Allergology International (2002) **51**: 39–45

Original Article

Inverse association between daily activity and sleep activity and related factors in elderly patients with chronic obstructive pulmonary disease and bronchial asthma

Kozui Kida, Tomoko Oozeki and Hideki Katsura

Pulmonary Division, Tokyo Metropolitan Geriatric Medical Center, Department of Nutrition, Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan

Abstract

Background: To test the hypothesis that both daily activities and sleep quality may be mutually disturbed in elderly subjects with chronic obstructive pulmonary disease (COPD) or bronchial asthma (BA) and to determine factor(s) that relate to deterioration.

Methods: Elderly subjects with chronic airflow obstruction (group R; $n = 60$), consisting of COPD and BA, were compared with subjects without respiratory symptoms (group C; $n = 53$). Both daily activities and sleep quality were assessed by force–gravity (GF) measurement using an accelerometer.

Results: The night study showed that both total sleeping period and frequency of GF in group R were increased significantly compared with group C. Subjects with BA showed fewer movements differing from those in COPD subjects. The daytime study indicated that the frequency of GF was greater in group C than in group R, suggesting reduced daily activities in group R. Subjects with BA showed more movement than COPD subjects. Hypercapnia was a significant factor causing COPD subjects to move more frequently during sleep and a decrease in peak flow rate was a significant factor in the reduction of movement during the day in subjects with BA.

Conclusions: It is assumed that elderly subjects with COPD or bronchial asthma require a longer sleep period than subjects without respiratory symptoms because of the deterioration of sleep quality in the former group and the sleeping pattern differs between subjects with COPD and BA. Hypercapnia is considered a possible factor disturbing sleeping quality in COPD, whereas decreased peak expiratory flow rate is a factor reducing daytime activities in subjects with BA.

Key words: bronchial asthma, chronic obstructive pulmonary disease, daily activities, elderly patients, sleep quality.

Introduction

Patients with chronic obstructive pulmonary disease (COPD) and bronchial asthma (BA) may demonstrate nocturnal alterations in ventilation and gas exchange related to the development of bronchospasm or unrelated to bronchospasm or to changes in airway resistance.[1] Nocturnal hypoxemia and hypoventilation may occur in subjects with severe COPD alone, but these changes are usually most pronounced when coexisting obesity and obstructive sleep apnea are present.[2] In such cases, which are often referred to as overlap syndrome, treatment that effectively eliminates obstructive sleep apnea is often sufficient to reduce the consequences of daytime hypercapnia and right ventricular dysfunction.[3] Elderly patients with COPD are prone to occasional sleep disorders or are at high risk for sleep apnea syndrome.[4–6] It has been reported that impaired night-time sleep quality may increase the risk of sudden death due to fatal

Correspondence: Dr Kozui Kida, Pulmonary Division, Tokyo Metropolitan Geriatric Medical Centre, 35-2 Sakae-cho, Itabashi-ku, Tokyo 173-0015, Japan.
Email: kkida@tmgh.metro.tokyo.jp

Received 2 July 2001. Accepted for publication 27 November 2001.

arrhythmias or severe hypoxemia during sleep.[1] However, most subjects with asthma waken with nocturnal asthma from time to time and even stable asthma impairs nocturnal sleep quality as well as daytime cognitive performance.[7] During the daytime, compensatory sleep may occur and, subsequently, a deterioration in the activities of daily living may occur in subjects with COPD or BA.

We tested the hypothesis that both daily activities and sleep quality may be mutually affected in elderly subjects with COPD or BA. If so, it would be useful to identify any causal factors. To assess small movements of the trunk during sleep and during the day we used a non-invasive monitor, namely an accelerometer.

METHODS

Between April 1996 and October 1996, consecutive patients consulting the outpatient clinic of the Pulmonary Division of the Tokyo Metropolitan Geriatric Medical Center (TMGMC), Tokyo, Japan, were screened to determine their eligibility for inclusion in the study. To be eligible, patients had to: (i) be over 60 years of age; (ii) be followed at the outpatient clinic of the Pulmonary Division of TMGMC; and (iii) have a clinical diagnosis of BA or COPD. All subjects with one of the above diagnoses were classified as having chronic airflow obstruction and designated as group R.

