International Journal of Technology (2017) 2: 329-337
ISSN 2086-9614

EVALUATING SMARTWATCH-BASED SLEEP QUALITY INDICATORS OF FITNESS TO WORK

Yassierli[1*], Rizqi Permana Sari[1], Khoirul Muslim[1]

[1] *Faculty of Industrial Technology, Institut Teknologi Bandung, Jl Ganesa 10 Bandung 40132, Indonesia*

(Received: October 2016 / Revised: December 2016 / Accepted: January 2017)

ABSTRACT

The study sought to evaluate smartwatch-based sleep quality indicators of fitness to work. Eighteen males (aged 20–26 years) were assigned to three randomized daytime sleep conditions (bad/moderate/good), which varied in terms of lighting, noise, and temperature, for a six-hour period. After this daytime sleep, participants completed simulated computer tasks during a 12-hour nighttime waking period. Prior to those tasks, participants' fitness to work was determined by subjective measures that included the Sleep Quality Index-Karolinska Sleep Diary (SQI-KSD)), the Psychomotor Vigilance Task (PVT)), and the Karolinska Sleepiness Scale (KSS) to measure drowsiness. Total sleep time (TST), light sleep quantity (LSQ), deep sleep quantity (DSQ), and REM sleep quantity (REMSQ) were recorded using a smartwatch. The results confirmed that TST, LSQ, and SQI-KSD can be used as measures of sleep quality and fitness to work ($p < 0.05$).

Keywords: Fitness to Work; Sleep Quality; Sleepiness; Smartwatch; Vigilance

1. INTRODUCTION

Sleep is a primary human need, playing an important role in the regulation of brain functions such as the neurobehavioral system, safety performance (Philibert, 2005), mood (Horne, 2000), and memory consolidation (Drummond & Brown, 2001). Additionally, sleep may affect physiological functions, including metabolism, immunity, and hormone functions, the cardiovascular system (Watson et al., 2015), and energy feedback (Scharf et al., 2008). Changes in the physiological system can affect a worker's physical and mental states. Disturbances such as lack of sleep time, poor quality of sleep, or circadian rhythm change in human biological time may lower readiness to work, which in combination with high workload can potentially lead to accidents.

An excessive deficit in sleep time has many negative effects on humans, including increased anger, distress, and exhaustion (Durmer & Dinges, 2005). It can also lead to drowsiness, which may reduce ability to work, increasing accident risk (National Institute of Health, 1997). Drowsiness-related accidents have been reported in jobs involving extended work hours (12-hour duration) in the oil, gas, and mining industries (Halvani et al., 2009). According to Schutte and Maldonado (2003), it is very important to establish a level of vigilance for work productivity and safety, highlighting the need for adequate sleep prior to work.

Sleep can be measured in terms of its quantity and quality; of these, sleep quantity (i.e., length of sleep) is easier to observe. In general, an adequate quantity of sleep can improve health,

*Corresponding author's email: yassierli@mail.ti.itb.ac.id, Tel. +62-22-2532081, Fax. +62-22-2532081
Permalink/DOI: https://doi.org/10.14716/ijtech.v8i2.6118

metabolism, immunity, and performance, as well as lengthening life expectancy (Watson et al., 2015). However, the amount of sleep needed is not the same for everyone; as long-time sleepers may require more sleep time than short-time sleepers (Aeschbach et al., 1996; Mairesse et al., 2012), sleep sufficiency cannot be determined merely on the basis of sleep duration.

Sleep quality can be measured subjectively or objectively. Subjective sleep quality measurement is based on one's own perceptions of drowsiness and vigilance after waking. Subjective measurement of sleep quality is commonly based on questionnaires such as the Pittsburgh Sleep Quality Index (PSQI), the Epsworth Sleepiness Scale (ESS), the Stanford Sleep Diary (SSD), the Karolinska Sleep Diary (KSD), and the Sleep Health Scale (SHS). Although the subjective method has been validated by objective means, it has a number of weaknesses, such as high individual subjectivity and inaccuracy in completing the questionnaire. For these reasons, the results may not adequately indicate actual sleep quality. Objective sleep quality can be measured using polysomnography (PSG), which is considered the gold standard for such measurements (Werner et al., 2015; Zambotti et al., 2015). PSG is laboratory-based and measures brain wave using electroencephalography (EEG), respiration frequency, eye muscle movement (electrooculography), and face muscle movement (electromyography). However, PSG measurement is complicated and uncomfortable, and must be performed in a clinical laboratory or a hospital, which makes the method inefficient for industry application (Natale et al., 2012).

