Sleep Quality of Shift Workers Through Actigraphy Sleep Analysis from SOMNOwatch™

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Abstract — We explore shift worker sleep quality by using actigraphic data from SOMNOwatch and Pittsburgh Sleep Quality Index (PSQI). Shift workers engaged in the manufacturing industry are our study subjects, using actigraphy to obtain the sleep latency, sleep disturbance and sleep duration of shift worker, and carry out statistical analysis through ANOVA. The results show that sleep latency of day shift workers is relatively shorter than evening shift. The sleep duration in the day shift and evening shift is relatively longer than night shift. We deal with the analytical aspect of the three sleep quality indicators of actigraphy and PSQI. PSQI sleep latency and sleep duration of the day shift is relatively longer than Actigraphy. PSQI sleep disturbance of the evening shift is relatively fewer than Actigraphy. PSQI sleep duration of the night shift is relatively longer than Actigraphy. The results show differences exist between the subjective (PSQI) and Objective (Actigraphy) sleep quality.

Keywords - actigraphy; sleep quality; sleep latency; sleep disturbance; sleep duration

I. INTRODUCTION

In almost all sleep quality studies conducted in the past, the Pittsburgh Sleep Quality Index (PSQI) has been adopted [1] for those surveyed to assess from a subjective their sleep quality during a specific period of time. Acting according to subjective cognition, the subjects are able to complete the surveys within a short time. However, since the parameters in sleep quality studies are related to time, observation of changes has to continue for a certain period and objective data must be collected so that all information associated with sleep quality can be completely presented. For this reason, objective measurement using apparatuses is applied in this study. Each shift worker surveyed is requested to wear an actigraphy to establish data on their sleep latency, sleep disturbance and sleep duration for analysis.

Compared to subjective questionnaire surveys, objective measuring methods are principally used for clinical purposes to study the sleep quality of patients receiving medication [2] or to observe the impact of deprivation of sleep on the cognitive abilities of the subjects [3-5]. Although such method can obtain reliable data, they are rarely applied to measure sleep quality.

SOMNOwatch™ is worn on the non-dominant arm for recording and objective recognition of the Sleep/Wake Rhythm. The activity is measured in epochs of 1 to 120 seconds and plotted as an actigraphy profile. Through the integrated light Sensor the relevant measurement period (time in bed) is determined. As a result disorders of the circadian rhythm, e.g. for shift workers or pilots, can be documented. The SOMNOwatch™ is a powerful, miniaturized, multi channel recorder that is as comfortable and user-friendly. As a multi-channel system, the SOMNOwatch™ can replace several common devices while providing excellent signal quality. SOMNOwatch™ can be used for actigraphy in order to determine circadian rhythm, PLM detection, tremor analysis, single channel ECG and EEG recording, body temperature, respiratory screening with flow & snoring, body position, and Sleep/Wake analysis. For more complex studies several SOMNOwatch™ devices can be used simultaneously on one patient [6].

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Actigraphy are used in this study to measure and collect data on the sleep quality of shift workers. To understand whether the results of sleep quality measured with subjective and objective tools are consistent, the PSQI is also applied to gather the workers’ subjective sleep quality data. In the end, the data established through the two approaches are analyzed to check the differences. Therefore, the purposes of this study are (1) to use actigraphy measuring methods analysis from SOMNOwatch to analyze the sleep quality of workers doing different shifts and (2) to examine whether differences exist between the results obtained by using PSQI and actigraphy sleep quality measurement tools.

II. THE SLEEP QUALITY OF SHIFT WORKERS

Benjamin [7] defines shift work as several people working at different time slots to increase the rate of utilization of machine equipment and production. The National Institute of Occupational Safety and Health of the US defines people not working between 7:00 AM and 6:00 PM as shift workers [8].

Studies conducted in the past on the sleep of shift workers indicate that shift work can influence the physiology and psychology of employees, including family life disturbances, social life restrictions, reduction of leisure activities, mealtime disruptions, and negative effects on sleep quality and health [9]. On average, shift workers sleep 5.5 hours a day. As a consequence, 32% of shift workers suffer insomnia or hypersomnia while only 18% of daytime workers have similar problems [10]. Meanwhile, the total sleep duration, sleep cycle, REM and sleep latency of shift workers have similar problems [10]. Meanwhile, the total sleep duration, sleep cycle, REM and sleep latency of shift workers have similar problems [10].