Chronic obstructive pulmonary disease and BA were diagnosed in accordance with the respective definitions of the recently published American Thoracic Society.[8] Because differentiation of COPD from BA in elderly subjects maybe controversial, special attention was paid to smoking history to distinguish COPD and to testing the bronchodilator response (greater 15% or 200 mL) to distinguish BA.[9]

A control group, elderly subjects with hypertension receiving regular regimens and without any respiratory symptoms (group C; $n = 53$) from whom similar informed consent was obtained, were compared with group R subjects. Prior to the study, subjects in groups R and C were selected at random without any criteria other than age, which was restricted to over 60 years.

Subjects were enrolled after obtaining appropriate informed consent from the subjects themselves or from their care givers. The study was approved by the ethics committee of the Institute.

Spirometry was performed with appropriate attention to elderly subjects, as described previously.[10] Arterial blood gas was simultaneously measured while breathing room air in a supine position. Pulmonary function tests and arterial blood gases were measured for all group R subjects.

Cognitive function was measured by the Mini-Mental State Examination (MMSE).[11]

Activities of daily living (ADL) were measured for basic ADL (BADL) which mainly reflects the basic or minimum daily activity (e.g. toilet, eating or bathing) and instrumental ADL (IADL), which mainly reflects active daily activity (e.g. shopping or hobby), as described previously.[12]

The accelerometer (GMS Co., Tokyo, Japan), which is designed to select the desired threshold of gravity–forces 0.02 *g*, along with the average gravity–force per minute, was fit on a belt at the iliac level. As described previously,[13] it is considered unlikely that the accelerometer would disturb the daily activities of subjects. However, each subject received careful advice by a trained nurse that the accelerometer should remain mobile on the body trunk, but should not touch the bed sheet in the absence of movement during the night. Measurements were obtained continuously for 48 h, but only the data from the second day were used to avoid the effect of the first day. All records obtained by the accelerometer were analyzed using a personal computer and appropriate software (GMS Co.).

The start of 'sleep' was defined as the point where continuous recording data changed from a vertical pattern (active mode) to a horizontal pattern (resting mode); similarly, 'waking' was defined as the time of change from a horizontal pattern to a vertical pattern. Total sleep period (TSP) was calculated using these points. Unrelated to the accelerometer recording, each subject was requested to log his own activity in detail, such as bathing, use of the toilet and eating, throughout each test day. Based on the logs and the accelerometer record in combination, these data were used to determine precisely the times of sleeping and waking.

The remaining time after subtracting TSP was defined as daytime.

To identify factors that influence the higher frequency of GF between group R and group C subjects or between COPD and subjects with BA, all 23 variables presented in Table 1 of pulmonary function and arterial blood gas were compared by stepwise logistic regression.

Results are expressed as the mean±SEM. We conducted categorical analysis using the Chi-squared test or Fisher's exact test. Group means were compared by analysis of variance (ANOVA) followed by multiple comparison of means by Fisher's least-significance procedures. All

statistical tests were two-tailed and $P < 0.05$ was considered significant. When a significant difference in age or gender distribution was observed, an adjustment calculation was made.

RESULTS

The mean age of group R subjects ($n = 64$) was 76.7 ± 0.9 years (range: 65–88 years), which was higher than that of group C subjects (34 males and 19 females; mean age 71.4 ± 1.0 years, range 65–90 years; $n = 53$; $P < 0.001$). Therefore, an age-adjustment calculation was made to avoid the effect of age difference in comparison with group C.

Background data of subjects with COPD and BA in group R are shown in Table 2. Group R consisted of COPD ($n = 46$; 37 males and nine females) and BA ($n = 18$; eight males and 10 females).

There was no significant difference in the distribution of males and females or in age between groups R and C or the subgroups of COPD and BA within group R, although there was a difference in gender distribution, with men accounting for 80.4% of COPD and 44.4% of subjects with BA.

