Scientific Research

Sleep Posture Affects Sleep Parameters Differently in Young and Senior Japanese as Assessed by Actigraphy

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Abstract

In an attempt to study the relationship between sleep postures and sleep parameters assessed by actigraphy, we applied the newly developed Activity Monitoring and Evaluation System (A-MES) and actigraphy at the same time to younger and senior Japanese volunteer groups. It was found that sleep postures and diurnal activity determines, to some extent, sleep parameters including activity mean score (AMS), activity index (ACTX), waking episodes (WEP) and sleep fragmentation index (SFX). It was also found that sleep properties are different in younger and senior Japanese. For example, increase in the proportion of time in the supine position resulted in enhancement and deterioration of the sleep in the younger and senior groups, respectively. Furthermore, there were correlations between supine posture and AMS, ACTX, SFX, total minutes scored as awake (TMSA) and WEP obtained by actigraphy in the younger group, but only AMS and ACTX in senior group. In addition, we also assessed sleep parameters by use of questionnaires, and found that objective sleep quality was rather poor but subjective sleep quality was better in the senior group. In the younger group, in contrast, objective sleep quality was better but subjective sleep quality was poor. On the other hand, there was no correlation between sleep parameters assessed by actigraphy and self-report at all. The present study with A-MES and actigraphy provides the first evidence that sleep posture affects sleep quality and is a convenient, inexpensive and home-based method for studying sleep.

Keywords

1. Introduction

Sleep evaluation in humans has been performed with polysomnography (PSG), a technique considered the "gold standard" for sleep studies. However, subjects have to stay in the sleep laboratory for at least four nights with many electrodes and sensors. As an alternative to PSG, the use of wrist actigraphy (activity-based monitoring), an instrument that measures wrist motor activity to provide an indirect assessment of sleep through the use of algorithm, has become an essential tool in sleep research and sleep medicine [1] [2]. However, it is not feasible to assess sleep postures per se by use of actigraphy, and till now little study has been carried out on the relation between sleep postures and sleep parameters assessed by actigraphy.

It was first noticed, from the analysis of the sleep characteristics and sleep positions of good and poor sleepers [3] [4], assessed with a Super 8 Camera taking one frame every 8 seconds providing 3600 frames over 8 hours, that sleep positions constitute an important sleep parameter that may be related to the sleep quality.

In a previous study, by use of a newly developed Activity Monitoring and Evaluation System (hereafter referred as A-MES) [5] [6], we observed postures, posture shifts, duration of postural immobility and frequency of body movements during the time in bed of four Japanese age groups [7]. The reliability made by A-MES on postures and movements was examined by the comparison with those obtained by video-recording the behavior of subjects, and the results obtained with A-MES yielded good agreement with those obtained by analysis of videotape recordings [8]. The subjects slept two or three consecutive nights at home wearing night clothes with two A-MES attached to trunk and left thigh. This method allows natural and undisturbed sleep in the subject's own bed and gives reliable data through one to two nights recording. We found that there is significant ontogenetic decrease in supine position, and corresponding increase in sleep posture lying on the right, although there was no difference in the number of posture shifts or the duration and frequency of the postural immobility across the four age groups. A-MES provides a convenient, inexpensive and home-based method for studying putative sleep movement. However, a limitation of this method was that it was not possible to distinguish awake and sleep states [7]. Therefore in the present study, we applied actigraphy and A-MES at the same time to younger and senior Japanese subjects in an attempt to study the relationship between sleep postures and sleep parameters. In addition, to assess the subjective sleep quality, we used Pittsburg Sleep Quality index [9] and Oguri-Shirakawa-Azumi Sleep Inventory MA version [10] (hereafter referred as PSQI and OSA-SI-MA, respectively).

Thus, the aim of the present study was threefold. Firstly we performed a comparative study on sleep postures and activities during 24 hours in younger and senior Japanese groups by use of A-MES and actigraphy at the same time. Secondly, we studied the relationship between sleep posture and diurnal activities with the sleep parameters obtained by actigraphy. Finally, we studied the relationship, if any, between subjective and objective sleep quality.