Research is ongoing to develop practical methods for assessing worker sleep quality effectively, efficiently, and in real time, but to date, no such method has been reported. The present attempt utilizes a smartwatch—a wireless instrument that can detect physiological signals in real time. The instrument is equipped with a heart rate sensor using photoplethysmography (PPG) and accelerometer technology that allows the wearer to measure their sleep quality based on the amount of movement during sleep. This instrument has been claimed to measure sleep quality with the same reliability as the objective method (i.e., PSG) (Ancoli-Israel et al., 2003; Jovanov, 2015; Noor et al., 2013; Zambotti et al., 2015), monitoring a cardiovascular indicator during sleeping or waking states (24/7) using PPG. Given its portability and potential for use outside the clinical laboratory, this instrument could potentially be used as an objective detection system to measure work readiness in real time. On that basis, this study aimed to develop a smartwatch-based sleep quality indicator to assess daily work readiness, and in particular to assess sleep time sufficiency.

2. METHOD

2.1. Participants

Participants were recruited through social media advertisements, with the following inclusion criteria: 1) males aged 20–30 years to remove hormonal factor in sleep quality (Tworoger et al., 2005); 2) normal sleep condition as measured by the Pittsburgh Sleep Quality Index (PSQI) ≤ 7 (Werner et al., 2015); 3) no serious health problems (e.g., diabetes, heart disease, insomnia, sleep apnea); and 4) no mental health disorder as measured using the SF-36 questionnaire. Initially, 78 individuals completed questionnaires; of these, only 21 participants who fulfilled the inclusion criteria, ranging in age from 20 to 26 years (mean = 22.3 ± 1.6) and with a normal Body Mass Index (mean = 20.8 ± 2.3), were willing to participate. Two participated in a pilot study, and 19 others were involved in the main study; of these, 18 completed all of the procedures.

2.2. Experimental Design and Procedure

Work and sleep conditions were designed to simulate a 12-hour night shift, requiring workers to sleep for six hours before commencing work. Sleep quality was manipulated by controlling and combining noise, temperature, and lighting in a laboratory setting under three different conditions (good, moderate, and bad), determined by reference to the relevant literature. Several studies have reported that noise can adversely affect sleep quality (Di Nisi et al., 1990; Dumont & Beaulieu, 2007). Temperature and lighting have also been reported to affect comfort during sleep (Cheung, 2015; Pan et al., 2012). These three factors were controlled within each condition (Table 1).

Each sleep condition was measured over a consecutive period of one day and two nights (Night A-Day-Night B), with a rest period of at least five days between conditions, as shown in Figure 2. The rest period was intended to eliminate the effects of sleep debt due to change in sleep duration. Participants were required to sleep for at least 7 hours one day prior to the experiment. In every case, participants were obliged to be present in the lab at 19:00; for their first session, they had to be present at 17:00 to learn the instrument and to complete the informed consent form. Before experiments began, participants were shown how to use the Basis Peak smartwatch, the Karolinska Sleep Diary (KSD), the Karolinska Sleepiness Scale (KSS), the Performance Vigilance Test (PVT), and the simulator game *Dig It Digger*.

Table 1 The three sleep conditions

	Good Condition	Moderate Condition	Bad Condition
Temperature	26°C	26–28°C	30–32°C
Noise	30 dB	30 dB	40–60 dB
Lighting	0–5 lux	0–10 lux	1500–2500 lux

The purpose of Night A was to ensure that all participants were aligned in terms of sleep deprivation prior to sleep on the following day. On Night A, participants were required to play the simulator game from 19:00 to 21:00. At 21:00, they were allowed to sleep until 01:00. Participants slept in an insulated room at the lab (Figure 1). Between 01:00 and 06:00, participants again had to play the simulator game. From 06:00 to 08:00, participants were allowed to pursue their own activities, including breakfast from 06:30 to 07:00.

