

[Skip to Content](#)

Library Menu: Cozby Library and Community Commons

 Select Language English

- [Afrikaans](#)
- [العربية](#)
- [Bahasa Indonesia](#)
- [Bahasa Malaysia](#)
- [česky](#)
- [Cymraeg](#)
- [Dansk](#)
- [Deutsch](#)
- [English](#)
- [Español](#)
- [Français](#)
- [Gaeilge](#)
- [Hrvatski](#)
- [Italiano](#)
- [magyar](#)
- [ইংরেজি](#)
- [Nederlands](#)
- [Polski](#)
- [Português](#)
- [Română](#)
- [Slovenščina](#)
- [slovenský](#)
- [suomi](#)
- [svenska](#)
- [Tagalog](#)
- [Tiếng Việt](#)
- [Türkçe](#)
- [Русский](#)
- [Ελληνικά](#)
- [বাংলা](#)
- [हिंदी](#)
- [தமிழ்](#)
- [ไทย](#)
- [中文 \(简体\)](#)
- [中文 \(繁體\)](#)
- [日本語](#)
- [한국어](#)

[Sign in with Google](#)

Save documents, citations, and highlights to Google Drive™

[Sign in with Microsoft](#)

Save documents, citations, and highlights to Microsoft OneDrive™

[Gale Academic OneFile](#)



Basic Search ▾

Search...

Submit

[Advanced Search](#)

Cite

Send to...

Download

Print

Get Link

[Highlights and Notes \(0\)](#)

Your session has timed out after 20 minutes of inactivity. If you do not click continue session, you will be logged out in 60 seconds

Evaluation of automatic analysis of SCSB, airflow and oxygen saturation signals in patients with sleep related apneas

Authors: [Tapani Salmi](#), [Tiina Telakivi](#) and [Markku Partinen](#)

Date: Aug. 1989

From: [Chest](#) (Vol. 96, Issue 2)

Publisher: Elsevier B.V.

Document Type: Article

Length: 4,206 words

Full Text:

Tapani Salmi, M.D.;(*1) Tiina Telakivi, M.D.;([unkeyable]) and Markku Partinen, M.D.(*2)

We have developed a computerized analysis of respiratory and body movements (static charge sensitive bed [SCSB]), [oxygen](#) saturation ([pulse](#) oximeter), and airflow (thermistor) for the evaluation of [sleep](#) related apneas. The cumulative distribution of oxygen saturation, the number and distribution of desaturation events, and the duration and type of apneas are assessed. Analysis is performed separately during the total recording time and during the time when the patient sleeps on his back. We have compared the automatic analysis with the results obtained on simultaneous daytime polysomnograph naps in 55 subjects (snorers or obstructive [sleep apnea](#) syndrome [OSAS] patients). The compressed graphs obtained automatically demonstrated a periodic breathing pattern in all 22 patients who presented sleep-related apneas at polygraphic recording. The cumulative distribution of oxygen

saturation was not as steep in the apnea patients as in patients not showing apneas; in 19 of the 22 OSAS patients, the value was outside our normal limits (80 percent of the recording time inside 3.6 percent [SaO.sub.2] variation band). The apnea index (AI) was 26.4 in manual and 23.3 in automatic analysis. Using the automatic method there were three false negative cases in the analysis of desaturations; in these patients periodic breathing was present in output graphs indicating need for further polygraphic assessment. The duration of apneas in the automatic analysis was shorter than in manual analysis, but the agreement was sufficient for screening purposes (mean error less than 3 s, mean duration of apneas 20.1 s). The automatic method is presently used in clinical routine for screening purposes, for assessment of the severity of the disorder and the type of treatment that a subject may need, in epidemiologic investigation and follow-up of the treatment.