2. Methods

2.1. Subjects

16 subjects (eight female and eight male) in each of the following age groups were studied: the younger group ranged between 21 - 23 years old (m = 21.8 ± 0.8 (SD)), and the senior group ranged between 66 - 84 years old (m = 74.3 ± 5.8 (SD)). **Table 1** shows socio-demographic characteristics of the subjects. The subjects were recruited by advertisements made by the university.

The inclusion criteria were: healthy, no physical handicap and no sleep disorder. The subjects were interviewed by A.N. and C.O. to confirm that they were normal and free from sleep and medical disorders. All subjects were fully aware of the present study on sleep and were actively willing to participate in the study. Senior or younger subjects slept for 5 to 6 or 2 to 3 consecutive nights respectively at home, and records of 2 consecutive nights for each subject were analyzed according to the previous studies [7].

It is known that sleeping postures vary among Japanese subjects but each subject has similar sleeping postures and position shifts at similar frequencies [11] [12]. Therefore, two similar records, taken when the subject felt they had slept well, were used for analysis.

The study was approved by the ethics committee of Kumamoto Health Science University on clinical experimentation.

2.2. Recording of Activity and Positions during 24 h by A-MES

Activity Monitoring and Evaluation System (A-MES) [5] [6], a commercially available product (Solid Brains,

Table 1. Socio-demographic characteristics of the subjects.

Characteristics	Number of subjects	
	Younger group	Senior group
Age (years)		
21 - 23	16	
66 - 84		16
Gender		
Male	8	8
Female	8	8
Marital status		
Married		16
Never married	16	
Employment		
Student	14	
Fulltime	2	2
Part-time		4
Retired		10
Ethnicity		
Japanese	16	16

2081-10 Tabaru, Mashiki-machi Kamimasikigun Kumamoto 861-2202, Japan), was used in the present study. A-MES consists of three-dimensional acceleration sensors (27.2 (D) × 27.2 (W) × 19.8 (H) mm) and a data logger. DC and AC components of signals of the three-dimensional acceleration sensors (sampling rate 5/second) detect the posture and movements of the subject. By use of A-MES attached to the trunk and left thigh of the subjects, it is possible to judge the following postures lying (supine, on the right or left side or prone), sitting, standing-up, walking and driving a wheelchair by the combination of the signals from trunk and left thigh [7].

The size and weight (28 g) are compact enough to attach to the subject's trunk or thighs. In the present study, however, we inserted A-MES into two pockets attached to the breast and left thigh of underwear (M, L and LL sizes) to monitor the postures and posture shifts during 24 h. The records were taken on two or three consecutive days. The subjects were asked to bring back the underwear and A-MES for the analysis of the data.

2.3. Actigraphy

The subjects were also asked to wear the actigraphy on the non-dominant wrist. The actigraphy used was the Mini Motion logger Actigraph-Basic32C (Ambulatory Monitoring Inc., Ardsley, USA). Data were collected on the "zero crossing mode", in 1-min periods, and were scored on Action W-2 version 2.6.9905 software (Ambulatory Monitoring Inc., Ardsley NY). The algorithm is the most commonly reported analysis, and the following sleep parameters were analyzed: TMSA, total sleep time (TST), wake after sleep onset (WASO), sleep efficiency (SE), sleep onset latency (SOL), AMS, ACTX, SFX, wake episode (WEP) and long wake episodes (LWEP). Computerized analyses were performed according to the algorithms proposed by Cole *et al.* and Sadeh *et al.* for the estimation of actigraphic sleep parameters [13] [14]. The algorithm developed by Cole *et al.* yielded an 88% agreement rate with PSG [13]. There have been numerous studies showing good concordance for sleep/wake estimation between actigraphy and PSG [15]-[22]. In normal sleepers, agreement coefficients between PSG and actigraphy of 0.90 and above have been reported [14].