(a) (b) (c)

Figure 1 (a) Good; (b) moderate; and (c) bad sleep conditions (daytime)

During the Day (from 08:00 to14:00), participants had to sleep wearing a smartwatch, with the Polar H7 attached to their body. Based on circadian conditions at 14:00, we assumed that people would find it easy to wake up and would have difficulty going back to sleep (Gander et al., 1998). Between 14:00 and 17:00, participants were again free to pursue their own recreational activities, such as watching TV or video or listening to music. On Night B, participants had to stay awake for 12 hours to play the simulator. Measures of fitness to work

(work readiness) prior to playing the simulator included KSD, KSS, and PVT. A rest period of one hour was allowed at 24:00. Participants were financially compensated after each experimental session.

2.3. Measures

The dependent variable (work readiness or fitness to work) was measured in terms of vigilance and drowsiness levels. Vigilance level was indicated by mean reaction time on a five-minute PVT tapping task. Drowsiness level was measured subjectively, using the nine-point KSS scale (Akerstedt & Gillberg, 1990).

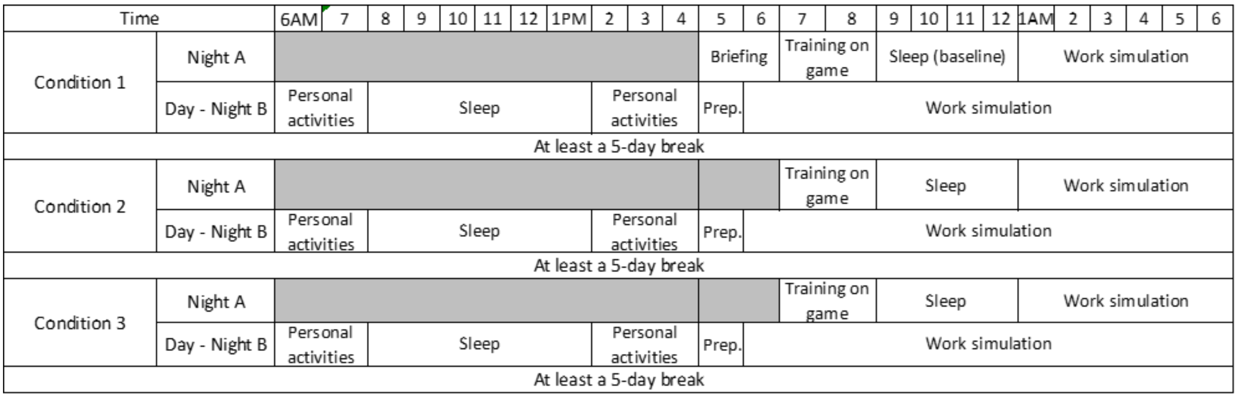

Figure 2 Timeline of the experiment

Using the KSD questionnaire, a subjective scale was obtained to measure sleep quality; an objective measure was obtained from the Basis Peak data provided by the smartwatch. KSD assessed sleep quality index (SQI) and fitness index. SQI was based on the mean of four point questions: 1) sleep quality phrases, such as "How well did you sleep?"; 2) calmness of asleep; 3) ease of falling asleep; and 4) sleep continuity. Fitness index was based on the mean of three point questions: 1) ease of waking up; 2) sufficiency of rest time; and 3) sufficiency of sleep to achieve fitness. All questions were rated using a Likert scale (Akerstedt et al., 1994; Westerlund et al., 2014). The Basis Peak smartwatch provided an objective measure that has been reported to achieve 83% accuracy in measuring sleep quality (Jovanov, 2015). The Basis Peak smartwatch indices include total sleep time (TST), light sleep quantity (LSQ), deep sleep quantity (DSQ), and REM sleep quantity (REMSQ).

2.4. Data Analysis

A repeated measures ANOVA was used to determine the effects of sleep quality condition on each measure. Where relevant, post-hoc analysis was applied using Tukey's HSD test. Correlation coefficients were computed for sleep quality measures and work readiness measures. If the data were normally distributed, Pearson's correlation coefficient was computed; for non-normally distributed data, Spearman's correlation was applied. For all statistical tests, the significance level was set at $p < 0.05$.