Cognitive function data, as shown by MMSE, ADL, including BADL and IADL, pulmonary function test data and arterial blood gas values for subjects with COPD and BA did not differ significantly.

Sleep study

Mean TSP in group R subjects was significantly longer than that in group C subjects (509.3 ± 11.8 *vs* 478.9 ± 14.5 min, respectively; $P < 0.04$).

The mean frequency of 0.02 *g* during TSP was compared between groups R and C. It was assumed that sleep quality may differ at the onset or near waking and the total sleep time may differ from person to person. Therefore, total sleep time was divided equally into eight parts for all subjects. The frequencies of 0.02 *g* per min was transformed to a log-scale for convenience of calculation.

Data on the frequencies of 0.02 *g* in all but the first (L1) and last (L8) parts were significantly larger in group R than in group C (Fig. 1). Because there was a difference in mean age between the two groups, all data were adjusted for age and gender ratio between groups R and C; however, the significance of the difference remained the same (data not shown).

Table 2 Cognitive function, activities of daily living, pulmonary function and arterial blood gas data

	COPD ($n = 43$)	BA ($n = 17$)
MMSE	26.88 ± 0.54	24.88 ± 1.26
BADL	19.72 ± 0.11	19.63 ± 0.38
IADL	21.52 ± 1.02	27.63 ± 0.96
VC	2.30 ± 0.13	2.36 ± 0.17
%VC	84.00 ± 3.77	96.35 ± 4.53
$FEV_{1.0}$	1.01 ± 0.07	1.25 ± 0.09
$FEV_{1.0}$/FVC (%)	52.72 ± 2.53	60.06 ± 4.11
$FEV_{1.0}$% predicted	43.83 ± 4.33	66.02 ± 10.50
P_aO_2	75.56 ± 2.06	80.88 ± 1.71
P_aCO_2	43.52 ± 1.10	40.28 ± 0.80

MMSE, Mini-Mental State Examination; BADL, basic activities of daily living; IADL, instrumental activities of daily living; VC, vital capacity; $FEV_{1.0}$, forced expiratory volume in 1 s; FVC, functional vital capacity.

Table 1 Parameters and stepwise analysis to detect factors contributing to the increase 0.02 *g* in chronic airflow obstruction

Parameter			
Vital capacity (VC)	Resudual volume/total lung capacity (RV/TLC)	$\dot{V}_{50}$	pH
		$\dot{V}_{25}$	P_aCO_2
Resudual volume (RV)			P_aO_2
	Tidal volume (TV)		HCO_3
Functional resudual capacity (FRC)	Minute ventilation (MV)		O_2 saturation
	Respiratory rate (RR)		Aa-DO_2
Total lung capacity (TLC)	Functional vital capacity (FVC)		
	FEV_1	Maximal voluntary ventilation (MVV)	BMI
	FEV_1/FVC		
	Maximum mid-expiratory flow (MMF)		
	Peak expiratory flow rate (PF)		

FEV_1, forced expiratory volume in 1 s; BMI, body mass index.

Among patients in group R, there was a trend for subjects with BA to show greater frequency than COPD subjects (Fig. 2) at the initial L1–2 and last parts L7–8, thus showing a U-shaped pattern; however, this was inverse at L5, suggesting that patients with BA showed more fluctuations during sleep than COPD subjects.

To determine the factors that influence the higher frequency in group R subjects compared with group C subjects, all 23 variables (Table 1) were compared for mean frequency during L1–8 by stepwise regression. Among all the variables, only the increase in P_aCO_2 was significant ($P < 0.02$) in COPD subjects but not in subjects with BA.