According to epidemiologic studies, the incidence of obstructive sleep apnea syndrome and/or heavy regular [snoring](#) with associated sleep hypopneas is remarkably high in middle-aged men (0.5-2 percent).[1-5] Considering the large number of subjects who snore and the unfeasibility of performing systematic all-night polygraphic recordings in a large population, different screening methods have been suggested.[6-14] The nocturnal polysomnogram is considered the best technique for detailed [diagnosis](#) of sleep-related breathing disorders.[15] Daytime nap recordings are controversial; Goode et al[16] suggested that these are sufficient to determine the predominant type of apneas (ie, mixed and obstructive or central). The "static charge sensitive bed" (SCSB) has proved useful in screening for sleep apneas and periodic movements during sleep.[11,17] We developed an automatic analysis based on a computer program.[12] We have since improved our sleep monitoring by adding measurement of airflow by thermistors, frequency and severity of oxygen saturation drops using pulse oximetry, and body position using a body position sensor. These variables are automatically scored. In the present article, we compare automatic scoring results with the results obtained simultaneously during daytime polysomnograph naps.

PATIENTS AND METHODS

Patients

Fifty-five consecutive patients (49 men, six women) with clinically suspected sleep apneas participated in the validation study. The mean age of the patients was 52 years (range 33-72).

Daytime Polysomnography

Daytime polysomnography of 90-120 minutes (16 channels, Siemens Elema) was performed in the afternoon for the validation study. The following variables were monitored: EEG, electro-oculography (EOG, right and left eye), submental electromyography (EMG), ECG (lead 1), airflow with thermistors (signal combined from right and left nostril and mouth), abdominal respiratory movements (strain gauge), respiratory movements (SCSB, Biomat[R] Biorec, Inc), ballistocardiography (BCG, with SCSB), and oxygen saturation ([SaO.sub.2] (Biox III pulse oximeter, finger transducer). Twenty-five to 90 minutes of airflow, [SaO.sub.2], and SCSB respiratory and body movement signals were simultaneously tape-recorded on a Racal 7DS instrumentation recorder for computerized analysis. The polygraphic recordings were manually scored and 22 recordings with more than five apneas or hypopneas during the tape-recorded period were selected for further analysis. The number of apneas exceeding 10 s in duration, apnea index (AI, number of apneas/hour), apnea percentage

(A%, percentage of apneic events during recording) were calculated. Before computer analysis, the duration of apneas in ten patients with AI higher than 10 was manually measured independently by two scorers (TS and TT) unconscious of the automatic analysis results. The comparison between manual and automatic scoring included 240 apneas and hypopneas of, at least, 10 s duration.

Automatic Recording and Analysis

Automatic recording of the five signals can be performed on-line in the patient ward or off-line from tape-recorded signals (with reproduction speed 64 times real-time). The flow-chart of the recording and analysis device is shown in Figure 1. The onset time and duration of recording are given manually. Everything else is performed automatically without manual operations. During recordings, the amplitude of respiratory movements and [SaO.sub.2] level of the preceding 30 minutes are displayed on the computer screen. Duration of recording is limited only by the memory capacity of the computer. When we use the method in the patient ward, a typical recording lasts 9 hours.

The sampling rate for all but the body position signal is 30 Hz. The signals are converted into digital values using Tecmar Labmaster analog-digital converter (12 bit). The accuracy of the conversion is better than 0.5 percent for the [SaO.sub.2] signal. Signals are rectified and integrated in epochs. The length of an epoch is 1.2 s for body and respiratory movements and the thermistor signal, and 3.6 s for the oximeter signal. The values describing the amplitude during the epochs are stored on a floppy disk. This data compression allows the data from one night to be stored on a floppy disk. The output is printed with a graphic printer.

The processing and compressed graphic output of SCSB body and respiratory movement signals have been described previously.[11] The statistics give the number and duration of body movements, and a simple "movement hypnogram" consisting of "quiet sleep" (no body movements), "active sleep" (many short body movements), and "wake state" (movements of high amplitude). The SCSB respiratory movement graph was divided visually into "regular," "irregular" and "periodic breathing" patterns as previously described.[11,12] "Periodic breathing" pattern indicates repeated apneas or hypopneas followed by hyperpneas.[12] An example of the compressed output of the five signals is given in Figure 2.

