一般名	商品名	本剤の代謝酵素	阻害する酵素	誘導する酵素
チミペロン	トロペロン、セルマニル	-	-	-
分類				
抗精神病薬				

効能・効果	用法・用量	高齢者へ投与時の影響	高齢者への投与方法
統合失調症	1日0.5～3mgよりはじめ徐々に増量し，通常成人1日3～12mgを分割経口投与する。年齢・症状により適宜増減。	錐体外路症状等の副作用があらわれやすい。	少量から投与を開始するなど患者の状態を観察しながら慎重に投与すること。

薬物動態

本剤の血中からの消失には大きな個人差が認められた。

Tmax	Cmax	T1/2	AUC
統合失調症患者 6mg： 3.286±0.561 hr	統合失調症患者 6mg： 5.947±1.873 ng/mL	統合失調症患者 6mg： 5.906±2.664 hr	-

併用	併用薬剤名	臨床症状・対処	機序・危険因子
禁忌	アドレナリン(ボスミン)	重篤な血圧降下	本剤のα受容体遮断作用により、β受容体刺激作用が優位となり、血圧降下作用が増強される。
注意	中枢神経抑制薬((バルビツール酸誘導体等))	中枢神経抑制作用↑ 用量を調節する。	相加作用
注意	アルコール	中枢神経抑制作用↑	相加作用
注意	リチウム	心電図変化，重症の錐体外路症状，持続性のジスキネジア，突発性の悪性症候群，非可逆性の脳障害 観察を十分に行う。	機序は明らかでないが，ブチロフェノン系薬剤は脳内ドパミン受容体とアデニルシクラーゼ活性を遮断し，リチウムもアデニルシクラーゼ活性を抑制して，相互に中枢神経抑制作用を増強すると考えられている。
注意	メトクロプラミド	内分泌機能調節異常又は錐体外路症状	相加作用
注意	ドンペリドン	内分泌機能調節異常又は錐体外路症状	相加作用
注意	タンドスピロン	錐体外路症状↑	相加作用
注意	ドパミン作動薬((レボドパ等))	相互に作用↓	拮抗作用
注意	カルバマゼピン	類似化合物(ハロペリドール)で作用が減弱し，運動性興奮や譫妄状態を起こすとの報告がある。 観察を十分に行う。	カルバマゼピンの代謝酵素誘導作用により，類似化合物(ハロペリドール)の代謝↑，血中濃度↓(平均60%)の報告がある。

一般名	商品名	本剤の代謝酵素	阻害する酵素	誘導する酵素
トリフロペラジン	トリフロペラジン	-	-	-
分類				
抗精神病薬				
効能・効果	用法・用量		高齢者へ投与時の影響	高齢者への投与方法
統合失調症	1日5～30mg(散として0.5～3g)を分割経口投与する。年齢・症状により適宜増減。		起立性低血圧，錐体外路症状，脱力感，運動失調，排泄障害等が起こりやすい。	患者の状態を観察しながら慎重に投与すること。

薬物動態			
-			
Tmax	Cmax	T1/2	AUC
-	-	-	-

併用	併用薬剤名	臨床症状・対処	機序・危険因子
禁忌	アドレナリン(ボスミン)	重篤な血圧降下	本剤のα受容体遮断作用により、β受容体刺激作用が優位となり、血圧降下作用が増強される。
注意	中枢神経抑制剤(バルビツール酸誘導体・麻酔剤等)	睡眠(催眠)・精神機能抑制作用↑ 麻酔効果↑，血圧↓等 減量するなど慎重に投与する。	相加作用
注意	降圧剤	起立性低血圧等 減量するなど慎重に投与する。	相加作用
注意	抗コリン作用を有する薬剤(原文:「アトロピン様作用を有する薬剤」)	抗コリン作用↑(口渇，眼圧上昇，排尿障害，頻脈，腸管麻痺等) 減量するなど慎重に投与する。	相加作用
注意	アルコール(飲酒)	眠気，精神運動機能↓	相加作用
注意	ドンペリドン	内分泌機能調節異常又は錐体外路症状	相加作用
注意	メトクロプラミド	内分泌機能調節異常又は錐体外路症状	相加作用
注意	リチウム	心電図変化，重症の錐体外路症状，持続性のジスキネジア，突発性の悪性症候群，非可逆性の脳障害 観察を十分に行い，慎重に投与する。なお，このような症状があらわれた場合には投与を中止する。	機序は不明
注意	ドパミン作動薬(レボドパ製剤，ブロモクリプチンメシル酸塩)	相互に作用↓	拮抗作用

一般名	商品名	本剤の代謝酵素	阻害する酵素	誘導する酵素
ゾテピン	ロドピン、ロシゾピロン、メジャピン、セトウス	-	-	-
分類				
抗精神病薬				

効能・効果	用法・用量	高齢者へ投与時の影響	高齢者への投与方法
統合失調症	1日75～150mgを分割経口投与する。年齢・症状により適宜増減し、1日450mgまで増量可。	錐体外路症状等の副作用が起こりやすい。	患者の状態を観察しながら、慎重に投与すること。

薬物動態

投与24時間後には最高血清中濃度のおよそ1／10の血中濃度となる。
統合失調症患者に連続投与した場合、投与量が多くとも血清中濃度が高いとはいえず、個人差がみられる。また、投与1週間以内に血清中濃度は定常状態に達すると考えられる。

Tmax	Cmax	T1/2	AUC
100mg：1～4 hr (n=5, 統合失調症患者)	100mg：0.03～0.24 μg/mL(平均0.129 μg/mL) (n=5, 統合失調症患者)	100mg：約8 hr (n=5, 統合失調症患者)	-

併用	併用薬剤名	臨床症状・対処	機序・危険因子
禁忌	エピネフリン(ボスミン)	重篤な血圧降下	本剤のα受容体遮断作用により、β受容体刺激作用が優位となり、血圧降下作用が増強される。
注意	中枢神経抑制剤(バルビツール酸誘導体,麻酔剤等)	中枢神経抑制作用↑	相加作用
注意	降圧剤	血圧↓	相加作用
注意	抗コリン作用を有する薬剤(抗コリン性抗パーキンソン剤, 三環系抗うつ剤等)	抗コリン作用↑	相加作用
注意	メトクロプラミド	内分泌機能調節異常又は錐体外路症状	相加作用
注意	ドンペリドン	内分泌機能調節異常又は錐体外路症状	相加作用
注意	ドパミン作動薬(レボドパ等)	相互に作用↓	拮抗作用
注意	アルコール((飲酒))	相互に中枢神経抑制作用↑	相加作用

一般名	商品名	本剤の代謝酵素	阻害する酵素	誘導する酵素
チアプリド 分類 抗精神病薬	グラマリール、グリノラート、チアプリム、チアラリード、チアリール、ノイリラーク、フルジサール、ポインリール、クックール	-	-	-

効能・効果	用法・用量	高齢者へ投与時の影響	高齢者への投与方法
脳梗塞後遺症に伴う攻撃的行為、精神興奮、徘徊、せん妄の改善 特発性ジスキネジア及びパーキンソニズムに伴うジスキネジア	1日75mg～150mgを3回に分割経口投与する。年齢・症状により適宜増減。 パーキンソニズムに伴うジスキネジアの患者では、1日1回、25mgから投与を開始することが望ましい。 脳梗塞後遺症:本剤の投与期間は、臨床効果及び副作用の程度を考慮しながら慎重に決定するが、投与6週で効果が認められない場合には投与を中止すること。	本剤は、主として腎臓から排泄されるが、高齢者では腎機能が低下していることが多く、高い血中濃度が持続するおそれがあるので、副作用(錐体外路症状等)の発現に注意する。	低用量(例えば1回25mg、1日1～2回)から投与を開始するなど慎重に投与すること。