3. RESULTS

Table 2 presents averages and standard deviations for each indicator value under the three sleep conditions. Indicators of SQI-KSD and KSS were sensitive to sleep condition, in which values of SQI-KSD increased significantly if sleep condition was improved; in contrast, KSS values were significantly higher under worse sleep condition. It follows that higher SQI-KSD and lower KSS were associated with better sleep condition. For both indicators, post hoc analysis indicated significant differences among the three sleep conditions (bad-moderate, moderate-good, and bad-good) for p < 0.05 (Figures 2 and 3).

A trend was identified indicating increased LSQ with enhanced sleep condition (a consistent change of 5% across participants from bad-moderate and moderate-good), but the effect was not statistically significant. Similarly, TST showed a trend indicating increased TST for better sleep condition, with no significant effect, although there was a change of 2–8% across participants for bad-moderate and moderate-good. Other indicators such as DSQ, REMSQ, and PVT were not sensitive to sleep condition.

Table 2 Indicator values for the three sleep conditions (mean ± standard deviation)

Variable	Bad	Moderate	Good	*p*-value
TST[a)]	252.6 ± 65.5	257.0 ± 64.3	278.5 ± 63.6	0.45
LSQ[a)]	148.6 ± 51.1	156.1 ± 43.0	166.1 ± 43.5	0.46
DSQ[a)]	46.1 ± 17.5	41.0 ± 27.7	48.8 ± 29.6	0.37
REMSQ[a)]	64.9 ± 20.4	59.9 ± 19.7	67.3 ± 16.4	0.3
SQI-KSD[b)]	2.8 ± 0.8	3.4 ± 0.7	3.8 ± 0.5	< 0.001*
KSS[c)]	3.2 ± 0.7	2.8 ± 0.8	2.4 ± 0.9	0.01*
PVT[d)]	474 ± 53	460 ± 55	470 ± 37	0.26

Note:
a) smartwatch subjective indicator
b) sleepiness indicator
c) vigilance indicator
* indicates significant at $p < 0.05$

Strong correlations ($p < 0.05$) were found among objective measures of smartwatch indicators, including between DSQ and REMSQ ($r = 0.41$), TST and REMSQ ($r = 0.60$), LSQ and TST ($r = 0.77$), and TST and DSQ ($r = 0.51$). However, correlations between LSQ and REMSQ, as well as between DSQ and LSQ, were weak, with correlation values of 0.12 ($p = 0.43$) and 0.10 ($p = 0.56$), respectively. Correlation coefficients among sleep quality measures and work readiness measures are shown in Table 3. There were strong correlations between two of the objective sleep quality indicators (TST and LSQ) and the SQI-KSD subjective sleep quality measure. Interestingly, there was also a strong correlation between TST (objective sleep quality indicator) and PVT (vigilance measure of fitness to work). Unfortunately, all sleep quality indicators showed weak correlations with the fitness to work indicators.

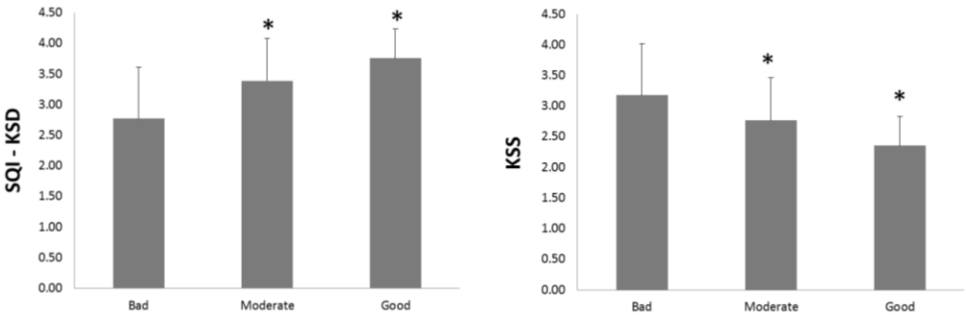

Figure 2 Significant effects of SQI-KSD and KSS on sleep condition
(Error bars represent standard deviations and * indicates significant differences)