After rejecting artifacts (an automatic rejection of desaturation peaks dropping below 30 percent [SaO.sub.2] and an optional manual rejection of other desaturation peaks) the analysis of oximeter signal gives a compressed graph of the signal and the cumulative distribution of oxygen saturation during sleep. The median, mean and mode values of the [SaO.sub.2] distribution are calculated. A curve giving [SaO.sub.2] in the abscissa and the percentage of time on the ordinate is drawn automatically (Fig 3), and the [SaO.sub.2] levels corresponding to the cumulative recording times of 10, 20, 30 etc (percentiles of the distribution) are printed. The difference between the [SaO.sub.2] levels above which the patient spent 90 percent and 10 percent of the total recording time is an estimate of the steepness of the [SaO.sub.2] curve (Fig 3). This value indicates the [SaO.sub.2] band within which the patient spent 80 percent of the recording time.

A decrease by at least 4 percent in [SaO.sub.2] lasting between 6 s and 120 s and followed by a return to the preceding level is accepted by the computer as a significant desaturation event. Both a slow fluctuation of [SaO.sub.2] and steep declines of [SaO.sub.2] due to transducer artifacts are rejected. The magnitude of the desaturation event is measured from

the maximum [SaO.sub.2] value during the preceding 120 s of signal. The desaturation events are collected and classified into ranks with 5 percent intervals. The cumulative distribution of the desaturations, the mean desaturation, and the mean value for the minimum [SaO.sub.2] during the desaturation events are printed. The mean and mode (the typical interapnea interval) of the intervals between desaturations are printed. A second analysis is performed, which includes desaturation events of more than 2.5 percent in magnitude. This is done in order to analyze "periodic breathing" and "heavy snoring." The mode of the intervals between the saturation drops are multiplied by the number of desaturation events; this gives an estimate of periodic breathing in minutes.

The analysis of apneas is based on the detection of desaturation events in the oximeter signal. There is a delay between restart of breathing and the [SaO.sub.2] increase seen after an apnea. This delay is due to physiologic factors and to the equipment characteristics.[20] The software looks for a local maximum point ("giant breaths" following an apnea) and for a local minimum level of airflow (the probable apnea or hypopnea) preceding a desaturation event (Fig 4). The local maximum and minimum points are detected after smoothing the signal with a digital low-pass filter. The mean amplitude of the airflow signal is measured during a period of 120 s preceding an apnea.

During the local minimum, the period of airflow signal with an integrated amplitude less than 35 percent of the mean value is considered to be an apnea, and a period with an integrated amplitude less than 65 percent of the mean is called hypopnea. The mean and distribution of the duration of apneas and hypopneas are calculated. In addition, the number of apneas and hypopneas exceeding 10 s in duration are given.

After computation of the number and duration of apneas, the number of apneas per one hour of recording (apnea index, AI), the number of apneas or hypopneas (apnea-hypopnea index, AHI), the percentage of apneic time of recording (apnea percentage, A%), and the percentage of apnea and hypopnea time (AH%) are calculated, and the distribution of AI and A% through the recording are displayed graphically (Fig 5).

Even the type of apneas and hypopneas is analyzed automatically. The SCSB respiratory signal is used as an indicator of breathing efforts during apneas. If the amplitude of the SCSB respiratory movement signal during an apnea is less than 30 percent of the mean amplitude (calculated during the preceding 120 s), the apnea is considered to be of central type. Typically in mixed apnea there is central onset and an obstructive end of the apnea. The duration of the obstructive part of every apnea is calculated (Fig 4). The mean duration of the obstruction and the duration and percentage of obstruction during every apnea are displayed graphically (Fig 5).

We have added a body position sensor (Vitalog, Inc) to the automatic analysis. The body position (supine vs not supine) is verified every 3.6 s and stored. The analysis of all the descriptors is performed separately while the patient is supine. Figure 2 presents the recording of a patient with position-related (supine) apneas.

Statistical Analysis

Measurements of the duration of apneas and calculation of AI and A% using the manual and automatic methods, respectively, were compared, as suggested by Bland and Altman.[18]

Student's t-test was used to compare the mean and the steepness of the [SaO.sub.2] distribution in patients with OSAS and in other patients.