2.4. Questionnaire

At the end of the study, we asked the subjects to assess OSA-SI-MA [10] which is a psychological measure to evaluate the sleep inspection at the time of rising. The inventory consists of sixteen items (choice of one out of four alternatives for each item) into five factors: 1) sleepiness on rising, 2) initiation and maintenance of sleep, 3) dreaming frequency, 4) refreshed feeling, 5) sleep length. The mean score is taken as 50 points for each factor,

and the larger score indicates better sleep quality. We also used PSQI [9], a self-rated questionnaire which assesses sleep quality and disturbances over a 1-month period. Nineteen individual items provide seven "component" scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medication and daytime dysfunction. The sum of scores for these seven components yields one global score, and the smaller the score the better the sleep quality. Scores more than six indicate sleep disorder of the subjects.

2.5. Data Analysis

We used Mann-Whitney's U test to analyze the proportion of time for each posture (lying, sitting, standing and walking) during 24 hours, sleep postures (supine, lying on right or left side, or prone) and sleep parameters (AMS, TMSW, SE, SOL, ACTX, WASO and LWASO) in the two age groups. For analysis of correlation between sleep posture or diurnal activity and various parameters in the two age groups, Spearman's correlation coefficient rank test was used. The difference in the ratio of sleep postures to the total time in bed was examined by use of the Steel-Dwass test. Values of p < 0.05 were considered significant.

3. Results

3.1. Postures in 24 Hours

Postures in 24 hours were assessed by A-MES in the younger and senior groups. **Figure 1** shows that lying and sitting were the main postures in both groups during 24 hours, and that standing and walking were more dominant in the senior than the younger group, whereas sitting was significantly longer in the younger group.

3.2. Postures and Posture Shifts in Sleep

We applied A-MES and actigraphy at the same time, to enable us to study the postures in sleep (**Figure 2(a)**). In general, four different postures, namely supine, lying on the right or left side, and prone, were observed in the two groups. The main postures in sleep were, in order, supine > lying on the right or on the left > prone in both groups, and the proportion of time in supine and prone postures were greater in the younger than the senior group. However, the proportion of time lying on the right was significantly larger in the senior than the younger group. In addition, the number of posture shifts was significantly greater in the younger group (**Figure 2(b)**).

3.3. Objective Sleep Parameters

In an attempt to assess the objective sleep quality, we used various parameters obtained by actigraphy.

Table 2 shows TMSA, TST, WASO, SE, SOL, AMS, ACTX, SFX, WEP and LWEP observed in the younger and senior groups. The scores for TMSA, AMS, ACTX and LWASO were larger in the senior than the younger group. On the contrary, scores for SE were higher in the younger than the senior group. These observations indicate that the objective sleep parameters in the younger were better than in the senior group.

3.4. Relationship between Sleep Postures and Sleep Parameters

In an attempt to study the relationship between the sleep postures and sleep parameters in the two groups, firstly we observed the relationship between supine posture and sleep parameters obtained by actigraphy. Interestingly, there was a positive correlation between supine postures and AMS or ACTX in the senior group and a negative correlation in the younger group. Increases in the proportion of time in the supine posture resulted in decrease and increase in AMS or ACTX in the senior and younger groups respectively (**Figures 3(a)-(d)**). Furthermore in the younger group, there were negative correlations between the proportion of time in the supine posture and SFX, WEP and TMSA (**Figure 4**), thereby indicating that the increases in the proportion of time in the supine posture resulted in enhancement of the sleep in the younger group.

3.5. Posture Shifts and Sleep Parameters

As shown in **Table 3**, there were also positive correlations between number of posture shifts and ACTX or WEP in younger, and TMSA, WASO, SE, ACTX, SFX or WEP in senior groups, respectively.
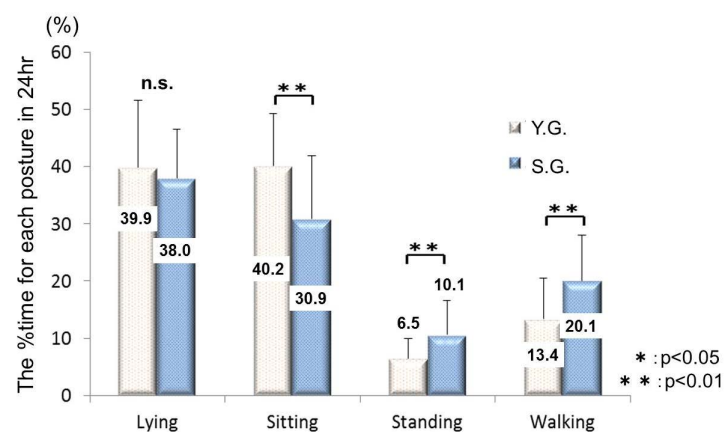
Figure 1. Postures (lying, sitting, standing and walking) during 24 hours assessed by A-MES in the younger and senior groups. S.G.: senior group, Y.G.: younger group.


