# DISCREPANCY AND ASSOCIATION BETWEEN PERCEIVED SLEEP STATE AND OBJECTIVE SLEEP MEASURES IN OLDER ADULTS WITH SLEEP COMPLAINTS 

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#### Abstract

Objective: We investigated sleep state and the perception of sleep state in a group of community dwelling elders with sleep disturbance. Discrepancy between perceived and measured sleep and its relation to sleep quality and sleep structure were examined. Design: A cross-section correlation study. Setting: Sleep laboratory in a medical center. Participants: Thirty-two healthy older adults (mean age 63.0 years, 19 women and 13 men) with sleep disturbance (Pittsburgh Sleep Quality Index score $\geq 5$ ). Measurements: Participants were scheduled to sleep three consecutive nights to receive overnight polysomnography (PSG) and completed the Morning Questionnaire the next morning. Results: PSG showed 379.5 minutes of total sleep time (TST) with nocturnal awakenings of 48 minutes, and a sleep efficiency of $85.7 \%$. Participants perceived 344.4 minutes of TST with awakenings of 29.6 minutes and a sleep efficiency of $80.4 \%$. Significant differences ( $\mathrm{t}=2.07-2.85, \mathrm{p}<.05$ ) existed between perceived and measured sleep. About one-third $(31.3 \%$ ) markedly underestimated ( $>60 \mathrm{~min}$ ) their TST. Discrepancy between the perceived and measured TST was negatively correlated with the duration of stage 1 sleep and sleep quality, which indicated that participants with poor sleep quality and longer stage 1 sleep perceived a shorter than actual TST. Conclusions: Older adults with sleep complaints have poor objective sleep. Both sleep structure and cognitive components affect the perception of sleep state.


Key words: Older adult, polysomnography, sleep quality, sleep state perception.

## Introduction

Sleep disturbance is prevalent in older adults who often complain about having trouble falling asleep, frequent and often prolonged nocturnal awakenings, and early morning awakening with an inability to return to sleep (1, 2). The most common method to assess sleep is the self-reporting of sleep state and sleep quality using sleep logs or questionnaires. However, self-reported measures tend to overestimate sleep latency and underestimate awakening and total sleep time when compared to the "gold standard" of sleep measure,

[^0]polysomnography (PSG) (3). Previous studies failed to find a significant correlation between perceived and PSGderived sleep latency, awakening, and total sleep time in healthy older adults (3, 4), and insomniacs (5). Greater discrepancies between perceived and PSG sleep parameters were reported between subjects than within subjects (3). Sleep structures and brain functions are also probably involved in the process of sleep state perception (6-8).

Compared to young adults, older adults have an increased amount of nocturnal wakefulness (2) and NREM stage 1 sleep with a reduced amount or complete absence of NREM stages 3 and 4 sleep $(1,9)$ and a small decrease or no change in REM sleep (10). Increased sleep latency (i.e., the time needed to fall asleep $>30$ minutes), reduced sleep efficiency (i.e., ratio of time spent asleep / time in bed $<85 \%$ ), and a sleep duration of $<6$ hours are common in older adults. These characteristics are consistent with the criteria of insomnia, although not all older adults complain of poor sleep (11), suggesting individual variation of sleep state appraisal.

Perceived sleep state is an important component of sleep quality. Given several age-related changes in older adults' sleep and a high likelihood of misperceptions of
sleep state in insomnia complainers, we investigated sleep state and the perception of sleep state in a group of community dwelling elders with sleep disturbance in Taiwan. We further examined the discrepancy between perceived and measured sleep and explored its relation to sleep quality and sleep structure.

## Methods

## Participants

Adults aged 55-80 years complaining of sleep disturbance were recruited from the community (12). Subjects with acute illness, renal failure, diabetes mellitus, peripheral vascular diseases, neurological diseases, or psychiatric disorders were excluded. After the initial assessment, 43 subjects were enrolled and screened for anxiety and depression, sleep disturbance, and sleep apnea on the first adaptation night in the laboratory. Subjects who had high anxiety ( $\mathrm{n}=1$ ) or sleep apnea $(\mathrm{n}=2)$, had no sleep disturbance $(\mathrm{n}=5)$, or withdrew themselves from the study ( $\mathrm{n}=3$ ) were excluded from further analysis.