RESULTS

Visual analysis of the compressed SCSB movement channels indicated a periodic breathing pattern in the 22 patients with AHI greater than 5 on manual scoring. The mean percentage of the periodic breathing pattern was 74.1 percent (range 33-100 percent of tape-recorded time). In addition, in 12 patients who snored, a periodic breathing pattern as defined above, was also identified in the SCSB graphs. The mean percentage of this periodic breathing pattern was 24.4 (range 6-40 percent). In these 12 patients, the desaturations associated with periodic breathing were small in magnitude (less than 4 percent). In one patient with periodic leg movements, a periodic pattern of "body movements" was identified in the SCSB graph. There were, however, no periodic desaturations in this recording. In 20 patients, no periodic pattern could be visually identified in the SCSB graph.

In the cumulative distribution of [SaO.sub.2] during the total recording time, the mean [SaO.sub.2] in the patients with no apneas was 94.4 percent (SD 1.3 percent), and the mean values of the first and ninth percentiles of the [SaO.sub.2] distribution were 93.0 percent and 95.4 percent; the mean difference was thus 2.4 percent (SD 0.6 percent), ie, the mean +2 standard deviations was 3.6 percent.

In the 22 patients with AI > 5, the mean [SaO.sub.2] was 92.4 percent (SD 2.2 percent), lower than in patients without apneas ($p < 0.01$). In the cumulative time distribution of [SaO.sub.2], the range from 10 to 90 percent was 87.4 and 94.6 percent and the mean difference was 7.2 percent (SD 3.6, $p < 0.001$). In 19 of these 22 apneic patients the variation of the [SaO.sub.2] distribution corresponding to 80 percent of the recording time was greater than 3.6 percent. The total number of apneas scored manually from the simultaneous polygraphic recordings was 473 (range 6-69 per recording). The mean desaturation associated with apneas was 8.3 percent (SD 3.2 percent). The mean [SaO.sub.2] value at the end of apnea was 84.9 percent (SD 3.0 percent).

The comparison between manual and automatic scorings performed on the 22 patients gave the following results: with manual analysis, the mean AI was 26.4 (range 5.5-70) and A% was 16.0 percent (range 1.2-47.6 percent); with automatic analysis, the mean AI was 23.3 and A% 12.2 percent. When the hypopnea amplitude was used as a criterion in automatic detection, AHI was 30.2 and AH% was 17.8 percent. The individual AI values are shown in Figure 6A.

The difference between the manual and automatic analysis was clinically significant in three patients: the automatic analysis gave a false negative diagnosis when AI > 5 was selected as the polygraphic limit of normality as demonstrated in Figure 6A. The error was caused by the small amount of desaturation associated with apneas during day-time recording. Visually, the amount of "periodic breathing" in the compressed output graphs was more than 10 percent of the total recording time in these three patients. With a cut-point of AI > 20, there were two false negative results (manual AI 21, and automatic AI 14 and 7).

The duration of apneas/hypopneas was measured in ten patients with more than 15 apneas during the tape-recorded period (altogether 240 apneas). The mean duration measured manually by two independent scorers was 21.6 s and the mean difference between the

scorers was 1.9 s (SD 3.2 s). The mean difference between the means of the two manual measurers and the automatic measurement was 1.9 s (SD 4.6 s). When the "hypopnea amplitude" was used as a criterion, the mean difference was - 1.5 s (SD 4.7 s), ie, the manual scorers had a shorter estimate. The individual measurements are shown in Figure 6B.

The duration of obstruction was measured automatically during all apneas. The mean percentage of obstruction was 90.4 percent (range 64-99 percent in the patients). There were no patients with central apneas in this series. In one patient with mixed type apneas, the percentage of obstruction was 68 percent using manual scoring, and 64 percent using automatic analysis. An example of the measurement of the duration of apnea and obstruction is given in Figure 5.