薬物動態

老年患者
老年患者(60～79歳、平均67歳)にチアプリド錠100mgを経口投与した場合、健康成人に比べ消失半減期が約1.5倍遅延したが、経口投与後の吸収は健康成人と同様に速やかであり、かつ良好であった。また、1日3回ずつの連続経口投与でも血清中濃度は投与1週間以内に定常状態に達し、蓄積傾向は認められなかった。
腎機能障害患者
腎機能障害患者にチアプリド錠100mgを経口投与した場合、Ccrの低下に伴って消失半減期は遅延し、中等度以上の腎機能障害患者(Ccr 60mL／min以下)では健康成人に比べて半減期は2倍以上になった。

Tmax	Cmax	T1/2	AUC
100mg：約 2 hr (n=6, 健康成人) 100mg：1.8±0.2 hr (mean±SE, n=6, 老年患者)	100mg：720ng/mL (n=6, 健康成人) 100mg：0.876±0.127 μg/mL (mean±SE, n=6, 老年患者)	100mg：3.91 hr (n=6, 健康成人) 100mg：5.75±0.59 hr (mean±SE, n=6, 老年患者) 100mg：21.6 hr (n=5, 高度の腎機能障害) (Ccr 0～10、平均Ccr 2.9) 100mg：8.63 hr (n=1, やや高度の腎機能障害) (Ccr 11～30、Ccr 16.0) 100mg：7.54 hr (n=3, 中等度の腎機能障害) (Ccr 31～60、平均Ccr 55.3) 100mg：4.24 hr (n=4, 軽度の腎機能障害) (Ccr 61～90、平均Ccr 69.6)	100mg：5.89±8.85 μg/mL·hr (mean±SE, n=6, 老年患者)

併用	併用薬剤名	臨床症状・対処	機序・危険因子
注意	QT延長を起こすことが知られている薬剤(ハロペリドール等)	QT延長、心室性不整脈等	相加作用(本剤もQT間隔を延長させるおそれがある)
注意	ベンザミド系薬剤(メトクロプラミド, スルピリド等)	内分泌機能調節異常又は錐体外路症状	相加作用
注意	フェノチアジン系薬剤(クロルプロマジン等)	内分泌機能調節異常又は錐体外路症状	相加作用
注意	ブチロフェノン系薬剤(ハロペリドール等)	内分泌機能調節異常又は錐体外路症状	相加作用
注意	ドパミン作動薬(レボドパ等)	相互に作用↓	拮抗作用
注意	中枢神経抑制剤(バルビツール酸誘導体, 麻酔剤等)	相互に中枢神経抑制作用↑	相加作用
注意	アルコール((飲酒))	相互に中枢神経抑制作用↑	相加作用

Ⅲ. 研究成果の刊行に関する一覧表

雑誌

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
Enomoto M, Endo T, Suenaga K, Miura N, Nakano Y, Kohtoh S, Taguchi Y, Aritake S, Higuchi S, Matsuura M, Takahashi K, Mishima K	Newly developed waist actigraphy and its sleep/wake scoring algorithm	Sleep and Biological Rhythms	In press		
Yokoyama E, Saito Y, Kaneita Y, Ohida T, Harano S, Tamaki T, Ibuka E, Kaneko A, Nakajima H, Takeda F	Association between subjective well-being and sleep among the elderly in Japan.	Sleep Medicine	9	157-164	2008

Ⅳ. 研究成果の刊行物・別刷

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ORIGINAL ARTICLE

Newly developed waist actigraphy and its sleep/wake scoring algorithm

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Abstract

The purpose of this study was to formulate an algorithm for assessing sleep/waking from activity intensities measured with a waist-worn actigraphy, the Lifecorder PLUS (LC; Suzuken Co. Ltd., Nagoya, Japan), and to test the validity of the algorithm. The study consisted of 31 healthy subjects (M/F = 20/11, mean age 31.7 years) who underwent one night of simultaneous measurement of activity intensity by LC and polysomnography (PSG). A sleep(S)/wake(W) scoring algorithm based on a linear model was determined through discriminant analysis of activity intensities measured by LC over a total of 235 h and 56 min and the corresponding PSG-based S/W data. The formulated S/W scoring algorithm was then used to score S/W during the monitoring epochs (2 min each, 7078 epochs in total) for each subject. The mean agreement rate with the corresponding PSG-based S/W data was 86.9%, with a mean sensitivity (sleep detection) of 89.4% and mean specificity (wakefulness detection) of 58.2%. The agreement rates for the individual stages of sleep were 60.6% for Stage 1, 89.3% for Stage 2, 99.2% for Stage 3 + 4, and 90.1% for Stage REM. These results demonstrate that sleep/wake activity in young to middle-aged healthy subjects can be assessed with a reliability comparable to that of conventional actigraphy through LC waist actigraphy and the optimal S/W scoring algorithm.

Key words: actigraphy, polysomnography, sleep/wake scoring algorithm, sleep-waking, waist-worn.

INTRODUCTION

An actigraphy is a small lightweight device for noninvasive and continuous monitoring of human rest/activity (sleep/wake) cycles.[1,2] The most commonly used actigraphy in current sleep research is a unit that is worn on the non-dominant wrist like a wristwatch for continuous measurement of forearm motor activity. The actigraphy unit generally consists of a piezoelectric accelerometer and a memory for storing the measured values for a specific time epoch, typically from 1 s to several minutes.

Algorithms using the activity level measured by the actigraphy to determine whether the person wearing the unit is awake or asleep during the time epoch have been developed for use with individual actigraphy units.[3–5] Studies to date investigating the agreement rate of polysomnography (PSG) and various actigraphy units in

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healthy adults have reported a very high agreement rate of 85 to 96% between the two methods with use of the optimal specific sleep/wake scoring algorithm.[3–7]

Although actigraphy is suitable for assessment of sleep/wake activity during a specific time epoch, it cannot be used independently for confirmation or diagnosis of sleep disturbances because, contrary to PSG, it does not allow for collection of data on electrooculogram (EOG), electromyogram (EMG), electrocardiogram (ECG), and breathing function during sleep.[7] On the other hand, it has a distinct advantage over PSG in that it allows for continuous recording of rest/activity (sleep/wake state) over long periods of time outside of the sleep lab with minimal disruption to the subject's normal life. It is therefore commonly used in human sleep physiology research and clinical studies in patients with insomnia and circadian rhythm sleep disorders.[8] Future beneficial applications of actigraphy include sleep disturbance screening in a large number of subjects and evaluation of the effectiveness and side effects of drug and non-drug therapies requiring continuous assessment of sleep/wake activity. Inexpensive multipurpose devices providing a favorable cost–benefit balance in the clinical setting are, however, necessary to realize these new potential applications. There have been a few previous studies that assessed sleep/wake activity using an actigraphy placed on the trunk[8,9] and the head[10] because the current mainstream wrist-worn actigraphy unit cannot be readily used in individuals with upper dystaxia, individuals with involuntary movement such as finger tremors, and children and dementia patients who may inadvertently interfere with the device. Most are also not waterproof and cannot thus readily be used in individuals whose work involves handling of water. So actigraphy units that can be worn on body sites other than the wrist, such as the trunk, are still needed.

We therefore focused our research on an inexpensive activity monitor that is worn around the waist to measure activity as a new actigraphy option in sleep research and sleep medicine. In our study, data obtained from healthy adults was used to formulate an algorithm to score sleep/waking measured by waist actigraphy and test the validity of the algorithm.