(a)

(b)
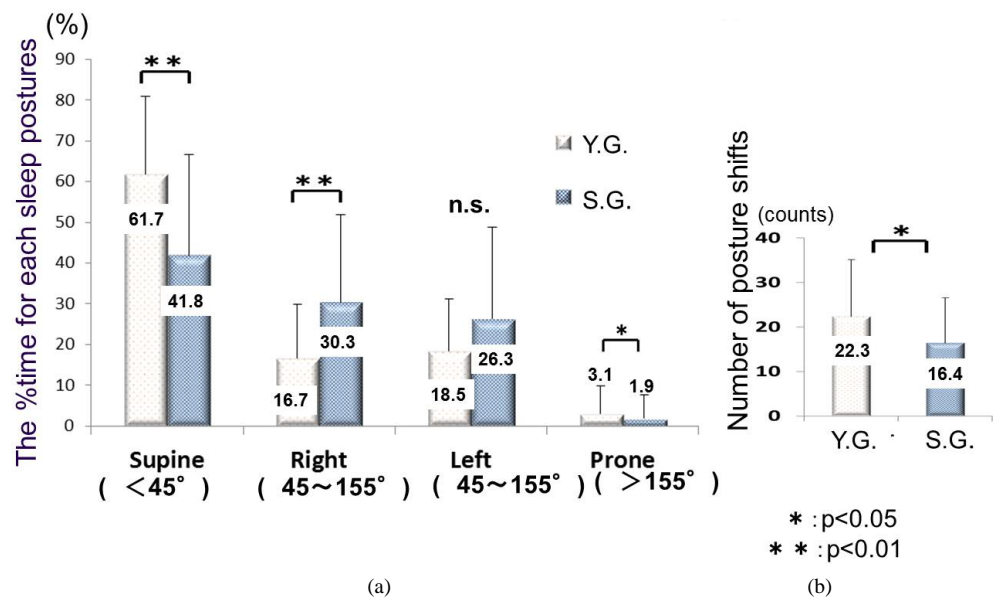
Figure 2. Postures (supine, lying on the right or left, and prone) in sleep assessed by actigraphy and A-MES at the same time, and posture shifts during sleep at night in younger and senior groups. S.G.: senior group, Y.G.: younger group.

(a)

(b)

(c)