Daytime study

Hours in the daytime were calculated by subtracting the TSP from 24 h. Mean counts of 0.02 *g* for the total daily hours were calculated and each count over the mean count per 1 min was calculated and designated as 'NCV'. The NCV was greater in group C than in group R ($P < 0.05$; Fig. 3). When the NCV was compared between BA and COPD, the former was larger than the latter ($P < 0.02$; Fig. 4). The NCV and both forced expiratory volume in 1 s ($FEV_{1.0}$) and peak expiratory flow rate

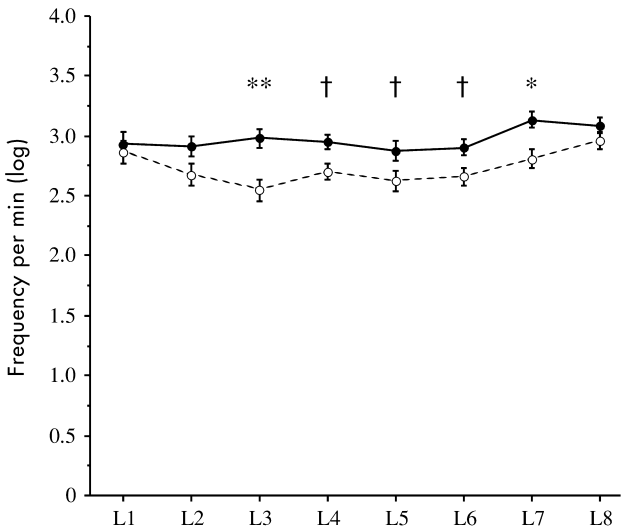

Fig. 1 Comparisons between groups and of chronic airflow obstruction combined with chronic obstructive pulmonary disease and bronchial asthma (group R; —●—) and control groups (group C; ---○---) during sleep. Data on the frequencies of 0.02 *g* during sleep in all but the first (L1) and last (L8) parts were significantly larger in the group with chronic airflow obstruction (group R) than in the non-respiratory control group (group C). †$P < 0.05$; *$P < 0.01$; **$P < 0.001$.

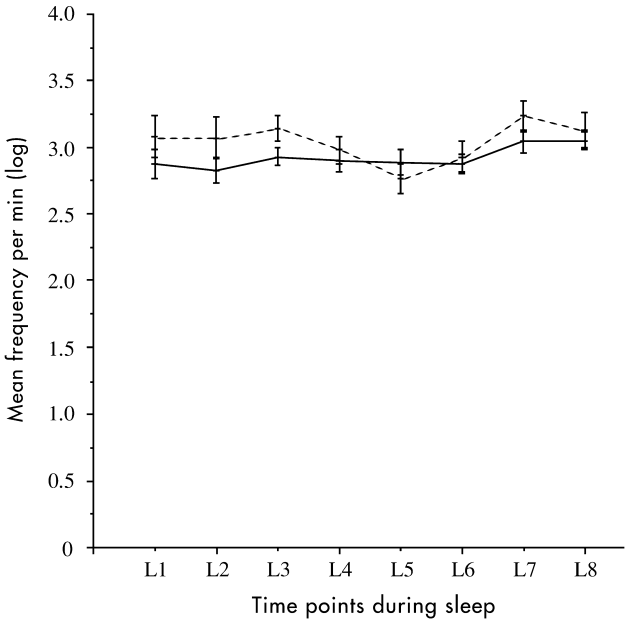

Fig. 2 Comparisons among groups of chronic obstructive pulmonary disease (COPD; —+—) and bronchial asthma (BA; (---+--- patients during sleep. Among patients with COPD and BA, there was a tendency for asthma patients to show a greater frequency of movement than COPD patients at the initial L1–L2 and last parts L7–8, thus showing a U-shaped pattern during sleep. However, there was an inverse tendency at L5, suggesting that patients with BA showed a greater frequency of movement at the mid-point of sleep than did COPD patients.