METHODS

Features of waist actigraphy

An inexpensive activity monitor that is worn around the waist (Lifecorder PLUS [LC]; Suzuken Co. Ltd., Nagoya, Japan; ¥14800 = €100 = $128) was used to measure activity level during sleep. The LC was originally developed for measurement of daytime physical-activity level and has been used for the assessment of physical-activity-related energy expenditure.[11,12] The LC measures acceleration along the longitudinal axis every 4 s with an internal piezoelectric accelerometer and classifies the intensity into 11 levels from 0 to 9 (0, 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9) every 2 min.[11] Level 0 (corresponding to <0.06 G) denotes immobility and Levels 0.5 to 9 (corresponding to ≥0.06 G) denote subtle to strong movements. The cut-off point of activity intensity (the acceleration value) for each level is not provided by the manufacturer. It is possible to continuously record the activity intensity level with the time information for at least 2 months. After the completion of measurement, the recorded activity intensity data can be downloaded to a personal computer through a USB cable. The scoring algorithm was formulated from these data.

Experimental subjects

The study consisted of 31 healthy adults (20 males and 11 females with a mean age of 31.6 ± 10.4 years). Monitoring was performed by the Sleep Electroencephalography Lab at Aoki Hospital and the Sleep/Biological Rhythm Monitoring Unit of the National Institute of Mental Health of the National Center of Neurology and Psychiatry. Subjects underwent simultaneous continuous monitoring of intensity of physical movement during sleep by PSG and LC. The study was approved by the ethics committee of the National Center of Neurology and Psychiatry. Subjects were informed of the purposes and methods of the study and gave written consent to participate in the investigation.

PSG and LC recordings

The PSG consisted of measurement of a standard electroencephalogram (C3-A2, C4-A1, O1-A2, O2-A1), EOG, chin EMG, ECG, breathing function, and tibialis anterior EMG data every 30 s. The Polymate 1524 (TEAC Corporation, Tokyo, Japan) and Comet PSG (Grass-Technologies, RI, USA) were used for the PSG. The sleep stage (Stage 1, Stage 2, Stage 3 + 4, Stage REM or Stage wake) was then determined every 30 s according to the rules of Rechtschaffen and Kales.[13] Four consecutive 30-s intervals of sleep stage data were used to assess sleep/wake state every 2 min to correspond with the intervals with LC data. When four consecutive data contained two or more of Stage wake, the data set was classified as wake (W_{PSG}) according to the definition

adopted the previous studies.[14-16] All other data sets were classified as sleep (S_{PSG}). Furthermore, S_{PSG} was subclassified as Stage REM, Stage 1, Stage 2, or Stage 3 + 4, according to the most frequent sleep stage in the data set (e.g. when S_{PSG} contained two or more Stage 1 data, it was classified as Stage 1). However, when S_{PSG} contained two of two different stages, the priority order (Stage REM → Stage 1 → Stage 2 → Stage 3 + 4) was used (e.g. when S_{PSG} contained two Stage 1 and two Stage REM, it was classified as Stage REM).

Formulation of an algorithm for assessing sleep/waking

A S/W scoring algorithm for LC was newly formulated by the discriminant analysis. The data used for the development were the datasets of S_{PSG} (=0) and W_{PSG} (=1) corresponding to the LC exercise intensities obtained from 7078 epochs obtained from 31 subjects on 31 nights over a total of 235 h and 56 min.

Taking the S/W algorithm for the present actigraphy into account, we assume the five-dimension linear model that incorporates the exercise intensities during 10 min with the center of the time epoch of interest. The activity intensities 4 min before the scored epoch, 2 min before the scored epoch, during the scored epoch, 2 min after the scored epoch, and 4 min after the scored epoch were represented by x_1, x_2, x_3, x_4, and x_5, respectively. A linear discriminant function was given as the following equation for an arbitrary set of weight coefficients of a_1, a_2, a_3, a_4, and a_5.

$$z = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5$$

Where the variable of z can be used as the discriminant score to classify a set of activity intensities into the stage of S_{LC} or W_{LC}.

The above discriminant function was determined by the discriminant analysis. Supposing that the LC activity intensity in sleeping status and in waking status are categorized in class 1 and 2, respectively, and the number of the datasets in each class is set to n_1 and n_2, the i-th ($i = 1$ to n_k) variable in class k ($k = 1, 2$), $z_i^{(k)}$ is given as

$$z_i^{(k)} = a_1x_{1i}^{(k)} + a_2x_{2i}^{(k)} + a_3x_{3i}^{(k)} + a_4x_{4i}^{(k)} + a_5x_{5i}^{(k)}.$$

The variation of $\{z_i^{(k)}\}$ is represented by the total sum of squares, S_T, which can be decomposed to the between sum of squares, S_B, and the within sum of the squares, S_W ($S_T = S_B + S_W$).

$$S_T = \sum_{k=1}^{2}\sum_{i=1}^{n_k}(z_i^{(k)} - \bar{z})^2$$

$$S_B = \sum_{k=1}^{2} n_k(\bar{z}^{(k)} - \bar{z})^2$$

$$S_W = \sum_{k=1}^{2}\sum_{i=1}^{n_k}(z_i^{(k)} - \bar{z}^{(k)})^2.$$

Since the better discriminability between the two classes using z is equivalent to the increase of the ratio of correlation, $\eta^2 = S_B / S_T$, the set of weight coefficients, $\hat{a}_1$, $\hat{a}_2$, $\hat{a}_3$, $\hat{a}_4$, $\hat{a}_5$, that gives the maximum η^2 can be calculated by the following equations:

$$\begin{bmatrix} s_{11} & s_{12} & s_{13} & s_{14} & s_{15} \\ s_{21} & s_{22} & s_{23} & s_{24} & s_{25} \\ s_{31} & s_{32} & s_{33} & s_{34} & s_{35} \\ s_{41} & s_{42} & s_{43} & s_{44} & s_{45} \\ s_{51} & s_{52} & s_{53} & s_{54} & s_{55} \end{bmatrix} \begin{bmatrix} \hat{a}_1 \\ \hat{a}_2 \\ \hat{a}_3 \\ \hat{a}_4 \\ \hat{a}_5 \end{bmatrix} = \begin{bmatrix} \bar{x}_1^{(1)} - \bar{x}_1^{(2)} \\ \bar{x}_2^{(1)} - \bar{x}_2^{(2)} \\ \bar{x}_3^{(1)} - \bar{x}_3^{(2)} \\ \bar{x}_4^{(1)} - \bar{x}_4^{(2)} \\ \bar{x}_5^{(1)} - \bar{x}_5^{(2)} \end{bmatrix}.$$

Where $\bar{x}_j^{(k)}$ is the average of the j-th variable in class k, $s_{jj'}$ is the within covariance between the j-th and j'-th variables. They are evaluated by

$$\bar{x}_j^{(k)} = \frac{1}{n_k}\sum_{i=1}^{n_k} x_{ji}^{(k)}$$

$$s_{jj'} = \frac{1}{n_1 + n_2 - 2}\sum_{k=1}^{2}\sum_{i=1}^{n_k}(x_{ji}^{(k)} - \bar{x}_j^{(k)})(x_{j'i}^{(k)} - \bar{x}_{j'}^{(k)}).$$

S/W agreement rate

The S/W scoring algorithm was used to determine the S_{LC}/W_{LC} state from the activity intensity data in a total of 7078 epochs in the 31 subjects, and the agreement rate with the corresponding S_{PSG}/W_{PSG} results was calculated by subject and sleep stage. The agreement rate with the PSG-based sleep epochs (sensitivity) and agreement rate with the PSG-based wakefulness epochs (specificity) were also calculated by subject. SPSS version 11.5 was used for the statistical analysis (SPSS Japan Inc., Tokyo, Japan). Results were expressed as mean ± SD.