DISCUSSION

In our automatic analysis the detection of apneas was based on widely used, sensitive transducers. Thermistors in front of the nostrils and mouth detect cessation of airflow.[15] Pulse oximeters are found to be relatively accurate in measuring [SaO.sub.2] within a physiologic range (over 80 percent),[19] but there are individual differences in both accuracy and response characteristics in different oximeters and even in different types of probes.[20] The SCSB is a very sensitive transducer for any body movements including respiratory movements,[12,16,21,22] short body movements[11,23] and BCG.[24] Although the pattern of the SCSB respiratory movements alone is suggested to be typical of obstructive apneas, [12,22,24] in our automatic analysis we used the amplitude of the respiratory movement signal to detect breathing efforts (indicating obstruction) combined with the simultaneous absence of thermistor signal (indicating an apnea).

While there are only a few articles describing automatic computer algorithms for the detection and analysis of sleep apnea recordings,[8,10,25] there are a growing number of commercial devices for this purpose without detailed documentation of the procedures. The digital signal analysis methods used in the present study are quite simple. The quality of the signals is enhanced by averaging the samples during epochs. The amplitude of signals is evaluated by rectifying and integrating the signals. The statistical analysis includes common descriptors: mean, mode, median, and cumulative distributions. Body movements, desaturations, apneas and hypopneas are detected using amplitude criteria.

The main advantage of automatic analysis is the calculation of the parameters commonly used in manual analysis of polysomnography. Both AI and A% (and AHI and AH%) are calculated and displayed graphically during the time in bed. The duration of apneas and obstruction are given during the time recorded. The median of [SaO.sub.2] and the number of apneas with different amounts of desaturation are used to estimate the effects of apneas, eg, on the cardiovascular system. The number of body movements and the amount of "quiet sleep" without body movements are used in evaluating the quality of sleep. The descriptors are printed separately for the supine and the lateral body position; this is useful in evaluating the possibility of conservative treatment such as a sleeping position training program.[26,27]

High sensitivity is of importance for any method suggested for screening purposes. In the present automatic analysis, the "periodic breathing" pattern was found in all patients with AI higher than 5. The high sensitivity of SCSB in detecting periodic movements has been emphasized earlier.[12,17,22,24]

In the sleep apnea patients, the mean [SaO.sub.2] was statistically lower than in our control subjects. Both patient-related (pulmonary disorders, [SaO.sub.2] during wakefulness) and oximeter-related factors (accuracy, response characteristics)[20] affect the distribution and absolute [SaO.sub.2] values. The steepness of the slope of the cumulative distribution (the [SaO.sub.2] band within which the patient spent 80 percent of the recording time) was outside our normal limit more frequently (19 of 22 patients with AI more than 5) than the mean [SaO.sub.2]. It can be used as a simple quantitative descriptor of [SaO.sub.2] distribution in the evaluation and follow-up of OSAS patients.

Traditionally the severity of apneas is approximated using their duration as a measure of the disorder. The amount of the desaturation associated with apneas is readily analyzed automatically.[25] The use of both parameters in combination has been attempted in the present method, just as previously described by West and Kryger.[8]

In three patients the small amount of desaturation (less than 4 percent) associated with apneas resulted in a false negative finding in the automatic determination of AI. This indicates that the parameter in question is not alone sufficient for screening purposes. As mentioned above, the periodic breathing pattern in the computer output of the SCSB respiratory movement and the airflow graphs indicated a significant amount of apneas in these patients and in this situation further polygraphic assessment is needed. In OSAS patients with a measured pathologic amount of apneas, AI and other indices are automatically available for follow-up.

Automatic calculation of the duration of apneas, AI and A% in the apneic patients gave lower values than manual analysis, when an amplitude criterion of 35 percent of the mean airflow signal amplitude was used. This is related to the better pattern recognition of the human observer. Agreement in the measurement of duration can be considered sufficient for screening purposes. At follow-up, the automatic method cannot subjectively distort the quantitative results.

Owing to the sigmoidal shape of the oxygen saturation curve, the amount of desaturation does not correlate linearly with the duration of apneas and the decrease in arterial oxygen pressure. Desaturation of at least 4 percent is commonly considered clinically significant,[28] and this was chosen as an indicator of apnea in the present method. The number of small desaturations ([SaO.sub.2] drops between 2.5 and 4 percent) may give additional information on patients with snoring. It may also be used in the follow-up of mild cases during "conservative treatment."