Institution Review Board approvals were obtained from the University of Washington, National Taiwan University Hospital, and Chun Shan Medical University Hospital. Written informed consent was obtained from all participants.

## Procedures

Participants were scheduled to sleep three consecutive nights to receive overnight PSG at a sleep laboratory in a medical center. Night one was for adaptation and screening. Sleep data from the second or the third night without intervention were combined and analyzed in this study. Participants kept their daily routine and came to the sleep laboratory three hours before their usual bedtime. The lights-off and lights-on schedule was based on each participant's habitual sleep. Perceived sleep quality was assessed by the Morning Questionnaire (MQ) the next morning (12). Sleeping environment was quiet and dark, and participants wore their own pajamas. Ambient temperature and humidity in the laboratory averaged $24.8 \pm 1.2^{\circ} \mathrm{C}$ and $56.1 \pm 5.2 \%$, respectively.

## Measurements

## Screening for Anxiety and depression

The Hospital Anxiety and Depression Scales (HADS) (13) were used to assess each participant's anxiety and depression. The HADS contains 7 items for anxiety and 7 for depression that are each rated on a 4-point Likert scale
ranging from 0 (not at all) to 3 (most of the time), giving a possible score of 0-21 in both the anxiety and depression subscales. A subscale score of 11 or more is indicative of a clinical diagnosis of anxiety or depression. High reliability and validity of the Chinese Version of the HADS have been reported in different populations of Taiwan.

## Screening for Sleep disturbance.

The Pittsburgh Sleep Quality Index (PSQI) was used to assess participants' subjective sleep disturbance (14). The PSQI is a well-validated instrument for assessing subjective sleep quality over a one-month period (14). It has 19 self-rated questions that generate scores from seven components: "Duration of sleep", "Sleep disturbance", "Sleep latency", "Day dysfunction due to sleepiness", "Sleep efficiency", "Overall sleep quality", and "Need meds to sleep". A global PSQI score is summed from each component to yield a range of 0-21. A score of 5 or greater is used to discriminate poor from good sleep. Previous research demonstrated good internal consistency (alpha $=0.82$ ) and test-retest reliability $(r=0.85)$ of the PSQI Chinese version (CPSQI) in Taiwan's populations (15).

## Screening for sleep apnea

The first-night PSG was used to screen out subjects with sleep apnea. As recommended by the American Academy of Sleep Medicine (16), a sleep apnea event was defined as the absence of airflow for at least 20 seconds with a reduction in oxygen saturation of more than $3 \%$. Participants with an apnea index (AI) $\geq 5$ events per hour were excluded.

## Polysomnography study

Electrodes for PSG including the electroencephalogram (EEG), electro-oculogram (EOG), and electromyogram (EMG) were placed according to standard procedures. Data were obtained and analyzed with the PolySmith system (NeuroFax 1100 system, Nihon Konden Co., Tokyo, Japan). The measurement of chest parameters was added to the PSG recording system on the first night. Respiratory movements were measured with bands placed around the chest and the abdomen (Nihon Konden Co., Tokyo, Japan). Air flow was measured by a nasal cannula pressure system. Oxygen saturation was measured from the left index finger by a pulse oximeter (Ohmeda Biox 3740, Susquehanna Micro, Inc.). Prior to each session, all PSG channels were calibrated.

Sleep stages were scored in 30 -second epochs by one of the authors according to standard criteria (17). The right central channel (C4-A1) was the main EEG signal for
sleep staging. Intra-rater reliability of sleep stages reflected an agreement of $85-90 \%$ in a $10 \%$ random sample of the recordings. For each participant, the following sleep variables were obtained: total sleep time, sleep efficiency, sleep latency, NREM sleep (stages 1-4), REM sleep, and waking after sleep onset (WASO).

