# Statistical Analysis between Sleep Status and Occupational Health Indicators for Detecting Depression Signs in Healthy Workers

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***Abstract*—Occupational health issues such as depressions have become a serious problem in recent years. There is an urgent necessity for the early preventive detection of depression rather than a yearly survey. Toward detecting depression signs, this paper statistically analyzes the relationship between occupational health indicators collected by questionnaires and sleep status (sleeping condition and heart rate data) during bedtime measured by a common wearable device.**

***Index Terms*—Sleep, wearable device, occupational health, depression, DAMS.**

## I. Introduction

To ascertain the mental condition of employees, questionnaires such as *Depression and Anxiety Mood Scale* (*DAMS*) [1] are commonly used. DAMS consists of three scales: *depression*, *positive*, and *anxiety*. However, these questionnaires are qualitative, and also it is difficult to measure a person's condition constantly because of the time required to answer the questionnaire.

Our study aims to realize the early detection of depression signs by using a common wearable device to monitor and assess the daily mental condition of office workers. In this paper, we especially focus on various sleep status data during bedtime, such as stages of sleeping condition, heart rate variability (HRV), and analyze the relationship between occupational health indicators and these data.

Existing research has reported the differences in sleep structure, e.g., sleep stage duration, the ratio of each sleep stage, between healthy people and patients with psychiatric disorders [2], [3]. Nutt *et al.* conducted a statistical analysis of REM sleep status (e.g., frequency, duration, time interval) via polysomnography on patients with depression symptoms [4]. The results showed that patients with depressive symptoms had increased REM sleep duration and increased REM density (frequency of rapid eye movements per REM period) compared to the healthy group. However, it requires specific equipment and facilities to measure sleep status, which is not suitable for monitoring daily life. They mainly target subjects with severe mental ill. To the best of our knowledge, there is no study that focuses on detecting depression signs for preventive medical care targeting healthy workers.



## II. Analysis of Sleep Status and Occupational Health Indicators

The dataset which has been collected from 60 office workers in four Japanese companies over 2–3 weeks by Tani *et al.* [5] is used for analysis in this paper. It includes data of occupational health indicators (DAMS) collected by questionnaires and sleep status (sleeping conditions and heart rate data) during bedtime measured by a common wearable device, Fitbit Charge 3.

Fitbit can detect four stages of sleep (awake state, REM sleep, light sleep, and deep sleep) with the sampling frequency of 1 Hz. Also, the heart rate data can be measured every three seconds. Based on these data, R-R Interval (RRI) is calculated with the formula, $RRI = \frac{60}{HeartRateData} \times 1000$, and HRV is calculated using those values. The sampling frequency of Fitbit is insufficient to calculate the index in a frequency-domain, so only a time-domain HRV is used in this paper. Moreover, we derived the area of Lorenz Plot (ALP) which has recently attracted attention as an indicator for understanding a state of a parasympathetic nervous system as well as HRV [6].

The purpose of this study is to detect the signs of daily depression in healthy workers, hence, we investigate whether there are differences in sleep status explained above between healthy workers and slightly depressed workers. Here, we divided subjects into two groups "high" and "low" by median values of each DAMS score for statistical analysis.

The procedure of the statistical test is following. First, we evaluated whether the distribution is normal by a Shapiro-Wilk test at a significance level of 5% for each of two high and low feature groups. Next, the difference between the high and low groups was statistically analyzed by using Mann-Whitney's U test (in case of a non-normal distribution), Welch's t-test (if a case of a normal distribution). A two-sided test is used and the significance level is set as 1%.