(d)
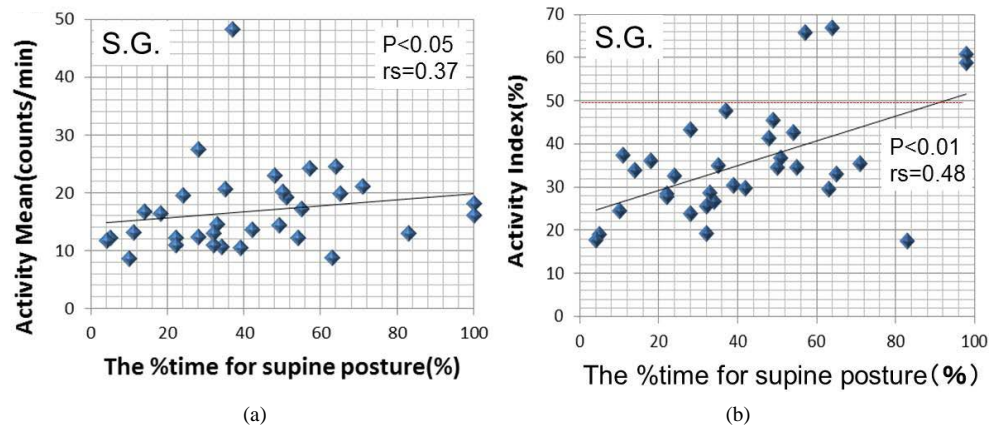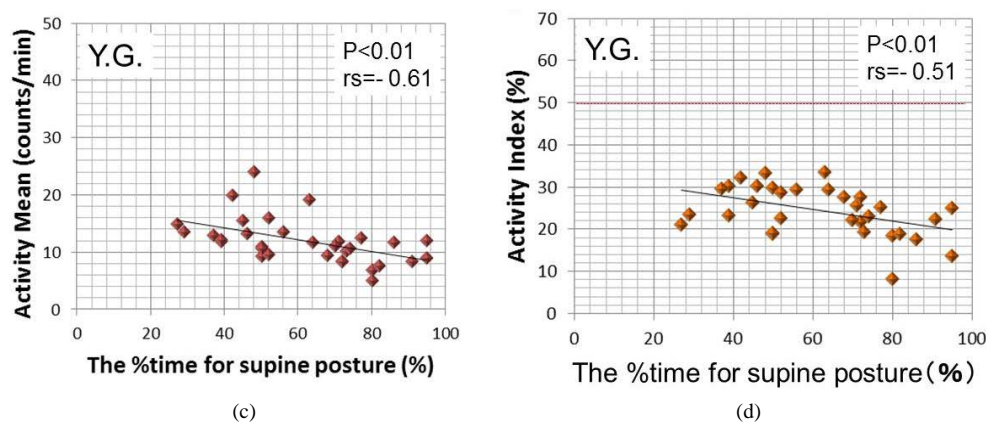
Figure 3. Relationships between the proportion of time in the supine posture in sleep and activity mean score (AMS) ((a) & (c)) or activity index (ACTX) ((b) & (d)). (a) & (b), (c) & (d): there were positive and negative correlations in senior and younger groups, respectively. S.G.: senior group, Y.G.: younger group.

(a)

(b)

(c)
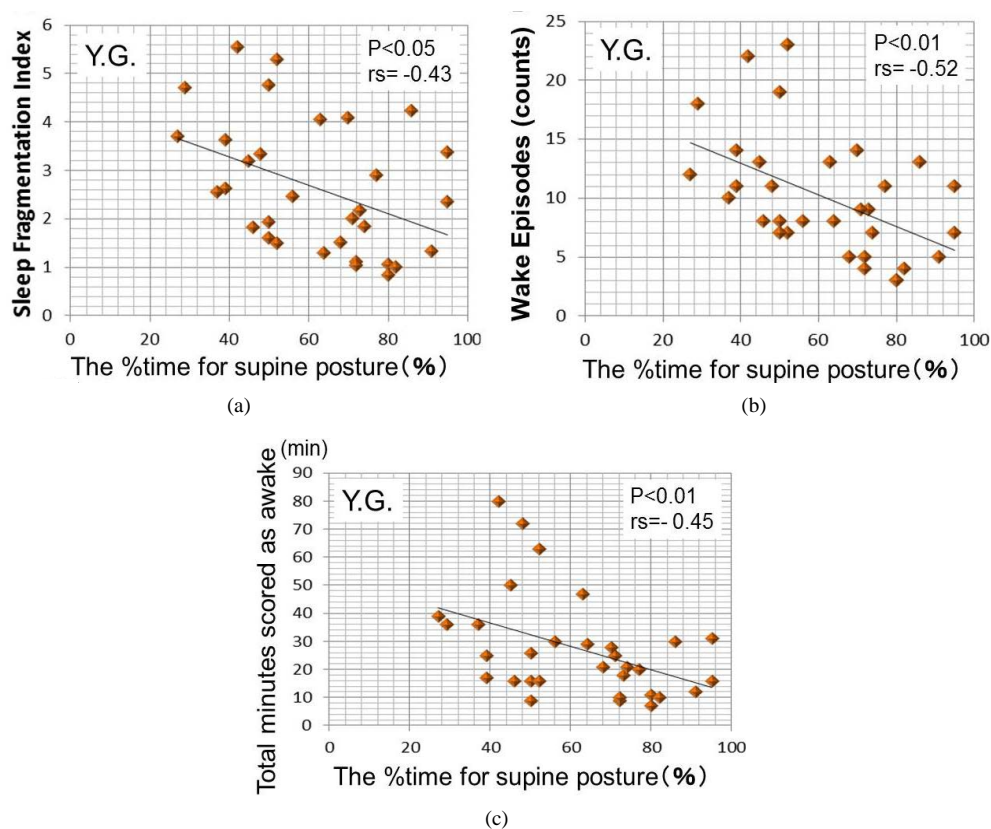
Figure 4. Relationships between the proportion of time in supine posture in sleep with (a): sleep fragmentation index (SFI) and (b): wake episode (WEP) and (c): total minutes scored as awake (TMSA) in the younger group. There were negative correlations for the three relationships. The coefficient values were −0.43, −0.52 and −0.45, respectively. Y.G.: younger group.