## Perceived Sleep Quality

A Morning Questionnaire (MQ) was used to assess the participants' perceived sleep quality (12). The MQ contains three questions regarding sleep latency, sleep duration, and the number and duration of awakenings, as well as three $10-\mathrm{cm}$ visual analog scales (VAS) to assess the individual's perception of restoration ( $1=$ not rested / restored to $10=$ rested / restored), overall sleep quality ( $1=$ very poor to $10=$ very good), and overall satisfaction ( $1=$ very dissatisfied to $10=$ very satisfied).

## Discrepancy between perceived and measured sleep state

The difference between perceived and PSG measured sleep time in terms of total sleep time (D_TST) and sleep latency (D_SL) were obtained. Values of the difference that were close to 0 indicate high accuracy. Positive values indicated an overestimate, and negative values indicate an underestimate of sleep time and sleep latency.

## Data analysis

Descriptive statistics including the mean, standard deviation, frequency and percentage were calculated to summarize the data. A paired t -test was used to examine the difference between the MQ and PSG sleep time. A Pearson correlation was used to examine the relationship between the PSG and MQ sleep variables. The relationship between the discrepancy (D_TST) and sleep quality or sleep structure was also examined with the Pearson correlation. Significance levels were set at p $<$ 0.05 for all of these two-tailed statistical tests.

## Results

## Demographic and clinical characteristics

Table 1 shows the demographic and clinical characteristics of the 32 participants. About $60 \%$ of them were women. Mean age of the participants was 63 ( $\mathrm{SD}=$ 6.7) years. Most of them were married, retired, and had more than 12 years of education. All participants had scores less than 11 in both HADS subscales indicative of the absence of clinically significant depression or anxiety. The participants' mean global PSQI score was $9.2 \pm 3.4$ with a range of 5-19 indicative of sleep disturbance.

Table 1
Demographic and clinical characteristics of the participants ( $\mathrm{n}=32$ )

|  | Values |
| :---: | :---: |
| Age, years | $63.0 \pm 6.7$ |
| Depression ${ }^{1}$ | $3.9 \pm 2.3$ |
| Anxiety ${ }^{1}$ | $4.1 \pm 3.1$ |
| Sleep quality ${ }^{2}$ | $9.2 \pm 3.4$ |
| Gender |  |
| Female | 19(59.4) |
| Male | 13(40.6) |
| Marriage |  |
| Single/widow | 6(18.7) |
| married | 26(81.3) |
| Education |  |
| 6-9 years | 7(21.9) |
| 12 years | 11(34.4) |
| 14-16 years and more | 14(43.7) |
| Working status |  |
| Working ${ }^{3}$ | 15(46.9) |
| Retired | 17(53.1) |

Data are presented as mean $\pm$ standard deviation or $n(\%) ; 1$. Hospital Anxiety and Depression Scale, overall rating; 2. Pittsburgh Sleep Quality Index, global score; 3. Work included teacher, house-keeping, engineer, etc.

Table 2
Habitual sleep from the PSQI prior to participating in study ( $\mathrm{n}=32$ )

|  | n (\%) |
| :---: | :---: |
| Habitual sleep |  |
| Subjective sleep latency |  |
| $<=30 \mathrm{~min}$ | 19(59.4) |
| $31-60 \mathrm{~min}$ | 5(15.6) |
| $>=60 \mathrm{~min}$ | 8(25) |
| Actual sleeping hours |  |
| >= 7 hrs | 3(9.4) |
| 6-6.9 hrs | 4(12.5) |
| $5-5.9 \mathrm{hrs}$ | 18(56.3) |
| $<=4.9 \mathrm{hrs}$ | 7(21.9) |
| Habitual sleep efficiency |  |
| >85\% | 10(31.3) |
| 75-84\% | 7(21.9) |
| <75\% | 15(46.9) |
| Sleep quality overall |  |
| Very good or good | 13(40.7) |
| Poor or very poor | 19(59.3) |
| Troubles during sleep |  |
| Can't get to sleep within 30 minutes |  |
| 0-2 times/wk | 20(62.6) |
| more than 3 times/wk | 12(37.5) |
| 0-2 times/wk | 22(68.7) |
| more than 3 times/wk | 10(31.3) |
| Have to get up to use bathroom |  |
| 0-2 times/wk | 13(40.6) |
| more than 3 times/wk | 19(59.4) |
| Daytime functioning |  |
| Trouble staying awake |  |
| 0-2 times/wk | 26(81.3) |
| more than 3 times/wk | 6(18.8) |
| Problem to get things done |  |
| 0-2 times/wk | 28(87.5) |
| more than 3 times/wk | 4(12.5) |
| Taking sleep medicine |  |
| none | 28(87.5) |
| 1-2 times/wk | 4(12.5) |

Data are presented as $\mathrm{n}(\%)$.