III. MEASUREMENT OF SLEEP QUALITY INDICES

A. Sleep quality indices

Cohen et al. [13] propose three indices for poor sleep quality. They are sleep latency (the time it takes to fall asleep after getting in bed) being over 30 minutes, sleep disturbance (frequency of waking up from sleep) being more than three times, and sleep duration being less than 6 hours. When any of these three situations occur, the sleep quality is regarded poor. However, sleep duration is the most often applied index for evaluating whether sleep quality is decent. Although it has been suggested in many studies that 6 hours of sleep is minimum for people to get enough rest, there are also studies that conclude on 7 to 8 hours of sleep being the required amount of rest [14, 15]. Sleep duration has an effect on sleep quality but it is difficult to apply the same standard on every one because the duration of sleep each person needs is different [16]. For this reason, researchers believe individuals should determine their sleep quality by evaluating whether they get enough sleep [17]. When an individual feels well rested, it means the sleep quality is good; otherwise, the sleep quality is poor. In other words, whether the sleep quality of each person is good or not depends on his or her feeling of restfulness. It should not be determined according to the sleep duration.

The restoration theory and the conservation theory both indicate that getting enough sleep is necessary for humans. It is an objective fact except the amount of sleep needed varies with different people and it is to be assessed subjectively by each individual. However, in order to examine whether consistency exists between the data acquired through subjective cognitive self-evaluation and through measurement with objective tools, sleep latency, sleep disturbance and sleep duration are taken as the indices of analysis in this study.

B. Measurement of sleep quality

Sleep quality can be measured subjectively and objectively. Subjective measurement is conducted by using a subjective evaluation scale, a questionnaire, interviews and sleep diaries for the subjects to express subjective feelings about their sleep. Objective measurement is carried out by using apparatuses or observers to monitor the sleep quality of an individual [18].

In subjective sleep quality evaluation, the subjects use the PSQI to answer questions related to sleep quality. The PSQI is a sleep quality questionnaire established by Buysse and some other researchers at Pittsburgh University in 1988 [1]. The scores are rated according to 7 sleep-related aspects, sleep latency, sleep disturbances, sleep duration, habitual sleep, use of sleeping medication, daytime dysfunction and subjective sleep quality.

In objective sleep quality evaluation, polysomnography (PSG), actigraphy and sleep observation are adopted. PSG is the most detailed and accurate apparatus available today. It is clinically applied to monitor and record sleep; the results include the EEG of the parietal lobe and occipital lobe, EOG, chin EMG, etc. These items are used to establish sleep architecture and stages [18]. Shaped like a watch and worn around the wrist or ankle, an actigraphy can record the activity of the wrist at a set interval (2 to 60 seconds). Sleep observation requires a medical professional or lab worker to monitor the sleep condition of the subjects. The advantage is that no apparatuses are used and the sleep behavior will not be affected. However, manpower and time or video recording is needed.
It takes time to observe and conclude on sleep quality. In objective measurement, PSG and sleep observation can be applied only in specific conditions. The equipment and manpower needed can be costly while the results obtained can only be used as references to determine sleep duration, movements during sleep and certain particular sleep disorders. Actigraphy, on the other hand, can be used on shift workers with different schedules and in various situations to monitor their movements and gain more objective results. They can also be applied over long periods to record the activity of the subjects at work or at home. Hence, most researchers prefer to use them [19,20]. Additional, actigraphic sleep analysis from SOMNOwatch collect more accurate sleep quality data than the PSQI that researchers often adopted in the past. And recode differentiate the sleep stages, the EEG option can be added to Actigraphy of the SOMNOwatch. The additional data allows for the differentiation of not only the Sleep/Wake Profile but also Wake, REM, 1,2,4 and Stag4 [21].

IV. STUDY METHODS

A. Subjects

Many jobs in the manufacturing industry involve machine equipment operation. These workers often face heavier work pressure and are exposed to loud noise; therefore, their health risk is also higher. Yet, no comprehensive studies have ever been conducted on the sleep quality of such workers [22]. For this reason, shift workers operating machine equipment in the manufacturing industry are recruited to take the survey in this study. They are divided in accordance with the work shifts in the manufacturing industry, including day shift (08:00~16:00), evening shift (16:00~24:00) and night shift (00:00~08:00). 12 workers are accepted for each shift. The subjects constantly taking sleeping pills or sedatives, having chronic diseases or having a history of diseases likely to affect the result of sleep quality measurement are excluded.

