of wearables on healthcare, research, and overall population health.

2 Objectives

The primary goal of this study was to evaluate how well the Xiaomi Mi Band 5 measures sleep-wake stages in comparison to polysomnography (PSG) conducted in a hospital sleep unit. Additionally, the study had several secondary objectives:

1. To establish the level of agreement between sleep measurements obtained from PSG and those from the Xiaomi Mi Band 5.
2. To assess the Xiaomi Mi Band 5's accuracy, specificity, and sensitivity in classifying sleep and wake stages in comparison to PSG.
3. To evaluate the Xiaomi Mi Band 5's performance in detecting specific sleep stages, including wakefulness, light sleep, deep sleep, and REM sleep, in comparison to PSG results.

3 Methodology

3.1 Study Setting and Participant Profile

This project is an observational and prospective study conducted within a sleep unit at a hospital in A Coruña. The study targeted individuals over 18 years of age who were undergoing polysomnography (PSG) for clinical purposes unrelated to this research.The study was approved by the A Coruña-Ferrol research ethics committee (2020/318).

Calculations indicated a required sample size of 43 participants for achieving statistically significant results, yet the study enrolled 58 participants. However, data from only 45 participants (predominantly males with a mean age of 53.24 ± 15.44 years) were included in the analysis due to missing or invalid data from the remaining 13 participants.

Participants were categorized into two groups based on the presence of sleep disorders: participants without sleep problems, $n = 20$) and SDis (with sleep problems, $n = 25$). Thus, data analysis was conducted both on the entire participant cohort and separately for the established groups based on sleep disorder presence.

3.2 Data Processing

In accordance with established standards, data processing followed the recommendations and guidelines set by the American National Standards Institute and the Consumer Technology

Association (ANSI/CTA Standard). These guidelines stipulate that the validation analysis of a device should be carried out using sleep stages segmented into 30-second epochs. While PSG records sleep states in 30-second epochs throughout the entire sleep cycle, the data provided by the Xiaomi Mi Band, whether in its application or in CSV files, consisted of the total duration of each sleep stage within its cycle (Kemp and Olivan, 2003).

To ensure the highest level of precision in the analysis, the research team reprocessed the data from both devices. This involved transforming the data into the European Data Format+ (EDF+) using a Python script developed with the PYEDFlib library (Concheiro-Moscoso et al., 2023). Specifically, the acquisition of Xiaomi Mi Band data in 30-second epochs was synchronized with the PSG-defined sleep onset and the recorded light on/off events, which were documented in the sleep unit's report.

3.3 Statistical Analysis

Statistical analysis was conducted using R software (version 4.1.2; R Foundation for Statistical Computing) with the entire sample size (n=45). Comparisons between summary measures of PSG and the Xiaomi Mi Band 5 equivalents were executed utilizing either the paired 2-tailed t-test (t) or the Mann-Whitney Wilcoxon test (z), contingent upon the normality of the data as determined by the Shapiro-Wilk normality test. Parametric 2-tailed t-tests were applied to normally distributed data, while non-normally distributed data underwent analysis via the Mann-Whitney Wilcoxon test. Moreover, the Bland-Altman method was employed to assess the concordance between PSG and the Xiaomi Mi Band 5 concerning each sleep parameter. Calculations included the mean difference (or bias) between the two methods, the standard deviation (SD), the 95% confidence interval (CI), and the Bland-Altman 95% limits of agreement (mean observed difference $\pm$ 1.96 $\times$ SD of observed differences). A positive bias indicated that the Xiaomi Mi Band 5 tended to underestimate a variable in comparison to the gold standard (PSG), while a negative bias indicated overestimation.