3.6. Diurnal Activity and Sleep Parameters

We found negative correlations between the AMS or proportion of time walking during the day and ACTX in the senior group (**Figure 5**), indicating that daytime activities enhanced the sleep in the senior group. However, there was no correlation between diurnal activities and sleep parameters in the younger group.

Table 2. Objective sleep parameters (total minutes scored as awake (TMSA), total sleep time (TST), wake after sleep onset (WASO), sleep efficiency (SE), sleep onset latency (SOL), activity mean score (AMS), activity index (ACTX), sleep fragmentation index (SFX), wake episode (WEP) and long wake episodes (LWEP)) assessed by actigraphy in younger and senior groups.

	Younger group	Senior group	
Total minutes scored as awake (TMSA) (min)	27.4 ± 18.2	41.8 ± 28.8	**
Total sleep time (TST) (min)	388.7 ± 69.0	375.0 ± 61.3	n.s.
Wake after sleep on set (WASO) (min)	20.1 ± 17.1	32.0 ± 26.1	**
Sleep efficiency (SE) (%)	95.1 ± 3.9	92.3 ± 5.3	**
Sleep on set latency (SOL) (min)	6.3 ± 4.8	7.5 ± 10.3	n.s.
Activity mean score (AMS) (counts/min)	12.0 ± 3.9	16.8 ± 7.4	**
Activity index (ACTX) (%)	24.4 ± 5.8	35.4 ± 12.9	**
Sleep fragmentation Index (SFX)	2.6 ± 1.4	2.9 ± 1.7	n.s.
Wake episodes (WEP) (counts)	10.1 ± 5.2	10.2 ± 4.4	n.s.
Long wake episodes (LWEP) (counts)	1.9 ± 1.4	2.6 ± 1.3	*

*: $p < 0.05$; **: $p < 0.01$.

Table 3. Relationships between the number of posture shifts in sleep and sleep parameters assessed by actigraphy in the younger and senior groups.

Objective sleep parameters	Number of posture shifts	
	Younger group	Senior group
Total minutes scored as awake (TMSA)	n.s.	0.36*
Wake after sleep on set (WASO)	n.s.	0.48*
Sleep efficiency (SE)	n.s.	−0.47**
Sleep on set latency (SOL)	n.s.	n.s.
Activity index (ACTX)	0.48**	0.37*
Sleep fragmentation Index (SFX)	n.s.	0.38*
Wake episodes (WEP)	0.38**	0.44*
Long wake episodes (LWEP)	n.s.	n.s.

*: $p < 0.05$; **: $p < 0.01$.