B. Measurement tools

1. Actigraphs

The actigraphy adopted in this study is the SOMNOwatch produced by German company SOMNO Medics. SOMNOwatch™ is worn on the non-dominant arm for recording and objective recognition of the Sleep/Wake Rhythm. The activity is measured in epochs of 1 to 120 seconds and plotted as an Actigraphy Profile. Through the integrated light Sensor the relevant measurement period (time in bed) is determined. As a result disorders of the Circadian Rhythm, e.g. for shift workers or pilots, can be documented. The actigraph uses 3 activity sensors (X, Y and Z axes) to record activity and provide objective data. The recording speed of the SOMNOwatch is set at 1/30 seconds (recording an entry every 30 seconds and the device monitors the subjects around the clock. Its analytic software is able to show the sleep latency, sleep disturbance and sleep duration of the surveyed workers [6].

2. The PSQI

The PSQI is used in subjective sleep quality measurement to evaluate sleep quality. Developed by Buysse et al. [1], it includes sleep latency, sleep disturbances, sleep duration, habitual sleep, use of sleeping medication, daytime dysfunction and subjective sleep quality. Cohen et al. [13] figure out three indices for poor sleep quality. They are sleep latency, sleep disturbance, and sleep duration. In this study, PSQI are adopted in this study to investigate the sleep latency, sleep disturbance and sleep duration of the subjects and the results are compared with those from objective measurement.

3. Research Process

Each subject wears an actigraphy to record sleep quality for five consecutive days, Monday through Friday. The device is retrieved on the 6th day and the subject is requested to fill out the sleep quality scale form which includes items such as basic information, bedtime, rising time, and number of arousals.
After the objective (actigraphy) and subjective (PSQI) sleep indices are collected, they are calculated and analyzed with SPSS software. Initially, descriptive statistics is applied to analyze the characteristics of the subjects and the average value of each index and the standard deviation related to sleep quality. Then, ANOVA is performed to examine whether differences exist in the sleep latency, sleep disturbance and sleep duration of the three shifts. If any difference is significant, the Tukey method is employed to conduct Post Hoc tests to analyze the shifts with differences. In the end, the paired t test is run to find out whether significant differences exist between subjective and objective measurement in sleep latency, sleep disturbance and sleep duration.

V. RESULT

A. Sample characteristics

The samples include 34 males and 2 females, indicating that shift workers are mostly male, making up 94.4%. Education-wise, those with a senior or vocational high school degree account for 36.1%, forming the largest group. In years of service, the ones having worked for 1 to 5 years take up 75%. Those ranging between 20 and 30 years of age constitute 66.7%, indicating that most shift workers in the manufacturing industry are young adults. Meanwhile, unmarried people account for 69.4%.

B. Analysis of sleep quality of shift workers from actigraphy

ANOVA is conducted to find out whether there were significant differences in the sleep latency, sleep disturbance and sleep duration of the surveyed workers of the three shifts and the results are shown in Table 1.

<table>
<thead>
<tr>
<th>TABLE I SLEEP QUALITY OF SHIFT WORKERS FROM ACTIGRAPHY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift</td>
</tr>
<tr>
<td>Sleep Latency (minutes)</td>
</tr>
<tr>
<td>Day</td>
</tr>
<tr>
<td>Evening</td>
</tr>
<tr>
<td>Night</td>
</tr>
<tr>
<td>Sleep Disturbance</td>
</tr>
<tr>
<td>Day</td>
</tr>
<tr>
<td>Evening</td>
</tr>
<tr>
<td>Night</td>
</tr>
<tr>
<td>Sleep Duration (Minutes)</td>
</tr>
<tr>
<td>Day</td>
</tr>
<tr>
<td>Evening</td>
</tr>
<tr>
<td>Night</td>
</tr>
</tbody>
</table>

Note: * p < .05, ** p < .01.

1. Sleep Latency

The sleep latency averages of the workers surveyed show that day shift workers fall asleep the fastest, followed by night and evening shift workers. ANOVA is performed to find out whether the differences between the workers of different shifts achieve significant and the results reveal that the p value between different shifts is .013, achieving significant (p<.05). Next, the Tukey method is conducted for Post Hoc tests and it shows that the p value between the day shift and the evening shift is .009, also achieving significant (p<.05). The p value between the other shifts, however, does not achieve significant. This means that the latency difference between day shift and evening shift workers achieve statistic significant and the sleep latency of evening shift workers is longer than that of day shift workers.