Table 3 Correlation coefficients: sleep quality measures and work readiness

Sleep Quality Indicator		Fitness to Work Indicator	R	*p*	CI
Objective Measure	Subjective Measure				
TST	SQI-KSD		**0.38***	0.01	0.09 to 0.61
LSQ			**0.46***	0.002	0.19 to 0.67
DSQ			0.11	0.48	-0.19 to 0.40
REMSQ			0.01	0.95	-0.29 to 0.31
TST		PVT	**-0.32***	0.04	-0.57 to 0.02
LSQ			-0.25	0.11	-0.52 to 0.06
DSQ			-0.17	0.29	-0.46 to 0.15
REMSQ			-0.13	0.40	-0.43 to 0.18
SQI-KSD			-0.16	0.28	-0.43 to 0.13
TST		KSS	0.01	0.97	-0.29 to 0.30
LSQ			0.02	0.89	-0.32 to 0.28
DSQ			0.09	0.56	-0.21 to 0.30
REMSQ			-0.04	0.81	-0.33 to 0.26
SQI-KSD			-0.19	0.17	-0.45 to 0.09

Note: * indicates significant at $p < 0.05$

4. DISCUSSION

The purpose of this study was to investigate smartwatch-based sleep quality indicators that can be used as a measure of fitness to work. In industry, there is a pressing need to find a good predictor of readiness to work, especially for night shift workers. Overall, the present results identified some promising smartwatch-based indicators for predicting sleep quality and fitness to work, including TST and LSQ. As obtained from the smartwatch, TST was found to be significantly correlated with an objective measure of sleep quality index based on the Karolinska Sleepiness Diary (SQI-KSD) and a vigilance measure (PVT). Additionally, LSQ exhibited a significant correlation with SQI-KSD, although there was no correlation with PVT.

These findings suggest that SQI-KSD can readily be used as a subjective measure to predict sleep quality. Until now, there has been no report of a conclusive predictor measuring qualitative sleep quality (Krystal & Edinger, 2008). In this study, three daytime sleeping conditions manipulated temperature, lighting, and noise, and it was assumed that this would result in considerable variations in sleep quality. The results indicate that SQI-KSD and KSS are sensitive to changes in environmental sleep conditions, but none of the smartwatch indicators was responsive. There are two possible explanations for this. First, assuming the smartwatch indicators are valid, the manipulation of environmental conditions failed to ensure good sleep quality. Although a number of studies have claimed that noise and light affect sleep quality, Griefahn et al. (2006) found that sleep quality (based on PSG indicators) was affected only by noise; similarly, Horowitz et al. (2001) reported that lighting had no effect. Second, there is a doubt about the validity of the smartwatch indicators. Further study is needed to investigate both explanations. While none of the smartwatch indicators was sensitive to environmental sleep conditions, TST and LSQ showed strong correlations with SQI-KSD. An association between SQI-KSD and TST was previously reported by Akerstedt and Simon (1997), and O'Donnell et al. (2009) confirmed a positive correlation between LSQ and NREM-2 sleep phase. However, Westerlund et al. (2014) reported a contradictory result, in which

NREM-2 (Light Sleep) was found to be negatively correlated with sleep quality. Additionally, they argued that DSQ should represent good sleep quality (Westerlund et al., 2014).

It is interesting to reflect on the remaining two smartwatch indicators (DSQ and REMSQ), which were not sensitive to sleep quality. We argue that this (and some results contradicting previous studies) may be due to the differing apparatus utilized here. In this study, we utilized a smartwatch that is considered practical, mobile, elegant, and financially affordable. Previous studies have used more sophisticated apparatus of a kind commonly used in clinical settings (PSG). It should be noted that the smartwatch detects DSQ and REMSQ on the basis of respiration rate, heartbeat, and body movement; better results might be obtained using EEG.

The present findings suggest that TST and LSQ can also be used to predict fitness to work. Two indicators were found to be strongly associated with the vigilance indicator PVT. Using similar smartwatch equipment (Basis Band), a previous study by Seitz (2014) found no association between sleep quality indicators and PVT-based fitness to work. Here, we would argue that sample size may be the issue. In fact, our sample of 18 participants can be considered large. We realized that PVT may not be an ideal indicator of fitness to work because of its inconclusive validity and sensitivity. We chose this indicator for its simplicity, but further study will be required, utilizing varying fitness to work indicators. PVT was reported to be sensitive to sleep loss (caused by sleep deprivation) but not to sleep quality, and a fitness to work indicator is needed that is sensitive enough to detect small differences in sleep (Seitz, 2014).