(a)

(b)
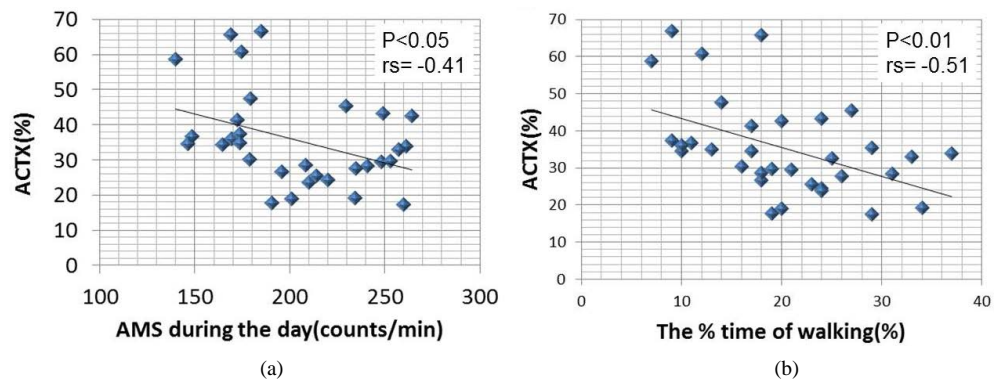
Figure 5. Relationships between activity mean score (AMS) (a) or the proportion of time for walking (b) with activity index (ACTX) in the senior group. All had a negative correlation.

3.7. Subjective Sleep Quality

The subjective sleep quality was assessed by use of PSQI and OSA-SI-MA methods. As shown in **Figure 6**, the PSQI score was slightly larger in the younger than the senior group. However all OSA scores were larger in the senior than the younger group, thereby indicating that subjective sleep quality is higher in the senior than the younger group.

### 3.8. Relationship between Objective and Subjective Sleep Quality

In an attempt to study the correlation, if any, between objective and subjective sleep quality, we plotted sleep parameters (TMSA, WASO, SE, SOL, ACTX, SFX, WEP and LWEP) obtained by actigraphy against PSQI and OSA-SI-MA scores. However, there were no correlations between those parameters in either the younger or the senior groups (data not shown).

4. Discussion

The present results could be summarized as follows; 1) the main postures observed by A-MES in 24 hrs were lying or sitting in both the senior and younger groups, 2) the proportion of time in the sleep postures were in the order supine > lying on the right, or left side > prone both groups, 3) there were correlations to some extent between sleep posture and sleep parameters obtained by actigraphy including AMS, ACTX, SFX and WEP, 4) there were correlations between sleep parameters and posture shifts in both younger and senior groups, and diurnal activity in the senior group, 5) objective sleep quality was better in the younger than the senior group, although subjective sleep quality was better in the senior group, 6) there was no correlation between sleep parameters assessed by actigraphy and self-report questionnaires.

In the previous study [7] we reported postures in bed by use of A-MES and found that there is an ontogenetic decrease in supine position. The present result confirmed this observation, and as shown in **Figures 3-5** there were positive and negative correlations between sleep parameters assessed by actigraphy with postures, number of posture shifts and diurnal activity assessed by A-MES. Therefore, it is reasonable to assume that postures in bed during the night observed by A-MES represent sleep postures, suggesting that the recordings by two A-MES attached to the trunk and left thigh could fulfill the minimum requirement to study sleep postures.

In the present study we found different sleep properties in younger and senior Japanese, and the differences are as followings; 1) there were correlations between the proportion of time in the supine posture in sleep and AMS, ACTX, SFX, TMSW and WEP obtained by actigraphy in the younger group, but only AMS and ACTX in senior group, 2) increase in the proportion of time in the supine posture enhanced the sleep parameters including AMS, ACTX, SFX and WASO in the younger group, but reduced these parameters in the senior group, 3) increase in the number of the posture shifts during sleep decreased the sleep parameters such as SFX and WASO in the senior group, but showed almost no effects in the younger group even though the number of position shifts were larger than in the senior group, 4) objective sleep quality was rather poor but subjective sleep
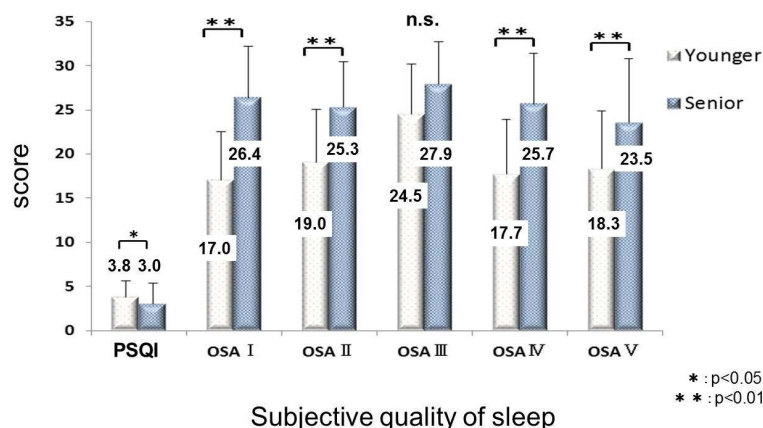
Figure 6. Subjective sleep quality assessed by PSQI or OSA-SI in younger and senior groups.