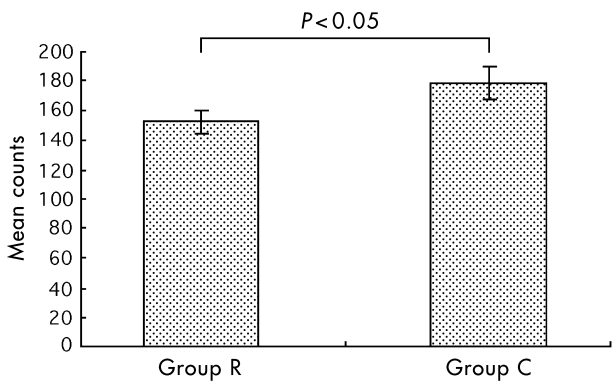

Fig. 3 Comparisons between groups with chronic airflow obstruction combined with chronic obstructive pulmonary disease (COPD) and bronchial asthma (BA) and the control group during the daytime. Rest hours in the daytime was calculated by subtracting total hours for sleeping time from 24 h for each patient. Mean counts of 0.02 *g* for all daytime hours was calculated and each count exceeding the mean for 1 min was calculated and designated as 'NCV' (see text). The NCV was greater in the control group without respiratory symptoms than in the groups with chronic airflow obstruction combined with COPD and BA ($P < 0.05$).

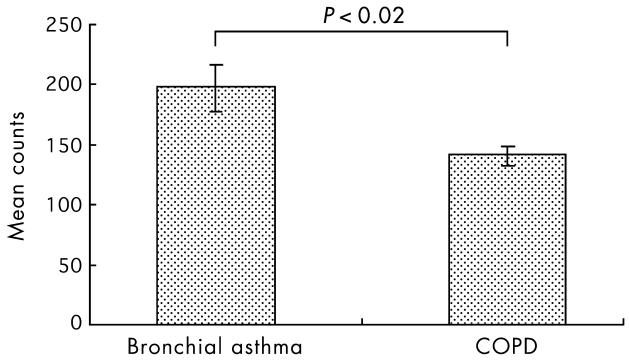

Fig. 4 Comparison of daily movement as assessed by the accelerometer between patients with chronic obstructive pulmonary disease (COPD) and bronchial asthma (BA). When NCV (see text) was compared between BA and COPD patients, the measurement in the former group was larger than that in the latter group ($P < 0.02$).

were significantly correlated (both $P < 0.02$). Stepwise analysis revealed that only the peak expiratory flow rate contributes significantly to changes in NCV ($P < 0.02$).

Discussion

The present study first clarified that both daily and nocturnal movements were mutually affected in subjects with BA or COPD and values of peak expiratory flow rate and hypercapnia were considered factors affected by BA and COPD, respectively.

Our study design has several limitations that may have influenced our results. The present study used an accelerometer to assess both ADL and sleep quality. This device has the advantage of being small, handy, non-invasive and inexpensive. It is easy to obtain subject cooperation because it requires only minimum disturbance of the usual life pattern and repeated examinations are possible. An actigraph was obtained from accelerometer measurements, which has been used to study insomnia,[14] depression[15] or nocturnal blood pressure dipping,[16] in order to assess sleep quality. It has been reported that data obtained by the accelerometer are well correlated with polysomnographic data[17,18] and that the accelerometer provides more objective information about sleep than do sleep logs.[14] Accelerometer data can also be used to assess daytime activity.[19] Although accelerometers used in previous studies were fitted onto the wrist, the present study fitted the accelerometer onto a belt at the iliac level to avoid touching the bed sheet in the absence of movement during the night. This seemed more reasonable for detecting trunk movements rather than wrist movements alone. Using the accelerometer, three kinds of gravity–force can be measured. Based on a preliminary study, we choose 0.02 *g* for analysis because two other scales of gravity–force were too small to detect the movements or too large to calculate. The TSP was divided equally into eight parts, based on an epidemiologic study of approximately 5000 Japanese that showed that the standard sleep period ranges between 7 and 8 h.[20]

Despite the precautions described above, the present study revealed several important findings, which included the following: (i) elderly subjects with COPD or BA may require longer sleep periods than control subjects; (ii) the sleeping pattern differed between subjects with COPD and BA; and (iii) hypercapnia is a likely factor disturbing the quality of sleep in COPD subjects, while decreased peak expiratory flow rate is a likely factor reducing daytime activities in subjects with BA.