Table 3
Comparison of polysomnography (PSG) and perceived sleep (MQ) ( $\mathrm{n}=32$ )

|  | MQ | PSG | $\mathrm{t}^{4}$ | p | corr ${ }^{5}$ | p |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Sleep |  |  |  |  |  |  |
| Total sleep time (min) | $344.4 \pm 63.7$ | $379.5 \pm 56.7$ | 2.85 | 0.008 | 0.334 | 0.061 |
| Sleep latency (to stg 1) (min) | $30.6 \pm 20.0$ | $17.9 \pm 18.4$ | -2.35 | 0.025 | -0.142 | 0.447 |
| Wake after sleep onset (min) | $29.6 \pm 43.4$ | $48.1 \pm 21.3$ | 2.17 | 0.039 | 0.166 | 0.398 |
| Sleep efficiency (tst/tib) (\%) | $80.4 \pm 14.0$ | $85.7 \pm 5.8$ | 2.07 | 0.047 | 0.231 | 0.212 |
| Sleep stages in PSG ( $\min \pm$ SD, \% sleep period time $\pm$ SD, respectively) |  |  |  |  |  |  |
| Wake |  | $48.1 \pm 21.3 \quad 11.3$ |  |  |  |  |
| Stage 1 |  | $57.4 \pm 41.5 \quad 12.9$ |  |  |  |  |
| Stage 2 |  | $218.2 \pm 45.9 \quad 51.2$ |  |  |  |  |
| Stage 3 \& 4 |  | $26.8 \pm 36.0$ 6.5 |  |  |  |  |
| REM |  | $77.1 \pm 22.2$ 18.2 |  |  |  |  |
| Perceived sleep quality in MQ |  |  |  |  |  |  |
| Overall sleep quality ${ }^{1}$ | $7.2 \pm 1.7$ |  |  |  |  |  |
| Overall sleep satisfaction ${ }^{2}$ | $7.7 \pm 1.4$ |  |  |  |  |  |
| Restoration ${ }^{3}$ | $6.8 \pm 1.9$ |  |  |  |  |  |

Data are presented as mean $\pm$ standard deviation; 1. Sleep quality visual analog scale in the Morning Questionnaire $1=$ very poor, $10=$ very good; 2 . Sleep satisfaction visual analog scale in the Morning Questionnaire $1=$ not satisfied, $10=$ very satisfied; 3 . Sleep quality visual analog scale in the Morning Questionnaire $1=$ not rested/restored, $10=$ rested/restored; 4 . Paired-t test, 2 tailed was used to test the differences between PSG and MQ sleep measures; 5 . Pearson correlation to examine linear correlation between PSG and MQ sleep measures.

## Habitual Sleep Quality

Table 2 shows habitual sleep patterns from the PSQI one month prior to participation in the study. Most participants had a usual bed time of between 22:00-24:00 h $(90.6 \%)$, and a usual rise time of before 7:00 h ( $84.4 \%)$. More than half of the participants perceived their sleep latency as less than 30 min ( $59.4 \%$ ) but estimated their duration of sleep below 6 hours ( $78.2 \%$ ) and sleep efficiency below $85 \%$ ( $68.7 \%$ ). The majority of the participants rated their overall sleep quality as poor or very poor ( $59.4 \%$ ). Their major troubles during sleep were that they had to get up to use the bathroom $(59.4 \%)$, could not get to sleep within 30 min ( $37.5 \%$ ), and would wake up in the middle of the night or in the early morning ( $31.3 \%$ ). However, during the day, most participants did not have trouble staying awake (43.8\%) or getting things done ( $59.4 \%$ ). Only four ( $12.5 \%$ ) of them ever needed medication to sleep.