The combination of different signals increases the specificity of the results: periodic leg movements without desaturations can be distinguished from apneas, breathing disorders causing a small amount of desaturation, but frequent arousals can be detected, and arousals (body movements) are quantitated. We have added sound recordings to the system in order to detect nocturnal snoring[4] or cough.[29] The only disadvantage of the transducers presently used is lack of tidal volume quantification which can be realized with calibrated inductive plethysmography or [spirometry](#). [6]

In addition to the present validation study, we have performed more than 400 all-night recordings in the patient ward for screening and follow-up. In patients with normal findings (no desaturations, no periodic breathing pattern, no periodic movements) no other recordings have been performed. In patients with OSAS, the quantitative indices from the

recording are used as follow-up parameters to evaluate the efficacy of the treatment. In those with atypical results or any disparity between the recording result, symptoms, clinical findings and history, polygraphic assessment is required.

ACKNOWLEDGEMENTS: We thank Prof. C. Guilleminault for his valuable suggestions during the preparation of this manuscript.

(*) Neurology, Helsinki University Central Hospital, and

([unkeyable]) Ullanlinna [Sleep Disorders](#) Clinic, Helsinki, Finland.

REFERENCES

- 1 Lugaresi E, Cirignotta F, Coccagna G, Piana C. Some epidemiological data on snoring and cardiocirculatory disturbances. *Sleep* 1980; 3:221-24
- 2 Lavie P. Incidence of sleep apnea in a presumably healthy working population. *Sleep* 1983; 6:312-18
- 3 Peter JH, Siegrist J, Podszus T, Mayer J, Selzerk, von Wichert P, et al. Prevalence of sleep apnea in healthy industrial workers. *Klin Wochenschr* 1985; 63:807-12
- 4 Telakivi T, Partinen M, Koskenvuo M, Salmi T, Kaprio J. Periodic breathing and hypoxia in snorers and controls: validation of snoring history and association with [blood pressure](#) and [obesity](#). *Acta Neurol Scand* 1987; 76:69-75
- 5 Gislason T, Almqvist M, Eriksson G, Taube A, Boman G. Prevalence of sleep apnea syndrome among Swedish men--an epidemiological study. *J Clin Epidemiol* 1988; 41:571-76
- 6 Miles L, Rule B, Benson K, Herakan S, Dement WC. Screening outpatients for sleep apnea: continuous measurement of tidal volumes and other parameters using the Vitalog PMS-8 portable microcomputer [Abstract]. *Sleep Res* 1982; 11:204
- 7 Cummiskey J, Williams TC, Krumpe PE, Guilleminault C. The detection and quantification of sleep apnea by tracheal sound recordings. *Am Rev Respir Dis* 1982; 126:221-24
- 8 West P, Kryger MH. Continuous monitoring of respiratory variables during sleep by microcomputer. *Meth Inform Med* 1983; 22:198-203
- 9 Guilleminault C, Connolly S, Winkle R, Melvin K, Tilkian A. Cyclical variation of the heart rate in sleep apnea syndrome. *Lancet* 1984; 1:126-31
- 10 Penzel T, Bauer W, Fuchs E, Mayer J, Meinzer K, Peter JH, et al. A computerized technique for progressive ambulatory and stationary diagnosis of sleep apnea in internal medicine. In: Koella WP, Ruther E, Schulz H, eds. *Sleep* 1984. Stuttgart: Fischer, 1985; 471-73
- 11 Salmi T, Leinonen L. Automatic analysis of sleep records with static charge sensitive bed. *Electroenceph Clin Neurophysiol* 1986; 64:84-7