quality was better in the senior group; in contrast, in the younger group objective sleep quality was better but subjective sleep quality was poor. The exact mechanisms involved in these different results are yet to be clarified. However, the present results indicate for the first time that sleep posture affects the sleep parameters obtained by actigraphy in younger and senior Japanese, and that sleep parameters might be one of the targets for aging.

We also found that there was no correlation between sleep parameters assessed by actigraphy and self-report questionnaires. However, self-report remains the most practical and cost-effective method in epidemiologic sleep studies attempting to collect information on large population-based samples, and it was found that a 3-item sleep questionnaire of the type typically used in epidemiologic studies show poor agreement with actigraphically recorded sleep habits [23]. Similarly, the skin condition of children with atopic dermatitis before and after treatment with pimecrolimus, an immunomodulating agent, was related to sleep parameters obtained by actigraphy, but subject perception of itching was not correlated with any sleep parameters [24].

On the other hand, there are reports which indicate correlations to some extent between subjective and objective sleep indices. Firstly, it was proposed that the probabilistic sleep mode (PSM) obtained by processing 3-second EEGs represents the sleep profile (not only the sleep stage but also sleep quality) and is correlated with psychometric tests [25]. Significant correlations between sleep architecture and dynamic variables of sleep quality have also been reported [26]. Secondly, the relationship between PSG and subjective sleep quality has been directly investigated [27] and it was found that the appearance duration/ratio of sleep stage II/III/IV shows a significant correlation with each OSA-SI-MA factor score. Thus, the authors claimed that they could estimate the OSA-SI-MA factor from hypnogram indices with maximum accuracy of 71% by use of artificial neural network.

Recently, the feasibility and acceptability of actigraphy to monitor sleep quality and quantity was examined in healthy self-rated good sleeping adults at home-based settings. Actigraphy data were used to prepare an individual sleep report and participants were also asked to complete a Self-report Health Related Quality of Life (HRQL) using the WHO five Well Being Index (WBI) questionnaire. Although all participants in the study were self-rated healthy and "good sleepers", there were cases where low sleep quality were noticed. Thus, it seems that actigraphy can be easily utilized to monitor sleep-wake patterns at home. Furthermore, a discrepancy between self-reported and actigraphic sleep quality was also reported [28].

These various results and the present observations, taken together, indicate that further studies are warranted to understand the relationship between objective and subjective sleep obtained by the various methods. Furthermore, it seems essential to examine the consistency of the results obtained by multiple measures of sleep parameters.

Till now, surprisingly little study has been carried out on the relationship between sleep posture and sleep quality, and the present observations indicate that sleep postures constitute an important sleep variable which is related to sleep quality. The present study with A-MES and actigraphy provides a convenient, inexpensive and home-based method for studying sleep.

5. Conclusion

By application of newly developed A-MES and actigraphy to younger and senior Japanese volunteer groups at the same time, we obtained following conclusions. Firstly, sleep postures and diurnal activity determine, to some extent, sleep parameters including AMS, ACTX, WEP and SFX assessed by actigraphy, and this is the first evidence that sleep posture affects sleep quality. Secondly, sleep properties are different in younger and senior Japanese, including the relationship between the proportion of time in the supine position and sleep quality, or AMS, ACTX, SFX, and TMSA. Thirdly, we also assessed sleep parameters by use of questionnaires; however there was no correlation between sleep parameters assessed by actigraphy and self-report at all. Finally, present study with A-MES and actigraphy provides a convenient, inexpensive and home-based method for studying sleep.

Acknowledgements

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