4 Results

The first test that marked the validation process involved comparing the summarized sleep measures obtained from both devices using a t-test. In this initial analysis, it is noteworthy that similar results were observed between the Xiaomi device and PSG in sleep-related variables such as initial sleep onset, total sleep period duration (TSPD), and sleep onset latency (SOL) across the entire participant group. Specifically, comparable outcomes were noted between both devices in total sleep time (TST), wake time after sleep onset (WASO), and deep sleep time in the group without sleep disorders, while there was similarity in SOL and light sleep time among participants with sleep disorders.

Table 1: Comparison of PSG and Xiaomi Mi Band 5 sleep measures in the total sample

Name	t	z	P
Initial sleep onset (hh:mm)	1.12	-	0.266
TSPD (minutes)	0.28	-	-0.778
SOL (minutes)	-	-1.07	0.288

Overall, the results of the Bland-Altman analysis (see Figure 1) indicated that the Xiaomi Mi Band 5 device tended to overestimate measures of TST, Sleep Efficiency (SE), time spent in light sleep, and time spent in deep sleep when compared to PSG. Conversely, Xiaomi Mi Band 5 showed a tendency to underestimate measures of WASO and Rapid Eye Movements (REM) sleep in comparison to PSG measurements.

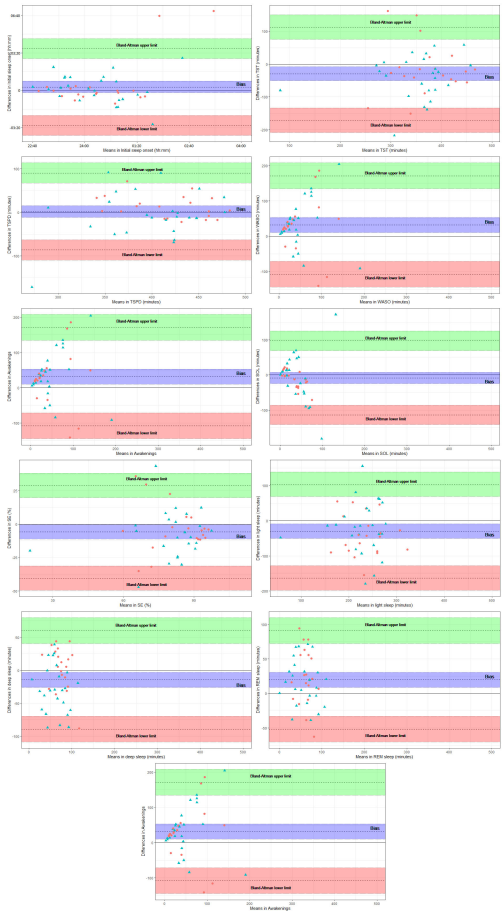

Figure 1: Bland Altman Plot

With regard to the results obtained from the Epoch by Epoch (EBE) detection test using a Python script, overall, the Xiaomi wristband exhibited greater accuracy (the ability to detect sleep-wake stages), as well as higher sensitivity (the ability to detect sleep stages) compared to its specificity (the ability to detect wake stages) in detecting the phases of the sleep-wake cycle.

Table 2: Comparison of PSG and Xiaomi Mi Band 5 sleep measures in the total sample

		Xiaomi	
		Wake	Sleep
PSG	Wake	3019	5525
	Sleep	3238	27786

5 Discussion and Conclusions

In comparison to existing literature, the results obtained with the Xiaomi Mi Band 5 wristband and PSG are consistent with findings from previous comparative studies involving devices such as Fitbit HR, Fitbit Charge 2, or Jawbone UP (de Zambotti et al., 2019). Specifically, minor differences were observed between the Xiaomi device and PSG in certain summarized measures when compared to these devices. Furthermore, it is noteworthy that the results obtained in the group without sleep disorders generally exhibited greater accuracy compared to the group with sleep disorders. In this regard, the Xiaomi Mi Band 5 could serve as a valuable tool for health monitoring in the population without sleep disorders (Concheiro-Moscoso et al., 2023). Nonetheless, further research comparing this device to the gold standard, PSG, in diverse populations with and without sleep disorders is needed to assess its accuracy and reliability.

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