At first, statistical analysis results with sleep status data are shown in Table I. $p$-values with bold text represent that feature shows a significant difference. We found the duration, number, and ratio of the REM sleep stage have a significant difference between the high and low groups in the *depression* and *anxiety* scales. The duration and the ratio of REM sleep stages among the high depression group are less than those of the low

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TABLE I
STATISTICAL ANALYSIS RESULT WITH SLEEP STATUS DATA

| Features | | $p$-value of statistical test | | |
|---|---|---|---|---|
| | | Depression | Positive | Anxiety |
| Duration of | whole sleep | 0.277 | 0.013 | 0.033 |
| | deep sleep stages | **0.001** | 0.046 | **0.002** |
| | light sleep stages | 0.053 | 0.672 | 0.172 |
| | REM sleep stages | **0.002** | **0.001**[a] | **0.000**[a] |
| | awake stages | 0.506 | 0.973 | 0.810 |
| Number of | deep sleep stages | 0.424[a] | 0.104 | 0.013 |
| | light sleep stages | 0.502 | 0.370 | 0.421 |
| | REM sleep stages | **0.000** | 0.031 | **0.002** |
| | awake stages | 0.019 | 0.204 | 0.051 |
| Ratio of | deep sleep stages | **0.000**[a] | 0.139[a] | **0.001**[a] |
| | light sleep stages | **0.000** | 0.022 | **0.000** |
| | REM sleep stages | **0.000** | 0.024 | **0.000** |
| | awake stages | 0.607 | 0.082 | 0.026 |
| Ratio for one hour after sleep onset of | | | | |
| | deep sleep stages | **0.000** | 0.056 | **0.000** |
| | light sleep stages | **0.002** | 0.036 | **0.000** |
| | REM sleep stages | 0.289 | 0.714 | 0.569 |
| | awake stages | **0.000** | 0.288 | 0.671 |
| Time until | first deep sleep | **0.000** | 0.169 | **0.000** |
| | first light sleep | 0.615 | **0.007** | 0.489 |
| | first REM sleep | 0.033 | 0.805 | 0.042 |
| | first awake | 0.588 | 0.015 | 0.037 |

[a] Normal distribution by Shapiro-Wilk test ($p > 0.05$).

depression group, and the number of REM sleep stages is 1.3 lower on average. When focusing on data for one hour after sleep onset, ratio of awake stages has significant differences in the *depression* and *anxiety* scales. Also, the time until falling into first deep and light sleep also has significant differences in the three DAMS scales. They suggest the situation that people have trouble falling asleep might strengthen the tendency of depression. This relationship between REM sleep and depression is consistent with the report of Pesonena *et al.* [3].

Secondlly, statistical analysis results with sleep status data are shown in Table II. $p$-values with bold text represent that feature shows a significant difference. SDNN and RMSSD represent the standard deviation of the RRI, and the root mean square of the successive RRI differences respectively. These features indicate an intensity of a parasympathetic nervous system, with higher values indicating a relaxed state. Note that the "Part" column means the data range which is used for calculation (see footnotes of Table II). We found statistical significance for features of ALP, SDNN and RMSSD between the high and low groups of the *depression* scale in all data ranges. Regarding *anxiety* scale, some of HRV data at the first deep sleep and last REM sleep are significantly different.

The results suggest that sleep status during bedtime measured by Fitbit can be used as an indicator to assess the depression sign, as in previous studies with costly devices. However, we also found the difference of *positive* scale does not give much effect to sleep status, except the duration of the REM sleep stage and time until falling into first light sleep.