RESULTS

S/W scoring algorithm

The following S/W scoring algorithm was derived from the results of discriminant analysis of the activity

Table 1 Sleep parameters scored by polysomnography (PSG) and Lifecorder (LC) data

Sleep parameters	PSG	LC	Significance
Sleep efficiency (%)	90.2 ± 9.6 (61.8–99.1)	86.8 ± 11.1 (44.1–100.0)	$t(60) = 1.26$, $P = 0.21$
Total sleep time (min)	406.6 ± 78.9 (179.3–587.0)	376.3 ± 76.3 (208.0–586.0)	$t(60) = 1.53$, $P = 0.13$
Wake after sleep onset (min)	45.2 ± 48.3 (3.67–232.7)	59.9 ± 68.5 (0–388.0)	$t(60) = 0.98$, $P = 0.33$

Table 2 Decision parameters of S/W prediction algorithm for the Lifecorder

			Number of epochs
Agreement rates (%)	Overall	86.9 ± 8.9	7078
	Stage W	58.2 ± 30.4	819
	Stage 1	60.6 ± 26.2	427
	Stage 2	89.3 ± 10.6	3694
	Stage 3 + 4	99.2 ± 2.1	838
	Stage REM	90.1 ± 17.5	1300
Sensitivity (%)		89.4 ± 10.6	
Specificity (%)		58.2 ± 30.4	
Percentage of S_{PSG} epochs misscored as W_{LC} (%)		10.6 ± 10.6	
Percentage of W_{PSG} epochs misscored as S_{LC} (%)		41.8 ± 30.4	

S, sleep; W, wakefulness.

intensity data and PSG-based sleep/wake data from the total 7078 epochs obtained from 31 subjects:

$$z = 0.635x_1 + 0.427x_2 + 0.701x_3 + 0.805x_4 + 0.718x_5$$

where $z \geq 1$ indicates wakefulness (W_{LC}) and $z < 1$ indicates sleep (S_{LC}).

The linear discriminant function was transformed in advance by using linearity of the discriminant function in such a way that the threshold (z) becomes 1. Here, x_1, x_2, x_3, x_4, and x_5, indicate the activity intensity 4 min before the scored epoch, 2 min before the scored epoch, during the scored epoch, 2 min after the scored epoch, and 4 min after the scored epoch.

Validity of the S/W scoring algorithm

The sleep parameters derived from PSG and the LC activity intensity data are shown in Table 1. Sleep efficiency, total sleep time, and wakefulness after sleep onset were each derived from PSG and the LC activity intensity data (Table 1). No statistically significant differences were observed between PSG and the LC in any of the sleep parameters.

Table 2 shows the sleep/wake agreement rates between the LC and PSG, and the sensitivity and specificity of the LC. The overall agreement rate between the LC and PSG in the 31 subjects was 86.9 ± 8.9%. By sleep stage, the Stage 1 agreement rate was low at approximately 60%, but the Stage 2, Stage REM, and Stage 3 + 4 agreement rates were high at approximately 90% for Stage 2 and Stage REM and close to 100% for Stage 3 + 4.

The S/W scoring algorithm had a mean sensitivity (S detection) of 89.4 ± 10.6% and a mean specificity (W detection) of 58.2 ± 30.4%. In other words, 10.6 ± 10.6% of S_{PSG} were misscored as W_{LC} and 41.8 ± 30.4% of W_{PSG} were misscored as S_{LC}.

Activity intensity distribution before and after the scored epoch

Figure 1 shows the mean activity intensity recorded by the LC for nine consecutive epochs (18 min) centered at the W_{PSG} epoch (averaged for a total of W_{PSG} 819 epochs obtained from 31 subjects). The mean activity intensity recorded by the LC peaked just after the W_{PSG} epoch.

DISCUSSION

In the study, an S/W scoring algorithm for the LC was formulated through linear-based discriminant analysis of the corresponding longitudinal "PSG-based sleep/wake state" and "LC-recorded activity intensity" data in 7078 epoch recordings in 31 subjects over a total of

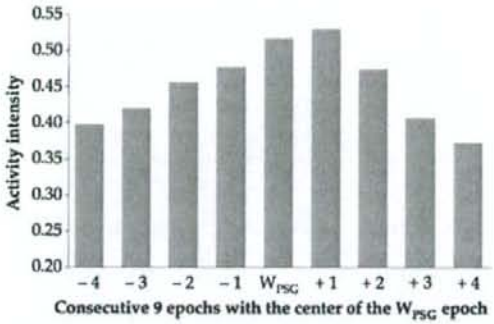

Figure 1 Activity intensity distribution before and after the scored epoch. The mean activity intensity recorded by the Lifecorder (LC) for nine consecutive epochs (18 min) centered at the W_{PSG} epoch. Vertical bars indicate the activity intensity. The mean activity intensity bars formed an inverted U-shape and peaked just after the W_{PSG} epoch.

235 h and 56 min. Comparison of the S/W activity determined from the LC data through the S/W scoring algorithm and the comparable activity determined from the PSG data through the rules of Rechtschaffen and Kales showed a mean agreement rate of approximately 87% in the 31 subjects. This rate is comparable to the 85 to 96% agreement rates obtained with conventional actigraphy units and their S/W scoring algorithms.[3–7] The LC and its S/W scoring algorithm yielded a high agreement rate of 90% or greater for Stage 2 and Stage 3 + 4 deep sleep and REM sleep, as well as an approximately 60% agreement rate for W_{PSG}, which is higher than that yielded by conventional algorithms. In order to examine the superiority of the five-dimensional model over the three-, seven-, or nine-dimensional models, we assumed linear models which incorporate the activity intensities during intervals of 6, 14, and 18 min centered at the time epoch of interest. The total agreement rates of the algorithms for the three-, five-seven-, and nine-dimensional models were 82.9%, 86.9% 86.0%, and 87.3%, respectively. Finally, we adopted the algorithm of the five-dimensional model since the agreement rate appeared to become saturated for models with more than five-dimensions. These findings show that when used with the S/W scoring algorithm developed in the study, the LC is a useful sleep assessment device with equivalent S/W identification capacity to conventional actigraphy systems.

Silent awakeness has been generally difficult to detect through actigraphic S/W assessment, in which it may be misscored as sleep, resulting in a pattern of overassessment of total sleep time and sleep efficiency compared to PSG-based assessment.[4,16,17] The LC and the S/W scoring algorithm derived in this study did not, however, result in a pattern of over-identification of S_{LC}, but contrarily yielded lower total sleep time and sleep efficiency values than the S_{PSG}/W_{PSG} assessment (Table 1). The specificity of the S/W scoring algorithm for the LC (58.2%) is in fact higher than that for conventional actigraphy units and their S/W scoring algorithms (40.6 *vs* 44%),[4,17] demonstrating that the S/W scoring algorithm for the LC developed in the study allows for more accurate identification of W_{LC}.

The S/W detection algorithm for wrist actigraphy used in a previous study assigned the highest weighting coefficient to the scored epoch.[4] However, in the S/W scoring algorithm for the LC, the highest weighting coefficient was assigned to the period immediately following the scored epoch. In fact, the mean activity intensity recorded by the LC peaked just after the W_{PSG} epoch (Fig. 1), and the delayed increase in truncal movement after awakening characterized the highest weighting coefficient assigned immediately after the scored epoch.

The LC is worn on the trunk while the conventional actigraphies used to be worn on the non-dominant wrist.[3–7] This may be related to the high specificity of the LC and its S/W scoring algorithm. The different application sites mean that S/W activity is assessed through different types of movement during sleep, either extremity or trunk movement (which are often independent),[18,19] which may produce the differences in assessment noted above. The LC and its S/W scoring algorithm investigated in the current study may more accurately detect silent awakeness due to the sensitivity to small movements of the torso during sleep and a resulting higher composite variable z value.