2. Sleep disturbance

The sleep disturbance averages of the workers surveyed show that day shift workers have the least disturbance, followed by evening and night shift workers. The ANOVA performed reveals that the sleep disturbance differences between various shifts do not achieve significant (p>.05), the result of sleep disturbance differences between different shifts is insignificant.

3. Sleep duration

The subjects, those doing the evening shift have the longest sleep duration, followed by the ones working the day shift and night shift. The ANOVA conducted indicates that the p value between different shifts is .000, achieving significant (p<.05). The Tukey method subsequently performed for Post Hoc tests shows the sleep duration difference between the day and evening shifts does not achieve significant while the p value between the day shift and the night shift is .003, achieving significant (p<.05) and the p value between the evening shift and the night shift is .000, also achieving significant (p<.05). This means the sleep duration differences between the three shifts all achieve significant (p<.05) and the sleep duration of day and evening shift workers is longer than that of day and night shift workers.

According to the sleep quality analysis results show that the sleep latency of day shift workers is shorter than that of evening shift workers while the sleep duration of day and evening shift workers is longer than that of night shift workers. Despite that the other indices do not achieve significant, it is still obvious that the sleep quality of day shift workers is better. The outcome is consistent with the sleep theories and the results of past studies. The sleep quality of night shift workers is not as good as that of day shift workers because their biological clock and circadian rhythms are disrupted [11,20,23,24] and the sleep latency of night shift workers is longer than that of day shift workers [12].

C. Analysis of actigraphy and PSQI sleep quality differences

1. Overall actigraphy and PSQI sleep quality analysis

The data obtained from the 36 surveyed workers of three different work shifts are analyzed to determine sleep quality. The data obtained with actigraphies indicate that the average sleep latency is 17.1 minutes, average sleep disturbance 1.3 times and average sleep duration 377.4 minutes. In the meantime, the averages obtained from the PSQI questionnaire are respectively sleep latency 22.2 minutes, sleep disturbance 1.0 time and sleep duration 419.6 minutes. The paired t test run on the differences in the three indices reveal that the t values of sleep latency and sleep disturbance are 1.44 and 1.06, failing to achieve significant. The t value of sleep duration is 3.21, achieving significant (p<.05). The results show that shift difference of the workers surveyed is not considered, subjective sleep duration and objective sleep duration do differ.
The average sleep latency is 13.8 minutes, average sleep duration 407.1 minutes. The PSQI results show that the average sleep latency of evening shift workers is 24.8 minutes, average sleep disturbance 1.4 times and average sleep duration 405.0 minutes. The paired t-test is conducted to analyze the differences in the three indices and the results show that the t values of sleep latency and sleep duration are 2.98 and 3.89, achieving significant (p<.05), whereas the t value of sleep disturbance is 1.0, there were no significant. Obviously, differences exist between the subjective and objective sleep latency and duration of day shift workers.

3. Evening shift actigraphy and PSQI sleep quality differences

The data recorded with the actigraphy units indicate that the average sleep latency of evening shift workers is 24.8 minutes, average sleep disturbance 1.4 times and average sleep duration 407.1 minutes. The PSQI results show that the average sleep latency is 13.8 minutes, average sleep disturbance 1.34 times and average sleep duration 373.8 minutes. In the meantime, the PSQI results reveal that the average sleep latency is 24.6 minutes, average sleep disturbance 1.63 times and sleep duration 373.8 minutes. The paired t test conducted to analyze the differences in the three indices unfolds that the t values of sleep latency and sleep duration are 1.79 and 1.90, both no significant difference. The t value of sleep disturbance, however, is 5.97 and achieves significant (p<.05). This means that differences exist between the subjective and objective sleep disturbance of evening shift workers.

4. Night shift actigraphy and PSQI sleep quality differences

The data recorded with the actigraphy indicate that the average sleep latency of night shift workers is 16.9 minutes, average sleep disturbance 1.34 times and average sleep duration 339.4 minutes. In the meantime, the PSQI results reveal that the average sleep latency is 24.6 minutes, average sleep disturbance 1.63 times and sleep duration 373.8 minutes. The paired t test conducted to analyze the differences in the three indices shows that the t values of sleep latency and sleep disturbance are 2.06 and 0.65, both no significant difference. The t value of sleep duration, however, is 3.0 and achieves significant (p<.05).