## Perceived (MQ) and Measured (PSG) Sleep

Table 3 shows the distribution and comparison of parameters between perceived (MQ) and measured (PSG) sleep. Participants perceived 344.4 minutes of total sleep time, with a sleep latency of approximately 30 minutes, and awakenings of about 30 minutes. A perceived sleep efficiency of $80.4 \%$ was calculated by perceived total sleep time over time in bed. PSG also showed borderline poor sleep (18) with the measured total sleep time of 379.5 minutes, nocturnal awakenings of 48 minutes, and a sleep efficiency of $85.7 \%$. The participant's perception of sleep length was underestimated. In the PSG sleep structure, wake and stage 1 sleep together accounted for
$24.2 \%$ of sleep, and the amount of slow wave sleep (stage $3 \& 4$ sleep) was only $6.5 \%$ (Table 3). Comparing the differences between the MQ and the PSG sleep measures with paired t-tests, participants perceived significantly longer sleep latencies but shorter total sleep time and awakening time than those measured by PSG. Moreover, there were no associations between MQ and PSG sleep parameters. The average of sleep restoration, overall sleep quality, and satisfaction using the $10-\mathrm{cm}$ VAS scales tended to be slightly restored (6.8), moderate sleep quality (7.2), and moderately satisfied (7.7) (Table 3). About $60 \%$ of participants were not satisfied with their sleep.

## Discrepancy between perceived and measured sleep state

Table 4 shows the distribution of the discrepancy between perceived and measured sleep latency and total sleep time. More than half ( $54.8 \%$ ) of the participants overestimated their sleep latency at greater than 10 minutes with an average excess of 12.4 minutes. More than half $(53.2 \%)$ of participants underestimated their total sleep time ( $>30 \mathrm{~min}$ ) and nocturnal awakening time ( $>30 \mathrm{~min}$ ) by an average of 35.1 and 18.4 minutes, respectively.

Discrepancy of perceived and measured total sleep time (D_TST) was negatively correlated with the duration of measured total sleep time, the duration of stage 1 sleep, and sleep quality (Figure 1). This implies that participants with poor sleep quality, longer measured total sleep time, and longer stage 1 sleep tended to underestimate their total sleep time. They perceived their sleep as shorter than the PSG measured.

Table 4
Distributions of discrepancy in perceived sleep latency, total sleep time, and wake after sleep onset ( $\mathrm{n}=32$ )

|  | Values | Range |
| :---: | :---: | :---: |
| D-SL ${ }^{1}$ | $12.4 \pm 29.2$ | -59~86.5 |
| <-10 min | 4(12.9) |  |
| $\pm 10$ min | 10(32.3) |  |
| 10~30 min | 12(38.7) |  |
| 30~60 min | 4(12.9) |  |
| $>60 \mathrm{~min}$ | 1(3.2) |  |
| D-TST ${ }^{2}$ | -35.1 $\pm 69.7$ | -169~78.5 |
| $<-120 \mathrm{~min}$ | 6(18.8) |  |
| $-60 \sim-120 \mathrm{~min}$ | 4(12.5) |  |
| $-30 \sim-60$ min | 7(21.9) |  |
| $\pm 30 \mathrm{~min}$ | 8(25.0) |  |
| $30 \sim 60 \mathrm{~min}$ | 5(15.6) |  |
| $>60$ min | 2(6.3) |  |
| D-WASO ${ }^{3}$ | -18.4土44.9 | -71~115 |
| -60 ~ -120 min | 2(7.1) |  |
| $-30 \sim-60 \mathrm{~min}$ | 13(46.4) |  |
| $\pm 30 \mathrm{~min}$ | 8(28.6) |  |
| $30 \sim 60 \mathrm{~min}$ | 4(14.3) |  |
| $>60$ min | 1(3.6) |  |

Data are presented as mean $\pm$ standard deviation or $\mathrm{n}(\%) ; 1$. D-SL= discrepancy of sleep latency between perceived and measured sleep, subjective sleep latency minus PSG sleep latency; 2. D-TST = discrepancy of total sleep time between perceived and measured sleep, subjective total sleep time minus PSG total sleep time; 3. D-WASO=discrepancy of wake after sleep onset between perceived and measured sleep, subjective WASO minus PSG WASO