There are several issues that require further exploration with respect to use of the LC as a novel option for sleep assessment. First, the time epoch of S/W scoring algorithms for conventional actigraphy is often 1 min or less.[3,5,14] The time epoch for the LC used in this study is 2 min, leading to the assumption that devices with higher temporal resolution may result in higher agreement rates. Although it is more expensive (¥37 000 = €230 = $350), there is an LC that is programmable to 4-s time epochs. It would therefore be of merit to formulate an S/W scoring algorithm for this LC to determine whether it yields a higher agreement rate. Second, the S/W scoring algorithm formulated in the study uses the data from the scored time epoch as well as the data from the two epochs (4-min interval) immediately prior

and immediately after to scoring S/W. This means that activity intensity data prior to onset of sleep will be included in the scoring formula for the scored time epoch unless at least 4 min have passed from the onset of sleep on PSG. This complicates detection of differences in sleep latency of the order of several minutes. Accordingly, sleep latency was not analyzed in this study. This perhaps poses a constraint to the use of the LC in studies and tests requiring accurate evaluation of sleep latency. It is expected that development of LCs with higher temporal resolution and their S/W scoring algorithms will solve this issue.

In the current study, an S/W scoring algorithm for the LC was formulated from the data of young to middle-aged healthy adults and the validity of the algorithm was tested. Other potential useful applications of the inexpensive LC include sleep disorder screening in a large number of individuals. In the future, it will be necessary to determine whether the high agreement rates can also be obtained when the LC and its S/W scoring algorithm are used to assess sleep/wake activity in subjects from different age groups, including children and the elderly, and in patients with common sleep disorders, such as insomnia and sleep respiratory disturbances.

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Original article

Association between subjective well-being and sleep among the elderly in Japan

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Abstract

Objective: The purpose of this study was to examine the association between sleep and subjective quality of life in an elderly Japanese population.
Methods: Elderly people aged 70 years or more ($n = 1769$) were selected randomly from all areas of Japan. They were visited and interviewed in November 2003. Subjective well-being of the subjects was assessed using the Philadelphia Geriatric Center (PGC) Morale Scale. A logistic regression analysis was performed using sleep-related factors as explanatory variables.
Results: A positive linear association was observed between subjective sleep sufficiency and the mean PGC Morale Scale score. The crude and adjusted odds ratios for sleep disorders such as difficulty initiating sleep, excessive daytime sleepiness, and restless legs syndrome were significantly low. The mean score was highest for a sleep duration of 7–8 h and became lower at sleep durations of <6 and $\geqslant 9$ h (inverted U-shaped association). However, the adjusted odds ratio for sleep duration did not show a significant reduction.
Conclusions: In order to improve the subjective well-being of the elderly, better subjective sleep sufficiency and alleviation of sleep disorders are necessary. Different mechanisms may reduce subjective well-being in individuals who sleep less than 6 h or who sleep 9 h or more.

Keywords: Subjective well-being; PGC Morale Scale; Subjective sleep sufficiency; Sleep disorders; Sleep duration; Elderly in Japan

1. Introduction

Since sleep disorders have been recognized as an important public health issue in developed countries, various epidemiological studies have been conducted. Among the elderly, insomnia is a common complaint. According to a survey targeting the general adult Japanese population, 29.5% people aged 60 years or more complained of insomnia [1]. The survey revealed that in comparison with young people, the number of elderly affected by early morning awakening (EMA) or difficulty maintaining sleep (DMS) was greater [1,2]. It is considered that shallow sleep caused by aging as well as physical factors such as nocturia and physical pain induce DMS in the elderly [3]. As a result of the rapid aging of Japanese society, sleep disorders among the elderly will reduce the quality of life (QOL) and become an increasingly serious issue in the future.

Conventionally, subjective well-being has been measured for assessment of QOL in the field of healthcare

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for the elderly [4]. However, no study has yet examined the associations between subjective well-being and sleep. Sleep disorder is recognized as being closely associated with depression [5,6], and a report has suggested that there is a significant association between depression and subjective well-being [7]. Thus, examination of the association between subjective well-being and sleep is considered useful. Therefore, we examined the associations between subjective well-being and subjective sleep sufficiency, sleep disorders, and sleep duration among the elderly.

2. Subjects and methods

Nihon University Center for Information Networking has conducted a longitudinal study entitled "A Survey on Health and Lifestyle" [8]. The subjects comprised 4995 people aged 65 years or more, selected from all areas of Japan by stratified two-step random sampling. First, the sample size was established on the basis of the estimated national population within this age bracket in November 1999. Individuals aged 75 or more were doubly sampled and weighted in the calculation to ensure that the results adequately represented the elderly population of Japan.

The baseline survey was carried out in November 1999. After obtaining informed consent from the subjects, well-trained interviewers interviewed the subjects at their homes. Similar interviews were repeatedly conducted on the same subjects in November 2001 and November 2003.

The present study used only the data of a cross-sectional study conducted in November 2003. People aged 70 years or more (3248) were selected as participants (Table 1a). After eliminating participants who omitted even one answer (including those who answered "I don't know"), the data for the remaining 1769 (54.5%) were analyzed (Table 1b).

Questions from the 11-item version of the Philadelphia Geriatric Center (PGC) Morale Scale [9,10] were included in the questionnaire as indicators of subjective QOL [11]. Scoring was performed in compliance with the conventional method, and a total score was obtained [9]. Subjective well-being is judged to be better if the scores are higher.

The subjects were divided into two groups according to the PGC Morale Scale total scores. Subjects with total scores of 9 or higher (9 being the median of the total PGC Morale Scale scores) were included in the high group, and those with scores of less than 9 were included in the low group. To investigate the factors that influence subjective well-being, crude and adjusted odds ratios and 95% confidence intervals were calculated by employing univariate and multivariate logistic regression models in which the high and low groups were used as response variables.

Table 1a
Numbers of subjects classified by age group and gender (original participants)

Gender	Age (year)				
	70–74	75–79	80–84	85&over	Total
Men	441	353	365	206	1365
Women	445	450	595	393	1883
Total	886	803	960	599	3248

Table 1b
Numbers of subjects classified by age group, PGC Morale Scale score, and gender (final participants)

Gender	PGC MS#	Age (year)				
		70–74	75–79	80–84	85 over	Total
Men	High	177	126	105	45	453
	Low	103	86	82	45	316
Women	High	161	150	149	73	533
	Low	115	114	164	74	467
Total		556	476	500	237	1769

#: PGC Morale Scale: high ≧9, low <9.

The following data were obtained as socio-demographic factors: age, gender, present place of residence (urban/rural), and educational history in four grades (junior high school, including primary school under the old education system; high school, including middle school under the old educational system; vocational school or college; and university, including high school under the old education system and graduate school). Educational history was categorized using an ordinal scale from 1 to 4.

First, the association between subjective sleep sufficiency and subjective well-being was examined. We then examined the associations of each of six sleep disorders (difficulty initiating sleep [DIS], difficulty maintaining sleep [DMS], early morning awakening [EMA], sleep-enhancing medication use [SEMU], excessive daytime sleepiness [EDS], and restless legs syndrome [RLS]) with subjective well-being. The manner in which associations between the sleep disorders and subjective well-being were modified by various factors, such as subjective sleep sufficiency and self-rated health, was also examined.