### Table II  Overall Actigraphy and PSQI Sleep Quality Difference Analysis

<table>
<thead>
<tr>
<th>Shift</th>
<th>N</th>
<th>Actigraphy</th>
<th></th>
<th></th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Latency</td>
<td>36</td>
<td>17.1</td>
<td>11.9</td>
<td>22.2</td>
<td>1.44</td>
<td>.160</td>
</tr>
<tr>
<td>Sleep Disturbance</td>
<td>36</td>
<td>1.3</td>
<td>0.6</td>
<td>1.0</td>
<td>1.1</td>
<td>1.06</td>
</tr>
<tr>
<td>Sleep Duration</td>
<td>36</td>
<td>377.4</td>
<td>42.0</td>
<td>419.6</td>
<td>3.21</td>
<td>.003**</td>
</tr>
</tbody>
</table>

Note. * p < .05, ** p < .01.

### Table III  Analysis of Different Shift Workers’ Sleep Latency, Disturbance and Duration Differences Indicated in the Actigraphy and PSQI Records

<table>
<thead>
<tr>
<th>Shift</th>
<th>N</th>
<th>Actigraphy</th>
<th></th>
<th></th>
<th>PSQI</th>
<th></th>
<th></th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Latency</td>
<td>12</td>
<td>10.2</td>
<td>3.3</td>
<td>28.30</td>
<td>2.98</td>
<td>.012*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day</td>
<td></td>
<td>12</td>
<td>16.90</td>
<td>18.50</td>
<td>1.29</td>
<td>.101</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evening</td>
<td></td>
<td>12</td>
<td>24.80</td>
<td>15.80</td>
<td>1.79</td>
<td>.000**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Night</td>
<td></td>
<td>12</td>
<td>1.05</td>
<td>9.30</td>
<td>1.00</td>
<td>.338</td>
<td></td>
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<tr>
<td>Sleep Disturbance</td>
<td>12</td>
<td>28.30</td>
<td>1.33</td>
<td>1.13</td>
<td>1.79</td>
<td>.000**</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Day</td>
<td></td>
<td>12</td>
<td>1.44</td>
<td>0.43</td>
<td>1.33</td>
<td>.338</td>
<td></td>
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<tr>
<td>Evening</td>
<td></td>
<td>12</td>
<td>1.63</td>
<td>0.81</td>
<td>1.07</td>
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<tr>
<td>Night</td>
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<td>12</td>
<td>385.80</td>
<td>23.60</td>
<td>1.63</td>
<td>.065</td>
<td></td>
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<tr>
<td>Sleep Duration</td>
<td>12</td>
<td>373.8</td>
<td>405.00</td>
<td>32.60</td>
<td>1.07</td>
<td>.531</td>
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<tr>
<td>Day</td>
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<td>407.10</td>
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<td>1.99</td>
<td>.072</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evening</td>
<td></td>
<td>12</td>
<td>339.40</td>
<td>30.60</td>
<td>3.00</td>
<td>.012*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. * p < .05, ** p < .01.

The results show the subjective (PSQI) sleep latency and duration of day shift workers are longer than the objective (actigraphy) sleep latency and duration. The subjective sleep disturbance of evening shift workers is less frequently than the objective sleep disturbance. The subjective sleep duration of night shift workers is longer than the objective sleep duration. Obviously, certain differences exist between the subjective and objective sleep quality indices of workers of various work shifts.

### VI. Discussion

#### A. The sleep quality of shift workers

Related studies indicate that the biological clock can have effects on sleep quality and job performance [25] yet shift work is inconsistent with the circadian rhythm of humans and leads to desynchronization. In this study, ANOVA is adopted to test the differences in sleep latency, disturbance and duration between day, evening and night shift workers. The results show that the sleep latency of day shift workers is shorter than that of evening shift workers while the sleep duration of day shift workers is longer than that of night shift workers. The outcome complies with the

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results of past studies that the sleep duration of night shift workers is shorter because they sleep in the daytime and their circadian rhythms are disrupted [26].

Studies conducted in the past indicate that when sleeping during the day, night shift workers are often affected by light, noise and other environmental factors. They do not get enough sleep and the quality of their sleep is poor. If they take night shift continuously, the condition worsens and sleep deprivation and sleep disturbance occurs [27]. However, the sleep disturbance difference between night and day shift workers does not achieve significant. To study the reason that it is because most of the surveyed workers are single, meaning that such workers would consider their own family situations before accepting shift work. Since there is less interference from family, they are able to get enough sleep and continue to do shift work.