- 12 Salmi T, Partinen M, Hyyppa M, Kronholm E. Automatic analysis of static charge sensitive bed (SCSB) recordings in the evaluation of sleep-related apneas. *Acta Neurol Scand* 1986; 74:360-64
- 13 Svanborg E, Carlsson-Nordlander B, Larsson H, Pirskanen R, Sterner J. Screening for sleep apnea syndrome: Static charge sensitive bed and ear oxymetr: *Electroenceph Clin Neurophysiol* 1986; 64:86
- 14 Gyulay S, Gould D, Sawyer B, Pond D, Mant A, Saunders N. Evaluation of a microprocessor-based portable home monitoring system to measure breathing during sleep. *Sleep* 1987; 10:130-42
- 15 Bornstein SK. Respiratory monitoring during sleep: polysomnography. In: Guilleminault C, ed. *Sleeping and waking disorders. Indications and techniques*. Menlo Park: Addison Wesley, 1982; 183-212
- 16 Goode GB, Slyter HM. Daytime polysomnogram diagnosis of sleep disorders. *J Neurol Neurosurg Psychiatry* 1983; 46:159-61
- 17 Partinen M, Alihanka J, Hasan J. Detection of sleep apneas by the static charge-sensitive bed. In: WP Koella, ed. *Sleep, 1982*. Basel: Karger, 1983; 312-14
- 18 Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; I: 307-10
- 19 Nickerson BG, Sarkisian C, Tremper K. Bias and precision of pulse oximeters and arterial oximeters. *Chest* 1988; 93:515-17
- 20 West P, George CF, Kryger MH. Dynamic in vivo response characteristics of three oximeters: Hewlett-Packard 47201A, Biox III, and Nellcor N-100. *Sleep* 1987; 10:263-71
- 21 Alihanka J, Vaahtoranta K, Saarikivi I. A new method for long-term monitoring of the ballistocardiogram, heart rate, and [respiration](#). *Am J Physiol* 1981; 240:R384-R92
- 22 Polo O, Brissaud L, Sales B, Besset A, Billiard M. The validity of the static charge sensitive bed in detecting obstructive sleep apneas. *Eur Respir J* 1988; 1:330-36
- 23 Alihanka J. Sleep movements and associated autonomic nervous activities in young male adults. *Acta Physiol Scand* 1982; Suppl 511:1-85
- 24 Alihanka J. Basic principles for analyzing and scoring Bio-Matt (SCSB) recordings. *Turku: Annales Universitatis Turkuensis*, 1987; 1-130
- 25 George CF, Millar TW, Kryger MH. Identification and quantification of apneas by computer-based analysis of oxygen saturation. *Am Rev Respir Dis* 1988; 137:1238-40
- 26 Cartwright RD. Effect of sleep position on sleep apnea severity. *Sleep* 1984; 7:110-14
- 27 George CF, Millar TW, Kryger MH. Sleep apnea and body position during sleep. *Sleep* 1988; 11:90-9

28 Block AJ, Boysen PG, Wynne JW, Hunt LA. Sleep apnea, hypopnea and oxygen desaturation in normal subjects. *N Engl J Med* 1979; 300:513-17

29 Salmi T, Sovijarvi ARA, Brander P, Piirila P. Long-term recording and automatic analysis of cough using filtered acoustic signals and movements on static charge sensitive bed. *Chest* 1988; 94:970-75

Copyright: COPYRIGHT 1989 Elsevier B.V.

<http://chestjournal.chestpubs.org/>

Source Citation

[MLA 9th Edition](#) [APA 7th Edition](#) [Chicago 17th Edition](#) [Harvard](#)

Salmi, Tapani, et al. "Evaluation of automatic analysis of SCSB, **airflow** and oxygen saturation signals in patients with sleep related apneas." *Chest*, vol. 96, no. 2, Aug. 1989, pp. 255+. *Gale Academic OneFile*, link.gale.com/apps/doc/A12682650/AONE?u=txshrp100416&sid=googleScholar&xid=078b4733. Accessed 26 Dec. 2023.

[Disclaimer](#)

Select

Export To:

*The RIS file format can be used with EndNote, ProCite, Reference Manager, and Zotero.

[NoodleTools](#) [EasyBib](#) [RefWorks](#) [Google Drive™](#) [OneDrive™](#)

[Download RIS*](#)

Gale Document Number: GALE|A12682650