Subjects were interviewed regarding their conditions during the past month. The question pertaining to subjective sleep sufficiency was "Do you obtain sufficient rest during sleep?" The following were the four optional answers to this question: (1) very sufficient, (2) sufficient, (3) insufficient, and (4) very insufficient. These four categories were regrouped into the following two categories: sufficient (1 + 2) and insufficient (3 + 4).

As to the questions on sleep disorders, in line with the questionnaires used in the previous studies [1,2,12–15], the following six questions were used in the present study:

1. "Do you have difficulty falling asleep at night?" (DIS)
2. "Do you wake up during the night after you have gone to sleep?" (DMS)
3. "Do you wake up too early in the morning and have difficulty getting back to sleep?" (EMA)
4. "Do you take any medications or use alcoholic beverages to help you sleep?" (SEMU)
5. "Do you feel excessively sleepy during the day?" (EDS)
6. "Is your sleep interrupted by a creeping sensation or hot flushes in your legs after you go to bed at night?" (RLS)

The following were the five optional answers to these questions: (1) never, (2) seldom, (3) sometimes, (4) often, and (5) always. These five categories were regrouped into the two categories: no (1 + 2) and yes (3–5).

In addition, the question pertaining to physical pain was "Do you often suffer from physical pain?" The optional answers were yes and no. The question pertaining to psychological stress was "Do you currently feel stress in your daily life?" The optional answers were yes and no. Regarding self-rated health, the question posed was "In general, how is your current health condition?" The three optional answers were good, fair, and poor [16].

The following criteria were used as covariates in the logistic regression model: age, gender, present place of residence, education history, sleep duration, six sleep disorders, physical pain, psychological stress, subjective sleep sufficiency, and self-rated health. For multivariate analyses, the following three models were created: a model in which subjective sleep sufficiency was not included among the covariates (Model 1), a model in which subjective sleep sufficiency was included (Model 2) among the covariates, and a model in which self-rated health was further included among the covariates (Model 3). All variables were applied to each model.

Based on nocturnal sleep duration, the subjects were divided into the following five categories based on their answers to the question "What is your daily average sleep duration (excluding the duration of naps)?": less than 6 h (<6 h), 6 h or longer but less than 7 h (6–7 h), 7 h or longer but less than 8 h (7–8 h), 8 h or longer but less than 9 h (8–9 h), and 9 h or longer (≥9 h). As shown in Table 4, several models were created to examine the associations between subjective well-being and sleep duration by using different combinations of the following covariates: socio-demographic factors plus six sleep disorders, psychological stress, physical pain, subjective sleep sufficiency, and self-rated health.

For statistical analyses, SAS (PC version, Ver. 8e) was employed. A variable having three or more categories was treated as a dummy variable in the analyses. The Kruskal–Wallis test and Bonferroni's correction for multiple comparisons were performed for comparison of multiple groups, and the Wilcoxon rank-sum test was performed for comparison of two groups. The level of significance was set at 5%.

3. Results

The numbers of respondents according to gender and age are shown in Tables 1a and 1b. The number of participants was 1769 (769 males (43.4%) and 1000 females (56.5%)).

Comparisons of participants' attributes and the mean PGC Morale Scale scores are shown in Table 2. The mean PGC scores decreased as age increased. The mean score for males was higher than that for females. No difference was observed with regard to current place of residence. The mean PGC score increased significantly with improved educational history. Every sleep disorder was significantly associated with the PGC score. With regard to the mean scores calculated by taking into consideration sleep duration, the mean score was highest for a sleep duration of 7–8 h. The mean scores were significantly lower for sleep durations of <6 and ≥9 h.

The association between subjective sleep sufficiency and the mean values of PGC scores is shown in Fig. 1. As subjective sleep sufficiency ameliorated, the mean values increased. A positive linear association was observed between subjective sleep sufficiency and PGC score.

The mean PGC Morale Scale scores plotted against sleep duration are shown in Fig. 2. The mean value was highest for a sleep duration of 7–8 h, and was decreased for sleep durations of <6 and ≥9 h, giving an inverted U-shaped association. There were significant differences between the mean PGC scores for sleep durations of 7–8 h and <6 h and those for sleep durations of 7–8 and ≥9 h.

The results of logistic regression analysis with regard to the associations of the PGC Morale Scale scores with socio-demographic indices and sleep-related factors are shown in Table 3. With regard to age, the odds ratio of PGC scores for subjects aged 70–74 years was used as a reference. No significant difference was recognized when comparing the adjusted odds ratios of other age groups with the reference. Similarly, no significant difference was recognized among the adjusted odds ratios for gender. However, with regard to educational history, as observed in the comparison of the mean PGC scores, the adjusted odds ratios also showed a significant association. The adjusted odds ratios for the PGC scores increased with improved educational history.

The influences of adjustments when the covariates of sleep disorders were used in the analyses are shown in Table 3. The crude odds ratios with regard to PGC scores showed significant associations with sleep disorders and the adjusted odds ratios with regard to PGC scores for DIS, EDS, and RLS were significantly lower

Table 2
Proportions and mean PGC Morale Scale scores of participants according to attributes and sleep-related items

Items	Category	Percentage of category (%)	Comparison of PGC scores			
			Mean ± SD		*p*-value	
Age (year)	70–74	42.2	8.59	2.4	<0.001	#1(KW)
	75–79	30.7	8.35	2.5		
	80–84	18.3	8.13	2.5		
	85+	8.9	7.88	2.6		
Gender	Women	54.9	8.14	2.6	0.003	#2
	Men	45.1	8.50	2.4		
Sleep duration (hours)	<6	9.6	7.82	3.0	#3	#1(MC)
	6–7	17.9	8.48	2.4		
	7–8	22.5	8.68	2.4		
	8–9	30.7	8.60	2.3		
	9+	19.4	8.01	2.6		
Place of residence	Urban	62.4	8.37	2.5	0.1991	#2
	Rural	37.6	8.22	2.5		
Educational history	Junior high school	60.0	8.07	2.6	<0.001	#1(KW)
	High school	30.8	8.59	2.3		
	Vocational school/College	2.9	8.81	2.3		
	University	6.3	9.16	2.3		
Physical pain	Yes	32.9	7.56	2.7	<0.001	#2
	No	67.1	8.76	2.3		
Psychological stress	Yes	23.3	6.55	2.9	<0.001	#2
	No	76.7	8.91	2.2		
Subjective sleep sufficiency	Very sufficient	51.0	8.93	2.1	#4	#1(MC)
	Sufficient	38.7	8.20	2.6		
	Insufficient	9.6	6.61	3.0		
	Very insufficient	0.7	5.75	3.3		
Difficulty initiating sleep (DIS)	Yes	35.4	7.37	2.8	<0.001	#2
	No	64.6	8.79	2.2		
Difficulty maintaining sleep (DMS)	Yes	63.1	8.19	2.6	<0.001	#2
	No	36.9	8.84	2.3		
Early morning awakening (EMA)	Yes	34.0	7.74	2.8	<0.001	#2
	No	66.0	8.70	2.2		
Sleep enhancing medication use (SEMU)	Yes	19.0	7.25	2.9	<0.001	#2
	No	81.0	8.51	2.4		
Excessive daytime sleepiness (EDS)	Yes	40.7	7.83	2.7	<0.001	#2
	No	59.3	8.54	2.4		
Restless legs syndrome (RLS)	Yes	11.4	6.87	2.9	<0.001	#2
	No	88.6	8.50	2.4		
Self-rated health	Good	30.8	9.31	2.2	<0.001	#1(KW)
	Fair	42.8	8.66	2.1		
	Poor	26.4	6.78	2.8		

#1:Kruskal–Wallis test(KW) and Wilcoxon rank-sum test with Bonferroni's correction for multiple comparison(MC).
#2:Wilcoxon rank-sum test.
#3: Refer to Fig. 2.
#4: Refer to Fig. 1.

