A Comparison of Objective and Subjective Sleep Quality Measurement in a Group of Elderly Persons in a Home Environment

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Abstract. The main aim of presented in this manuscript research is to compare the results of objective and subjective measurement of sleep quality for older adults (65+) in the home environment. A total amount of 73 nights was evaluated in this study. Placing under the mattress device was used to obtain objective measurement data, and a common question on perceived sleep quality was asked to collect the subjective sleep quality level. The achieved results confirm the correlation between objective and subjective measurement of sleep quality with the average standard deviation equal to 2 of 10 possible quality points.

1 Introduction

Sleep is an essential part of our life. It is necessary for the restoring of our physical and mental health [1]. However, it is essential to consider that sleep duration alone is not enough for the complete recuperation of our body and brain – sleep quality is another significant factor [2].

Measurement of sleep quality can be, in general, separated into two main classes:

- Objective – with the help of devices, which collect bio-vital data.
- Subjective – the information is reported using questionnaires [3].

Both mentioned above groups of measurement approaches have different methods. For example, polysomnography or actigraphy can be used for objective measurement. Using a sleep diary or a PSQI questionnaire may provide the data for the subjective measure of sleep quality. However, of course, also other approaches are existing and being described in several scientific publications [4–6].

The primary motivation in this manuscript research is to compare the objective and subjective measurement of sleep quality. To understand the tendency, if persons are more likely to under- or overestimate the quality of their sleep and to check if it is possible to avoid subjective measuring in case of long-term use of technologies for objective measurement.

2 State of the Art

Sleep quality, in general, among the elderly, is mainly a topic of a lot of scientific research. In the following, only a small selection of relevant approaches are presented.

General information about the measurement of sleep quality and the comparison of different approaches is a central topic of [4]. It combines the description of different methods of measurement and challenges of sleep quality determination.

Investigation of age-related differences in self-reported sleep quality in correlation with health outcomes is presented in [1]. The conclusion was reached that there is a correlation between better self-reported sleep and better health outcomes, especially for mental health. Furthermore, a decrease in sleep quality across the lifetime was reported, particularly about sleep efficiency.

In [6], the comparison of subjective and objective sleep analysis, including measurement of sleep quality, is done. The total amount of 17 persons (14 females and three males) has participated in this study. The correlation between objective and subjective determination of sleep quality was reported, though it was small ($r = 0.270$, $p < 0.01$).

Another study on the comparison of subjective and objective measurement of sleep quality, but with a focus on the age group 55+, is presented in [5]. As a result, there is a significant difference between these two types of measurement, at least for the mentioned above age group. The final recommendation was made to use both subjective and objective methods of measurement to get a complete conclusion on sleep quality. Another system for the recognition of Sleep/Wake states, which can be used to calculate sleep quality, is presented in [7].

It is essential to measure the sleep quality in the older adults' group but also to understand what can affect it. This topic was discussed in [8], where the correlation between subjectively measured sleep quality and physical activity was determined. This result confirms that subjective measurement of sleep quality can be correlated with the lifestyle.

3 Methodology

Our study was running over two weeks with ten subjects; the group consisted of elderly persons (65+). Each participant was in his private home to maintain a routine environment. On the first day, the necessary devices were installed and explained. Additionally, the questionnaires have been taught. On the last day, the devices were picked up, and the final survey was filled out with the participant. During the study, a technical solution for sleep monitoring (EmFit [9]) was provided for each participant, which should be used over the test period. This device is based on ballistocardiography principle, it is contact-free, autonomous, automatic and can be placed under a bed mattress. This allowed sleep quality to be measured objectively during the two weeks. The used device can measure heart rate [10], heart rate variability [11], monitor breathing and sleep (incl. Sleep staging) [12]. Besides, two short daily questionnaires (including sleep diary and a general question of perceived sleep quality), there was a more detailed sleep questionnaire (PSQI) at the end of the two weeks.

For the subjective documentation of the sleep quality, a graphical representation of this question was used (see Fig. 1), here, the participant tagged the perceived sleep quality for the last night. For the evaluation, a scale was graduated in 10 sections, so that we could get a value between 1 to 10.

Fig. 1. Graphical representation of the sleep quality question

As mentioned above, the EmFit device was used for the objective measurement of sleep quality (sleep score). This device calculates the value of sleep quality according to following Formula 1 [6]:

$$
\begin{aligned}
&\mathit{SleepScore} = \\
&(\text{total\_duration\_of\_sleep} + \\
&(\text{duration\_of\_REM\_sleep} * 0.5) + \\
&(\text{duration\_of\_DEEP\_sleep} * 1.5)) - \\
&8.5 * \left(0.5 * \left(\frac{\text{sleep\_class\_awake\_duration}}{3600}\right) + \frac{\text{number\_of\_wakenings}}{15}\right)
\end{aligned} \tag{1}
$$

The maximal value of this objective measurement is 100 points. For the evaluation, we have divided this number by 10 leaving one position after the decimal point to get the same range of values as by subjective measurement.