TABLE II
STATISTICAL ANALYSIS RESULT WITH HRV DATA DURING BEDTIME

| Part | Stage | Features | $p$-value of statistical test | | |
|---|---|---|---|---|---|
| | | | Depression | Positive | Anxiety |
| WS[a] | - | Mean (HR) | 0.028 | 0.354 | 0.135 |
| | | SD (HR) | 0.566 | 0.423 | 0.342 |
| | | Mean (RRI) | 0.025 | 0.364 | 0.127 |
| | | SDNN (RRI) | **0.004** | 0.884 | 0.022 |
| | | RMSSD (RRI) | **0.000** | 0.444 | 0.107 |
| | | ALP | **0.000** | 0.557 | 0.036 |
| FS[b] | Deep | Mean (HR) | 0.606 | 0.089 | 0.987 |
| | | SD (HR) | 0.066 | 0.109 | **0.000** |
| | | Mean (RRI) | 0.614 | 0.094 | 0.974 |
| | | SDNN (RRI) | 0.014 | 0.355 | **0.000** |
| | | RMSSD (RRI) | 0.131 | 0.534 | 0.407 |
| | | ALP | 0.019 | 0.688 | **0.001** |
| | REM | Mean (HR) | 0.045 | 0.382 | 0.332 |
| | | SD (HR) | 0.076 | 0.683 | 0.086 |
| | | Mean (RRI) | 0.041 | 0.384 | 0.314 |
| | | SDNN (RRI) | **0.005** | 0.522 | 0.041 |
| | | RMSSD (RRI) | **0.001** | 0.171 | 0.026 |
| | | ALP | **0.001** | 0.317 | 0.033 |
| LS[c] | Deep | Mean (HR) | 0.076 | 0.110 | 0.024 |
| | | SD (HR) | 0.125 | 0.333 | 0.571 |
| | | Mean (RRI) | 0.077 | 0.070[d] | 0.025[d] |
| | | SDNN (RRI) | **0.001** | 0.887 | 0.073 |
| | | RMSSD (RRI) | **0.004** | 0.199 | 0.219 |
| | | ALP | **0.001** | 0.654 | 0.084 |
| | REM | Mean (HR) | 0.011 | 0.535 | 0.045 |
| | | SD (HR) | 0.019 | 0.700 | 0.452 |
| | | Mean (RRI) | **0.003**[d] | 0.414[d] | 0.041[d] |
| | | SDNN (RRI) | **0.000** | 0.665 | 0.040 |
| | | RMSSD (RRI) | **0.000** | 0.468 | **0.005** |
| | | ALP | **0.000** | 0.554 | 0.010 |

[a] HRV data for the whole sleep.
[b] HRV data for the first sleep stage after falling asleep.
[c] HRV data for the last sleep stage before waking up.
[d] Normal distribution by Shapiro-Wilk test ($p > 0.05$).

## III. CONCLUSION

In this paper, we have conducted the statistical testing of difference in sleep status during bedtime between high and row groups of each DAMS scale. The findings in this paper show the possibility that signs of depression and anxiety can be detected using daily sleep status data measured by a common wearable device. In future work, we will build a model for anomaly detection of depression and anxiety situations, and evaluate it.


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## REFERENCES


[1] Lee Anna Clark. The anxiety and depressive disorders: Descriptive psychopathology and differential diagnosis. 1989.

[2] Norifumi Tsuno, Alain Besset, and Karen Ritchie. Sleep and depression. *The Journal of clinical psychiatry*, 2005.

[3] Anu-Katriina Pesonen, Michael Gradisar, Liisa Kuula, Michelle Short, Ilona Merikanto, Riin Tark, Katri Räikkönen, and Jari Lahti. Rem sleep fragmentation associated with depressive symptoms and genetic risk for depression in a community-based sample of adolescents. *Journal of affective disorders*, 245:757–763, 2019.

[4] David Nutt, Sue Wilson, and Louise Paterson. Sleep disorders as core symptoms of depression. *Dialogues in clinical neuroscience*, 10(3):329, 2008.

[5] Yuri Tani, Shuichi Fukuda, Yuki Matsuda, Sozo Inoue, and Yutaka Arakawa. Workersense: Mobile sensing platform for collecting physiological, mental, and environmental state of office workers. In *2020 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*, pages 1–6. IEEE, 2020.

[6] Jesper Jeppesen, Sándor Beniczky, Peter Johansen, Per Sidenius, and Anders Fuglsang-Frederiksen. Detection of epileptic seizures with a modified heart rate variability algorithm based on lorenz plot. *Seizure*, 24:1–7, 2015.