Nocturnal hypoxemia and hypoventilation may occur in subjects with severe COPD alone, but such changes are usually most pronounced when coexisting obesity and obstructive sleep apnea (OSA) are present.[2] In such cases, which are often referred to as overlap syndrome, the effects of obesity and OSA are usually predominant and treatment that effectively eliminates OSA is often sufficient to reduce the consequences of daytime hypercapnia and right ventricular dysfunction.[3] Daytime hypercapnia in COPD subjects was found to determine sleep quality in the present study. Alterations in nocturnal gas exchange, particularly oxygen desaturation, are an important clinical problem in subjects with COPD. The present data suggest that subjects with COPD and hypercapnia require treatment of sleep-disordered breathing in COPD, including oxygen therapy and pharmacologic agents, as well as non-invasive positive pressure ventilation, and it is expected that the improved sleep quality results in increased daily activities. Sleep deprivation can result in significant changes in cognitive functioning, which is occasionally seen in elderly subjects.[21] Sleepy subjects often report difficulty with short-term memory. Attention may be impaired and subjects may actually present themselves as having attention deficit disorder. Sleep deprivation can also result in an alteration of mental status, which resembles depression or anxiety. Patients may report poor mood, irritability, low energy, decreased libido and other signs of psychologic dysfunction. These symptoms often disappear abruptly when normal sleep is restored.

The present study revealed that mutual effects were observed in both daily activity and sleep quality in subjects with COPD or BA, respectively. Currently, it is reported that the level of daytime activity is positively correlated with sleep efficiency during the subsequent night, especially for the consistently less-active elderly.[19]

Recently, Punjabi *et al*.[22] reported that nocturnal hypoxemia and sleep fragmentation are independent determinants of hypersomnolence in sleep-disordered breathing. This raises a question of whether nocturnal hypoxemia during sleep occurred in these subejcts with COPD or BA in the present study. This issue needs further investigation.

The present data indicated that the frequency of daytime movements differed between BA and COPD subjects; the movement in the daytime of subjects with BA was suppressed and this is likely correlated with the changes in peak expiratory flow rates. It is of interest to note that subjects with BA showed a greater frequency of movement during mid-sleep than COPD subjects, suggesting that the sleep of asthma subjects may be disturbed by arousals at the initial or late stage. Reduction of the peak expiratory flow rate in asthma subjects was found to deteriorate daily activities, which is in accordance with the present guidelines for treating BA, although the present observation was based on older subjects only. Subjects with COPD had fewer IADL and, similarly, a lower $FEV_{1.0}$ and lower P_aO_2 (Table 2) than asthma subjects had, although there was no significant difference between COPD and asthma patients. All these factors, along with other possible factors, such as muscle weakness, desaturation during exercise and malnutrition, may contribute to reduction of daily activities as well as deterioration of sleep quality in COPD subjects compared with that in asthma subjects. This issue also needs further investigation.

In conclusion, elderly subjects with COPD or BA may require a longer sleep time than non-respiratory control subjects because the quality of sleep in the former group may be disturbed. However, the sleeping pattern may differ between subjects with COPD and those with BA. Hypercapnia was a factor disturbing the sleep quality in COPD subjects, while reduced peak expiratory flow rate was a factor disturbing daytime activities in subjects with BA.

Acknowledgments

The present study was funded by the Pollution-Related Health Damage Compensation and Prevention Association in Japan. The authors thank Ms Ritsuko Wakabayashi, RN, for her devotion to the patients and to the program.