Ethical officers of HTWG Konstanz and the University of Applied Sciences Kempten approved the experiment design.

After the study's execution, the objective and the subjective measurements were collected and evaluated. The total amount of 140 nights was recorded. Due to missing data from a used technical device or not filled out questionnaires on some days, finally, only the records of 73 nights are available for the evaluation. Its outcome is presented in the section 'Results'.

4 Results

All sleep quality data collected with the objective (sleep tracking device) and subjective (questionnaire) approach were used for the evaluation. As mentioned before, some night records were excluded from the evaluation due to missing parts.

Table 1 represents the calculated statistical values of differences in an objective and subjective measurement ('subjective measurement - objective measurement') for each subject, where negative numbers of median and mean that these values represent the case that subjects underestimate the quality of sleep. It is recognizable that 8 of 10 subjects (highlighted light red in the table) have a feeling that their sleep was of less quality than a sleep tracking device measured it. For 8 out of 10 subjects, the value of the standard deviation is low and stays in range between 1.2 and 2.1; the average standard deviation is equal to 2. According to the '68-95-99,7 rule' [13], 68% of all values will not differ more than by ± 2, and 95% of all values will not differ more than by ± 4 means that there is a strong correlation between objective and subjective measurement.

Table 1. Statistical values of sleep quality subjective-objective measurement.

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8	Subject 9	Subject 10
Median	-1,8	-2,3	-5,3	2,5	-1,0	-1,6	-0,5	-1,8	-3,9	0,8
Mean	-1,5	-1,5	-4,2	2,8	-1,3	-1,4	-1,3	-1,9	-3,2	0,8
Standard deviation	2,1	2,0	2,5	1,2	1,6	1,5	2,0	1,8	3,2	1,9
Variance	4,6	3,9	6,2	1,4	2,6	2,1	4,0	3,1	10,2	3,5

The graphical representation of calculated values in Fig. 2 represents the stable value of standard deviation for all subjects.

Although the calculated statistical values for most of the subjects are similar, there is some outlier, which could be partially explained by not complete night records for all the days. It means if, from 14-night records for some of the subjects, only seven or less are complete (subjective and objective measurements are available). These records have a high variance. The average variance value will also be high, whereas, with all 14 complete records, it could be lower, because the outliers would be less significant with the higher amount of analyzed data. This is one of the reasons why in future research, the focus will be done on getting a higher amount of complete records to decrease the influence of outliers.

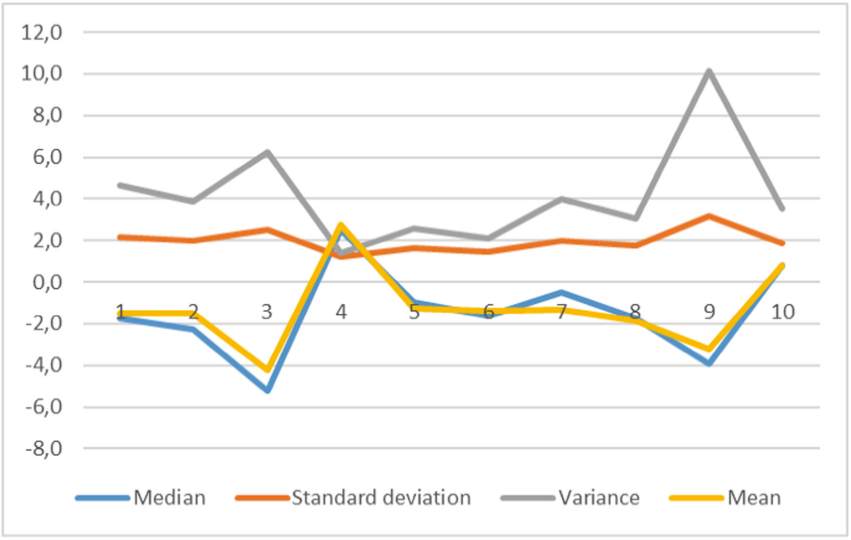

Fig. 2. Median, standard deviation, variance, and mean values

5 Conclusion

As presented in this manuscript, research has confirmed a strong correlation between subjective and objective measurement of sleep quality. This knowledge is important for assessing possible substitution of subjective measure using only the information obtained with devices collecting bio-vital data (objective measurement). This substitution could be necessary for the development of AAL-Systems with sleep quality measurement as one of its parts.

Our group is planning to develop a prototype of an AAL-System for the home environment with several devices working in the area of health monitoring. The results described in this document study are providing necessary information for this future development. Furthermore, a new study with a higher number of participants of the same age group is currently planning.

Acknowledgments. This research was partially funded by the EU Interreg V-Program "Alpenrhein-Bodensee-Hochrhein": Project "IBH Living Lab Active and Assisted Living", grants ABH040, ABH041 and ABH066. Thomas Penzel has been partially funded by RF Government grant Nº 075-15-2019-1885. We also thank the caregivers of the Workers' Welfare Association (AWO) Schwarzwald-Baar e.V. for their contribution in conducting the study.

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