This study has several limitations that are worth noting. First, we assumed that sleep quality could be manipulated by changing environmental conditions, which we hoped would yield significant differences in sleep quality. To that end, we implemented three extreme conditions in terms of lighting, temperature, and noise level. Second, we assumed that the indicators obtained from the smartwatch (TST, LSQ, DSQ, and REMSQ) were reliable, and we believe that the technology is evolving rapidly.

5. CONCLUSION

Two smartwatch-based indicators (TST and LSQ) were found to be highly correlated with the subjective sleep indicator (SQI-KSD), which was sensitive to sleep conditions. TST also exhibited a high correlation with PVT, used here as a measure of fitness to work.

6. ACKNOWLEDGEMENT

This research was funded by ITB Grant. We thank all those who participated in this study.

7. REFERENCES

Aeschbach, D., Cajochen, C., Landolt, H., Borbély, A.A., 1996. Homeostatic Sleep Regulation in Habitual Short Sleepers and Long Sleepers. *American Journal of Psychology*, Volume 270(1) pp. 41–53

Akerstedt, T., Gillberg, M., 1990. Subjective and Objective Sleepiness in the Active Individual. *Neuroscience*, Volume 52(1-2), pp. 29–37

Akerstedt, T., Hume, K., Minors, D., Waterhouse, J., 1994. The Meaning of Good Sleep: A Longitudinal Study of Polysomnography and Subjective Sleep Quality. *Journal of Sleep Research*, Volume 3(3), pp. 152–158

Akerstedt, T., Simon, F., 1997. The Three-Process Model of Alertness, and Its Extension to Performance, Sleep Latency and Sleep Length. *Chronobiology International*, Volume 14(2), pp. 115–123

Ancoli-Israel, S., Cole, R., Alessi, C., Chambers, M., Moorcroft, W., 2003. The Role of Actigraphy in the Study of Sleep and Circadian Rhythms. *Sleep*, Volume 26(3), pp. 342–392

Carter, N., Henderson R., Lal, S., Booth, S., Hunyor, S., 2002. Cardiovascular and Autonomic Responses to Environmental Noise during Sleep in Night Shift Workers. *Sleep*, Volume 25(4), pp. 457–464

Cheung, I.N.S., 2015. Impact of Light Exposure on Sleep and Cardiometabolic Function. *Doctoral Dissertation*. Northwestern University

Di Nisi, J., Muzet, A., Ehrhart, J., Libert, J.P., 1990. Comparison of Cardiovascular Responses to Noise during Waking and Sleeping in Humans. *Sleep*, Volume 13(2), pp. 108–120

Drummond, S.P.A, Brown, G.G., 2001. The Effects of Total Sleep Deprivation on Cerebral Responses to Cognitive Performance. *Neuropsychopharmacology*, Volume 25(5), pp. 68–73

Dumont, M., Beaulieu, C., 2007. Light Exposure in the Natural Environment: Relevance to Mood and Sleep Disorders. *Circadian Rhythms in Sleep Medicine*, Volume 8(6), pp. 557–565

Durmer, J.S., Dinges, D.F., 2005. Neurocognitive Consequences of Sleep Deprivation. *Seminars in Neurology*, Volume 25(1), pp. 117–129

Gander, P.H., Rosekind, M.R., Gregory, K.B., 1998. Flight Crew Fatigue VI: An Integrated Overview. *Aviation, Space, and Environmental Medicine*, Volume 69, pp. B49–B60

Griefahn, B., Marks, A., Robens, S., 2006. Noise Emitted from Road, Rail and Air Traffic and their Effects on Sleep. *Sound and Vibration*, Volume 295(1), pp. 129–140

Halvani, G.H., Zarei, M., Mirmohammadi, S.J., 2009. The Relation between Shift Work, Sleepiness, Fatigue and Accidents in Iranian Industrial Mining Group Workers. *Industrial Health*, Volume 47(2), pp. 134–138

Horne, J.A., 2000. REM Sleep—by Default? *Neuroscience and Behavioral Reviews*, Volume 24(8), pp. 777–797

Horowitz, T.S., Cade, B.E., Jeremy, M.W., Czeisler, C.A., 2001. Efficacy of Bright Light and Sleep/Darkness Scheduling in Alleviating Circadian Maladaptation to Night Work. *American Journal of Physiology—Endocrinology and Metabolism*, Volume 281(2), pp. 384–391