B. Subjective and objective sleep quality differences

Use of questionnaires in subjective sleep quality measurement has the advantages of low cost, prompt results and obtaining of large quantities of samples. It is therefore preferred by researchers [23]. In comparison, objective measurement of sleep quality requires use of apparatuses that the subjects have to wear for a long period of time. It can acquire data accurately but it is time-consuming and therefore suitable only when the number of samples is small [4,19].

In this study, three sleep quality indices obtained with actigraphy and the PSQI are compared. Without taking shift difference into account, the sleep latency, sleep disturbance and sleep duration of the 36 surveyed workers doing three different shifts are analyzed and compared. The average sleep duration of subjective measurement is 419.6 minutes, longer than the 377.4 minutes from the objective measurement. Further analysis conducted on the 12 workers of each shift indicates that differences exist between the subjective and objective sleep latency and sleep duration of day shift workers. Differences also exist between the subjective and objective sleep disturbance of evening shift workers and between the subjective and objective sleep duration of night shift workers.

There are two reasons why this study is focused on the differences between subjective and objective sleep quality. First, the results of the PSQI are subjective cognition toward sleep duration over a period of time and the subjects answer sleep quality-related questions by recalling the total sleep duration they had sometime in the past. Such an approach could easily lead to misjudgment because of time. By contrast, actigraphy record the sleep duration of each day and personal misjudgment because of time is ruled out. Second, since night shift work disrupts the biological clock of workers, it also has an impact on the perception of shift workers about sleep [9,28,29]. These are factors that can create differences between subjective cognition about sleep duration and objective facts.

VII. Conclusions and implications of the study

To boost equipment utilization rates, enterprises divide their employees into two or three shifts to work around the clock. Extra allowances are offered to increase employees’ willingness to work the night shift and compensate for their circadian desynchronization problems. However, as extended night shift work is inconsistency with the human rhythm of working in the daytime and sleeping in the nighttime, it can lead to deterioration of the immune system and jeopardize health [2]. Therefore, besides giving monetary compensation, enterprises should also take into consideration the health of their employees. Based on the biological clock of humans, psychologists have suggested the system of latershift of work to solve the physical adjustment problems of shift workers. The design is to allow shift workers to change shifts each week, i.e., day shift for one week, evening shift for one week and night shift in the third week [30]. Therefore, this study also recommends enterprises to make shift changes on a regular basis, each week, month or season, when making shift arrangements so that extended circadian desynchronization of night shift workers can be prevented. In addition, when recruiting shift workers, enterprises must point out to them the impact of doing night shift work on their sleep and also assess their health and family conditions before deciding whether they are suitable for night shift work. At the same time, enterprises can conduct sleep hygiene education programs [22,31] to teach shift workers to avoid drinking beverages containing alcohol or caffeine to maintain decent sleep quality.

The PSQI is commonly applied in sleep quality studies for individuals to evaluate whether they get enough sleep. In this study, however, objective approaches are adopted to measure sleep quality. Certain differences exist between the results and data established with subjective measurement. Besides the differences occur due to the methods employed in this study, how the perception of shift workers may affect subjective sleep quality is worthy of further exploration.

VIII. Research limitations and suggestions for future research

This study proves that differences exist between subjective and objective sleep quality measurement results. The outcome also indicates that sleep duration measured with subjective tools is longer than that measured with objective ones. Further exploration is required to determine the causes of this phenomenon. Hence, the author of this paper suggests that related psychological variables may be applied in further studies to discuss the influence of subjective factors on sleep quality, such as use of the stress theory to examine the impact of work pressure or workload [32] on subjective feelings about sleep quality or application of the motivation theory to discuss the effect of internal motivation or external motivation [33] on subjective sleep quality to make inferences on the causes behind the subjective sleep duration being longer or shorter than the objective one. In the future, the more important issues will be how to integrate the cloud intelligence processing technology and use wearable sensors for individuals like actigraphy in

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combination with detectors to measure individual physical activity (heart beat rate, pulse and blood pressure) and sleep environment parameters (temperature, humidity, luminosity and sleep music), and transmit such data with smartphones and apps to allow users, their families or medical personnel to understand the daily rhythms and movement patterns of users or shift workers or the influence of the environmental parameters on their sleep quality. At the same time, the data collected can also be analyzed to sort out the important factors that affect sleep quality and provide them to users so they can help improve their sleep quality so that their job performance or living quality can be better.

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