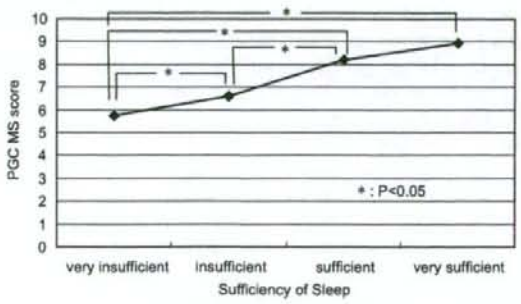

Fig. 1. Mean values of PGC Morale Scale scores according to the level of subjective sleep sufficiency.

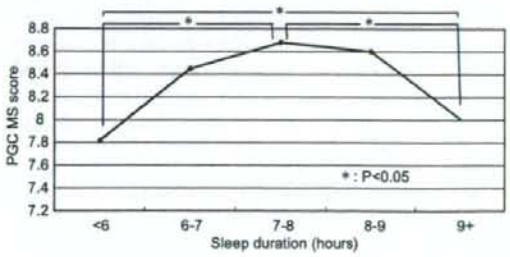

Fig. 2. Mean values of PGC Morale Scale scores according to sleep duration.

Table 3
Analysis of association between the PGC Morale Scale scores and sleep-related items using logistic regression analysis $

Items	Category	Crude				Adjusted (Model 1)#1				Adjusted (Model 2)#2				Adjusted (Model 3)#3			
		Odds ratio	95%CI‡		p-value	Odds ratio	95%CI		p-value	Odds ratio	95%CI		p-value	Odds ratio	95%CI		p-value
			lower	upper			lower	upper			lower	upper			lower	upper	
Age (year)	70–74	1.000§				1.000				1.000				1.000			
	75–79	1.010	0.817	1.248	0.926	1.014	0.797	1.290	0.911	1.012	0.794	1.291	0.923	1.057	0.824	1.356	0.661
	80+	0.718	0.560	0.922	0.009	0.801	0.602	1.066	0.129	0.780	0.584	1.040	0.091	0.814	0.605	1.095	0.173
Gender	Women	0.814	0.676	0.980	0.029	1.076	0.864	1.340	0.511	1.075	0.862	1.341	0.521	1.051	0.837	1.319	0.669
	Men	1.000				1.000				1.000				1.000			
Sleep duration (hours)	<6	0.499	0.376	0.663	<0.001	0.867	0.580	1.296	0.487	1.051	0.692	1.595	0.817	1.056	0.688	1.621	0.804
	6–7	0.721	0.572	0.910	0.006	0.997	0.719	1.382	0.984	1.056	0.759	1.471	0.745	1.027	0.732	1.440	0.878
	7–8	1.000				1.000				1.000				1.000			
	8–9	0.941	0.765	1.159	0.569	0.932	0.696	1.247	0.634	0.932	0.696	1.248	0.637	0.932	0.691	1.257	0.647
	9+	0.632	0.497	0.803	<0.001	0.649	0.465	0.907	0.011	0.653	0.467	0.913	0.013	0.729	0.516	1.031	0.074
Place of residence	Urban	0.771	0.661	0.900	0.001	0.902	0.719	1.132	0.372	0.875	0.696	1.099	0.251	0.881	0.697	1.114	0.289
	Rural	1.000				1.000				1.000				1.000			
Educational history	by 1 step	1.319	1.174	1.483	<0.001	1.306	1.137	1.499	<0.001	1.285	1.118	1.478	<0.001	1.242	1.076	1.434	0.003
Physical pain	Yes	0.436	0.371	0.514	<0.001	0.646	0.512	0.815	<0.001	0.667	0.527	0.844	0.001	0.825	0.645	1.056	0.127
	No	1.000				1.000				1.000				1.000			
Psychological stress	Yes	0.209	0.171	0.255	<0.001	0.241	0.184	0.316	<0.001	0.252	0.192	0.331	<0.001	0.274	0.207	0.363	<0.001
	No	1.000				1.000				1.000				1.000			
Difficulty initiating sleep(DIS)	Yes	0.580	0.505	0.420	<0.001	0.612	0.477	0.787	<0.001	0.627	0.487	0.808	<0.001	0.622	0.480	0.807	<0.001
	No	1.000				1.000				1.000				1.000			
Difficulty maintaining sleep(DMS)	Yes	0.531	0.451	0.626	<0.001	0.929	0.729	1.183	0.549	0.946	0.741	1.206	0.652	0.919	0.717	1.179	0.508
	No	1.000				1.000				1.000				1.000			
Early morning awakening(EMA)	Yes	0.423	0.360	0.497	<0.001	0.766	0.599	0.980	0.034	0.807	0.629	1.036	0.092	0.870	0.673	1.123	0.285
	No	1.000				1.000				1.000				1.000			
Sleep enhancing medication use (SEMU)	Yes	0.464	0.381	0.565	<0.001	0.744	0.554	1.000	0.049	0.752	0.558	1.014	0.062	0.851	0.625	1.159	0.306
	No	1.000				1.000				1.000				1.000			
Excessive daytime sleepiness(EDS)	Yes	0.543	0.464	0.634	<0.001	0.689	0.552	0.861	0.001	0.724	0.578	0.907	0.005	0.783	0.621	0.981	0.038
	No	1.000				1.000				1.000				1.000			
Restless legs syndrome(RLS)	Yes	0.726	0.662	0.796	<0.001	0.583	0.419	0.812	0.001	0.573	0.410	0.802	0.001	0.678	0.480	0.957	0.027
	No	1.000				1.000				1.000				1.000			
Subjective sleep sufficiency	Sufficient	1.000								1.000				1.000			
	Insufficient	0.244	0.176	0.340	<0.001					0.399	0.269	0.592	<0.001	0.472	0.315	0.707	<0.001
Self-rated health	Good	1.000												1.000			
	Fair	0.484	0.382	0.612	<0.001									0.604	0.467	0.780	<0.001
	Poor	0.141	0.107	0.185	<0.001									0.253	0.185	0.346	<0.001

$: Univariate and multivariate logistic regression analysis, Response variable: PGC Morale Scale score ≧9.
#1: Model 1 includes all variables except self-rated health and subjective sleep sufficiency.
#2: Model 2 includes all variables except self-rated health.
#3: Model 3 includes all variables for adjustment.
‡: CI, Confidence interval.
§: Reference.

in all models. No significant association was recognized in the adjusted odds ratios for DMS in Model 1. Significant associations disappeared in adjusted odds ratios for EMA and SEMU in Model 2.

When the crude odds ratio for a sleep duration of 7–8 h was used as the reference, the crude odds ratios for sleep durations of <6 and ⩾9 h were significantly lower. An inverted U-shaped association was observed, as shown in Fig. 2. Similarly, in Model 1, the adjusted odds ratio showed an inverted U-shaped association, and the adjusted odds ratio for a sleep duration of ⩾9 h was significantly lower. However, in Model 2, an inverted U-shaped association of the adjusted odds ratio was not recognized, and in particular, there was no tendency for the odds ratio to be lower for a sleep duration of <6 h. In Model 3, there was no tendency for the adjusted odds ratios to be lower for sleep durations of <6 and ⩾9 h. Therefore, various models were created using different combinations of covariates (Tables 3 and 4). Based on this table, we concluded that the covariates influencing the lowering trend of the odds ratio for a sleep duration of <6 h were (1) existence of DIS, (2) psychological stress combined with sleep disorders, (3) poor subjective sleep sufficiency, and (4) an association with the level of self-rated health. The level of self-rated health was suggested to be a factor that influenced the lowering trend of the odds ratio for a sleep duration of ⩾9 h.