Figure 1
Correlation plots between D_TST (difference between perceived and measured total sleep time) and (a) sleep quality represented by the global PSQI score and PSG sleep structure, (b) total sleep time, (c) stage 1 sleep, (d) stage 2 sleep, (e) slow wave sleep (SWS), and (f) rapid eye movement sleep (REM) in the participants ( $\mathrm{n}=32$ ). D_TST was negatively correlated with sleep quality, the duration of total sleep time, and the duration of stage 1 sleep


## Discussion

In this study we found that older adults with poor habitual sleep perceived poor sleep quality. Their PSG results showed that older adults had difficulty in maintaining sleep with frequent nocturnal awakenings of more than 30 minutes. Most of their sleep was light sleep ( $64 \%$, stage $1 \& 2$ sleep) with significantly decreased deep sleep ( $6.5 \%$ stage $3 \& 4$ sleep) to a level far below the normal range of adult sleep (15-20\%) (19). Function of the deep sleep on humans is to repair cells and restore energy (20). A shortage of deep sleep could result in the nonrestorative sleep in the next morning. Comparing the perceived sleep to the PSG sleep, participants overestimated their sleep latency but underestimated their total sleep time and sleep efficiency. The discrepancy implied a misperception of their sleep state. The misperception of sleep state, especially the underestimation of their total sleep time, further contributed to their sense of non-satisfaction about their sleep. Insomnia may be classified as sleep state misperception (subjective insomnia, subjective complaints without objective findings) and true insomnia (objective insomnia, subjective complaints with corresponding objective findings) (3). Cognitive components affect the perception of sleep state for both subjective and objective insomnia $(21,22)$ and it should not be ignored in the assessment and intervention of older adults with sleep complaints and/or insomnia.

In addition, we found that the duration of stage 1 sleep was negatively correlated with the amount of underestimation of the total sleep time (D_TST); and the amount of underestimation of total sleep time was further associated with poor sleep quality. Thus, sleep structure is an important factor of sleep state perception compatible with previous studies $(8,23)$. To improve sleep quality in older adults, it is necessary not only to increase total sleep time and sleep efficiency, but also to decrease light sleep and nocturnal awakening and enhance slow wave sleep.
Although older adults with sleep complaints in this study also showed evidence of insomnia in PSGmeasured sleep, there were no correlations between the perceived and measured sleep. On the contrary, significant differences existed between the perceived and measured sleep that was supported by previous studies on various populations $(3,5)$. Neuroimaging studies of the humans showed that the cerebellum, prefrontal cortex and a corticostriatal network in the basal ganglia are responsible for the ability of time perception during wakefulness (24). Among them the prefrontal cortex may play an important role in the estimation of time during sleep (7, 26). Sleep induced prefrontal cortical deactivation progresses in a sleep-stage dependent manner, which might influence the accuracy of time estimation (23). This may, at least in part, account for why subjects
with more light sleep (stage 1) perceived the sleep state (total sleep time) with better accuracy because the human brain is disengaged from the outer world from stage 2 and beyond (including deep sleep and REM sleep) when a close estimation of the time passed becomes very difficult. Brain function plays a role in the perception of sleep state.

In conclusion, older adults with sleep complaints have poor objective sleep. Discrepancies between the perceived and the measured sleep are negatively associated with the reported sleep quality suggesting that cognitive components may play a role in sleep appraisal and sleep satisfaction (23). Older adults with poor sleep quality and longer stage 1 sleep perceived a shorter than actual sleep time. Sleep structure, especially the duration of stage 1 sleep affects the perception of sleep state with an effect on a more accurate estimation of the total sleep time in older adults with sleep complaints. Misperception of sleep state may have an adverse effect on sleep quality in older adults with sleep complaints. Therefore even subjective insomnia without corresponding objective findings should be taken serious consideration because poor reported sleep quality predicts poor quality of life in different clinical populations and healthy persons $(27,28)$.

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