Jovanov, E., 2015. Preliminary Analysis of the Use of Smartwatches for Longitudinal Health Monitoring. *Conf Proc IEEE Eng Med Biol Soc*. *IEEE Xplore*, pp. 865–868

Krystal, A.D., Edinger, J.D., 2008. Measuring Sleep Quality. *Sleep Medicine*, Volume 9, pp. S10–S17

Mairesse, O., Neu, D., Migeotte, P.F., Pattyn, N., Hofmans, J., Theuns, P., Cluydts, R. De Valck, E., 2012. Judgment of Daytime Sleepiness in Self-Reported Short, Long and Midrange Sleepers. *Psicologica: International Journal of Methodology and Experimental Psychology*, Volume 33(3), pp. 609–629

Natale, V., Drejak, M., Erbacci, A., Tonetti, L., Fabbri, M., Martoni, M., 2012. Monitoring Sleep with a Smartphone Accelerometer. *Sleep and Biological Rhythms*, Volume 10(4), pp. 287–292

National Institute of Health, 1997. *Facts about Problem Sleepiness*. NIH Publications, US

Noor, Z.M., Z.N., Smith, A.J., Smith, S.S., Nissen, L.M., 2013. Feasibility and Acceptability of Wrist Actigraph in Assessing Sleep Quality and Sleep Quantity: A Home-based Pilot Study in Healthy Volunteers. *Health*. Volume 5(8A2), pp. 63–72

O'Donnell, D., Silva, E.J., Munch, M., Ronda, J.M., Wang, W., Duffy, J.F., 2009. Comparison of Subjective and Objective Assessments of Sleep in Healthy Older Subjects without Sleep Complaints. *Journal of Sleep Research*, Volume 18, pp. 254–263

Pan, L., Lian, Z., Lan, L., 2012. Investigation of Sleep Quality under Different Temperatures Based on Subjective and Physiological Measurements. *HVAC&R Research*, Volume 18(5), pp. 1030–1043

Philibert, I., 2005. Sleep Loss and Performance in Resident and Non-Physicians: A Meta-Analytic Examination. *Sleep*, Volume 28(1), pp. 392–402

Scharf, M.T., Nirinjini, N., Zimmerman, J.E., Allan, I., 2008. The Energy Hypothesis of Sleep Revisited. *Progress in Neurobiology*, Volume 86(3), pp. 264–280

Schutte, P.C., Maldonado, C.C., 2003. *Factors Affecting Driver Alertness during the Operation of Haul Trucks in South Africa Mining Industry*. Safety in Mines Research Advisory Committee

Seitz, V.B., 2014. Using a Sleep and Activity Monitor to Operationalize Fatigue Risk Management. *Master Thesis*. Louisiana State University Department of Mechanical and Industrial Engineering

Tworoger, S.S., Davis, S., Vitiello, M.V., Lentz, M.J., McTiernan, A., 2005. Factors Associated with Objective (Actigraphic) and Subjective Sleep Quality in Young Adult Women. *Psychosomatic Research*, Volume 59(1), pp. 11–19

Watson, N.F., Badr, M.S., Belenky, G., Bliwise, D.L., Buxton, O.M., Buysse, D., Dinges, D.F., Gangwisch, J., Grandner, M.A. and Kushida, C., 2015. Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society on the Recommended Amount of Sleep for a Healthy Adult: Methodology and Discussion. *Sleep*, Volume 38(8), pp. 1161–1183

Werner, G.G., Ford, B.Q., Mauss, I.B., Schabus, M., 2015. High Cardiac Vagal Control is Related to Better Subjective and Objective Sleep Quality. *Biological Psychology*, Volume 106, pp. 79–85

Westerlund, A., Lagerros, Y.T., Kecklund, G., Axelsson, J., Åkerstedt, T., 2014. Relationships between Questionnaire Ratings of Sleep Quality and Polysomnography in Healthy Adults. *Behavioral Sleep Medicine*, Volume 14(2), pp. 1–15

Zambotti, M., Claudatos, S., Inkelis, S., Colrain, I.M., Baker, F.C., 2015. Evaluation of a Consumer Fitness-Tracking Device to Assess Sleep. *Chronobiology International*, Volume 32(7), pp. 1024–1028