4. Discussion

This is the first report to have examined the associations between PGC scores and sleep.

"The level of happy aging" is generally termed as "subjective well-being." Up to now, the most widely used measure for evaluating this condition has been the PGC Morale Scale developed by Lawton [9]. Studies of the Japanese version have also yielded sufficient validity and reliability. This scale is intended to evaluate morale in terms of three constituent factors subdivided into 11 items: agitation (4 items); attitude toward own aging (3 items); and lonely dissatisfaction (4 items). The total score thus obtained represents the examinee's subjective well-being. According to a comparative study of the 11-item PGC Morale Scale conducted in Japan and the United States [11], factor analysis demonstrated that the factorial structure did not differ significantly. In the present investigation, therefore, we used the 11-item PGC Morale Scale to study subjective well-being.

Table 4
Adjusted odds ratios for PGC Morale Scale scores according to sleep duration using various combinations of covariates and changes in their statistical significances ¶

Combination of covariates#	Sleep duration (hour)				
	<6	6–7	7–8	8–9	9⩽
Base	0.603*	0.819	1†	1.012	0.669*
Base + DIS	0.730	0.921	1	0.636	0.387*
Base + DMS	0.635*	0.836	1	1.012	0.692*
Base + EMA	0.669*	0.853	1	0.974	0.651*
Base + SEMU	0.671*	0.829	1	1.020	0.694*
Base + EDS	0.629*	0.818	1	0.996	0.689*
Base + RLS	0.622*	0.821	1	1.032	0.712*
Base + Stress	0.672*	0.883	1	1.004	0.684*
Base + Stress + DIS	0.781	0.956	1	0.959	0.672*
Base + Stress + DMS	0.704	0.894	1	1.010	0.729*
Base + Stress + EMA	0.730	0.901	1	0.985	0.693*
Base + Stress + SEMU	0.731	0.885	1	1.000	0.726*
Base + Stress + EDS	0.702	0.883	1	0.999	0.721*
Base + Stress + RLS	0.689	0.874	1	1.022	0.739
Base + Pain	0.647*	0.828	1	0.972	0.677*
Base + Pain + DIS	0.758	0.925	1	0.931	0.628*
Base + Pain + DMS	0.673*	0.849	1	0.973	0.678*
Base + Pain + EMA	0.704	0.861	1	0.939	0.639*
Base + Pain + SEMU	0.706	0.842	1	0.981	0.679*
Base + Pain + EDS	0.668*	0.832	1	0.958	0.675*
Base + Pain + RLS	0.661*	0.836	1	0.994	0.696*
Base + Sufficiency	0.839	0.907	1	0.988	0.653*
Base + Sufficiency + Stress	0.897	0.945	1	1.000	0.715*
Base + Health	0.710	0.841	1	1.025	0.795
Base + Health + Sufficiency	1.054	1.017	1	0.952	0.761

#: Covariates: Base: [Age + Gender + Place of residence + Educational history], Stress: Psychological stress, Pain: Physical pain, Sufficiency: Subjective sleep sufficiency Health: Self-rated health.
¶: Multivariate logistic regression analysis, Response variable: PGC Morale Scale score⩾9.
*: $p \leqq 0.05$.
†:Sleep duration: 7–8 h as a reference.

With regard to the association between subjective sleep sufficiency and PGC score, the mean score values increased with increasing subjective sleep sufficiency. There was a positive linear association between subjective well-being and subjective sleep sufficiency. Moreover, a similar association was observed with regard to the adjusted odds ratios in Model 3. Thus, it was indicated that an improvement in subjective sleep sufficiency, a qualitative parameter, must be considered to improve subjective well-being.

With regard to sleep disorders, since subjective well-being was significantly associated with DIS, EDS, and RLS in the logistic regression model, it was suggested that these sleep disorders had an independent and strong association with deterioration in subjective well-being. Conventionally, it is believed that DMS and EMA are common among the elderly [1,2]. The fact that DMS and EMA were not associated with subjective well-being may be because both are extremely common symptoms among the elderly and are not particularly recognized as irritants.

Among the sleep disorders included in this study, DIS was the strongest factor associated with deterioration in subjective well-being. A previous study has reported a significant association between DIS and depression, but not between DMS/EMA and depression, among the Japanese elderly [6]. Thus, depression among the Japanese elderly may affect their subjective well-being. Another study supports this inference of an association between depression and subjective well-being [7]. A similar trend may apply to sleep disorders that are associated with depression and subjective well-being.

In Model 2, after the odds ratios had been adjusted for subjective sleep sufficiency, no significant associations were observed between the EMA/SEMU and PGC scores. This suggests that if subjective sleep is sufficient, EMA and SEMU may not be associated with deterioration in subjective well-being.

The strong association of EDS with deterioration in subjective well-being may be due to the fact that (1) EDS is a symptom that may be caused by various sleep disorders, (2) it is strongly associated with depression, and (3) a previous study has reported that EDS is also associated with RLS [2].

A strong significant association was observed between RLS [17] and subjective well-being, and a previous study has reported an association between depression and RLS [7] among Japanese elderly men. Here, too, a depressive state may be involved.

The present study is the first to indicate that there are strong associations between subjective well-being and DIS/EDS/RLS, and that the associations of subjective well-being with DMS, EMA, and SEMU could be modified by using variables for adjustment.

With regard to sleep duration, previous studies that examined associations between subjective indices (such as mortality) and sleep duration obtained dissimilar results. Many studies have reported that health level was maximal for a sleep duration of 7–8 h and became lower for sleep durations that were shorter or longer (U-shaped association) [18,19]. However, some studies have reported gender-specific differences in whether or not a U-shaped association was observed [20,21]. Some other studies have reported no U-shaped association [22]. With regard to associations between objective indices using the Center for Epidemiologic Studies Depression Scale (CES-D) scores and sleep duration, a U-shaped association has been reported, the scores being lowest for a sleep duration of 6–8 h [5]. Therefore, in the present study, analyses were performed to clarify if there was an inverted U-shaped association between subjective well-being and sleep duration and, if present, to identify the mechanism that contributed to this association.

With regard to the association between subjective well-being and sleep duration, the mean values of the PGC scores (measurement of subjective well-being) showed an inverted U-shaped association, with the peak occurring at a sleep duration of 7–8 h. Based on this, it is inferred that for better subjective well-being, it is important to ensure appropriate sleep duration. However, the adjusted odds ratios for sleep duration in Model 2, in which psychological stress and subjective sleep sufficiency were added as variables for adjustment, did not show an inverted U-shaped association. However, significant lowering of the odds ratio at a sleep duration of $\geqslant 9$ h was observed. This suggests that for better subjective well-being, mitigation of psychological stress and a higher level of sleep sufficiency are important, regardless of sleep duration. It also suggests that subjective well-being of those whose sleep duration was <6 h is not deteriorated if measures are taken to alleviate both psychological stress and sleep disorders and if the subjective sleep sufficiency is high. It also suggests that the subjective well-being of those whose sleep durations are <6 or $\geqslant 9$ h can be modified by self-rated health, a known strong predictor of prognosis [16]. Furthermore, deterioration in health is always associated with a deterioration in QOL, regardless of sleep duration.

Briefly, as shown in this study, it is suggested that a universal association (U-shaped or inverted U-shaped association) exists between subjective well-being and sleep duration, which is similar to the association observed between mortality and sleep duration, and that it can be modified by various factors. It is also suggested that different factors are involved in the modification of subjective well-being for sleep durations of <6 and $\geqslant 9$ h. In order to improve subjective well-being, it is necessary to elucidate its associations with these factors. Further studies with this objective are expected.