References

1 Fleetham JA, Kryger MH. Sleep disorders in chronic airflow obstruction. *Med. Clin. North Am.* 1981; **65**: 594–61.
2 Bradley TD. Right and left ventricular functional impairment and sleep apnea. *Clin. Chest Med.* 1992; **13**: 459–79.
3 Chaouat A, Weitzenblum E, Krieger J, Ifoundza T, Oswald M, Kessler R Association of chronic obstructive pulmonary disease and sleep apnea syndrome. *Am. J. Respir. Crit. Care Med.* 1995; **151**: 82–6.
4 Burger CD, Shepard Jr JW. Sleep-disordered breathing and aging. In: Mahler DA (ed.). *Pulmonary Disease in the Elderly Patient*. New York: Marcel Dekker, 1993; 61–80.
5 Phillips BA, Berry DTR, Lipke-Molby TC. Sleep-disordered breathing in healthy, aged persons. Fifth and final year follow-up. *Chest* 1996; **110**: 645–58.
6 Bixler EO, Vgontzas AN, Have TT, Tyson K, Kales A. Effects of age on sleep apnea in men. 1. Prevalence and severity. *Am. J. Respir. Crit. Care Med.* 1998; **157**: 144–8.
7 Fitzpatrick MF, Engleman H, Whyte KF, Deary IJ, Shapiro CM, Douglas NJ. Morbidity in nocturnal asthma: Sleep quality and daytime cognitive performance. *Thorax* 1991; **46**: 569–73.
8 Amerian Thoracic Society Guidelines. Standards for the diagnosis and care of patients with chronic obstructive pulmonary disease. I. Definitions; epidemiology; pathophysiology; diagnosis and prognosis. *Am. J. Respir. Crit. Care Med.* 1995; **152**: S77–120.
9 Barbee RA. Epidemiology and natural history. In: Barbee RA, Bloom JW (eds). *Asthma in the Elderly*. New York: Marcel Dekker, 1997; 1–31.
10 Sherman CB, Kern D, Richardson ER, Hubert M, Fogel BS. Cognitive function and spirometry performance in the elderly. *Am. Rev. Respir. Dis.* 1993; **148**: 123–6.
11 Folstein MF, Folstein SE, McHugh PR 'Mini-mental state.' A practical method for grading the cognitive state of patients for the clinician. *J. Psychiatr. Res.* 1975; **12**: 189–98.
12 Siu AL, Reuben DB, Moore AA. Comprehensive geriatric assessment. In: Hazzard WR, Bierman EL, Blass JP, Ettinger Jr WH, Halter JB (eds). *Principles of Geriatric Medicine, Gerontology*, 3rd edn. New York: McGraw-Hill, 1994; 203–11.
13 Steele BG, Holt L, Belza B, Ferris S, Lakshminayan S, Buchner DM. Quantitating physical activity in COPD using a triaxial accelerometer. *Chest* 2000; **117**: 1359–67.
14 Verbeek I, Klip EC, Declerk AC. The use of actigraphy revised: The value for clinical practice in insomnia. *Percetp. Mot. Skills* 2001; **92**: 852–6.
15 Jean-Louis G, Mendlowicz MV, Gillin JC *et al*. Sleep estimation from wrist activity in patients with major depression. *Physiol. Behav.* 2000; **70**: 49–53.

16 O'Shea JC, Murphy MB. Nocturnal blood pressure dipping: A consequence of diurnal physical activity blipping ? *Am. J. Hypertens*. 2000; **13**: 601–6.
17 Hauri PJ. Evaluation of a sleep switch device. *Sleep* 1999; **22**: 1110–17.
18 Jean-Loius G, Kripke DF, Cole RJ, Assmus JD, Langer RD. Sleep detection with an accelerometer actigraph: Comparisons with polysomnography. *Physiol. Behav.* 2001; **72**: 21–8.
19 Shirota A, Tamaki M, Hayashi M, Hori T. Effects of daytime activity on nocturnal sleep in the elderly. *Psychiatry Clin. Neurosci*. 2000; **54**: 309–10.
20 Kojima M, Wakai K, Kawamura T *et al*. Sleep patterns and total mortality: A 12-year follow-up study in Japan. *J. Epidemiol*. 2000; **10**: 87–93.
21 Ancoli-Israel S, Klauber MR, Butters N, Parker L, Kripke DF. Dementia in institutionalized elderly: Relation to sleep apnea. *J. Am. Geriat. Soc*. 1991; **39**: 258–63.
22 Punjabi NM, O'Hearn DJ, Neubauer DN *et al*. Modeling hypersomnolence in sleep-disordered breathing. A novel approach using survival analysis. *Am. J. Respir. Crit. Care Med*. 1999; **159**: 1703–9.