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Light sleep and sleep time misperception – Relationship to alpha–delta sleep

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ABSTRACT

Objective: We investigated the association of alpha–delta sleep (A–DS) with: (1) perception of light sleep and (2) discrepancy between subjective and objective sleep duration.
Methods: We analyzed data from 5764 individuals who underwent polysomnography (PSG) and replied questions about quantity and quality of sleep, including sleep depth. The difference between objectively recorded sleep time and subjectively estimated sleep time was calculated. Alpha–delta sleep (A–DS) was visually scored in a scale from 1 to 4, based on the density and overnight duration of alpha activity and confirmed using spectral array of the electroencephalographic activity.
Results: A–DS scores 1–4 occurred in, respectively, 37.9%; 31.3%; 20.5%; and 6.2% of the cases. ANOVA showed significant difference of light sleep sensation ($p < 0.001$) and sleep time underestimation ($p < 0.001$) among the four A–DS categories. Regression to explain both light sleep and sleep time underestimation, controlling for confounders, confirmed A–DS as a significant regressor.
Conclusions: This study of a large prospective sample provides evidence for the association of alpha–delta sleep with subjective sensation of light sleep and with sleep time underestimation.
Significance: Alpha–delta sleep may be a marker of the physiological disorder underlying light sleep and sleep state misperception.

1. Introduction

The electroencephalographic (EEG) feature identified as alpha–delta sleep (A–DS) consists of alpha waves, low-voltage fast activity, typical of relaxed wakefulness (Davis et al., 1937), superimposed on delta waves, characteristic of deep nonrapid eye movement (NREM) sleep (Moldofsky, 2008). This pattern was described for the first time by Hauri and Hawkins (1973), in psychiatric patients with diverse complaints. Later, it was linked to painful syndromes such as rheumatoid arthritis and fibromyalgia (Moldofsky et al., 1975; Wittig et al., 1982; Moldofsky, 1989; Chediak et al., 1990; MacLean et al., 1995; Harding, 1998; Guilleminault et al., 2006), physical discomfort (Roizenblatt et al., 2001), excessive daytime sleepiness, sleep apnea, upper airway resistance syndrome, movement disorders in sleep, narcolepsy, as well as alcoholism, HIV infection, and blindness in elderly men (Schneider-Helmert and Kumar, 1995). It has also been associated with conditions such as chronic fatigue syndrome (Guilleminault et al., 2006; Van Hoof et al., 2007), nonrestorative sleep (Anch et al., 1991; Latta et al., 2005), and light sleep sensation (Saletu, 1975; Bader et al., 1997).

Because of the supposed excitatory state suggested by the presence of wakefulness-related alpha waves, A–DS has been implicated in two particular topics: the perception of sleep depth and the estimation of sleep time. Regarding the first topic, Saletu (1975) compared polysomnography (PSG) and questionnaires on the subjective experience of sleep quality in 35 healthy male patients, reporting correlation of whole-night alpha activity with light sleep sensation. Perlis et al. (1997) classified 20 patients as high or low alpha generators and reported association of alpha activity during sleep with the perception of light sleep. In terms of the second topic, the search for an association of A–DS with patient-reported sleep time has provided contradictory evidence. Saskin and Moldofsky (1989) reported higher A–DS associated with sleep time underestimation, due to overestimation of sleep latency. On the contrary, Mahowald et al. (1989) and Schneider-Helmert and Kumar (1995) reported correlation between A–DS and sleep time overestimation. These studies enrolled small number of patients, with no control groups.

Considerable controversy exists in the literature about the relevance of A–DS as an indicator of subjective sleep sensations (Moldofsky, 1989, 2008; Horne and Shackell, 1991; Manu et al., 1994; Pivik and Harman, 1995; Mahowald and Mahowald, 2000; Drewes et al., 2001; Guilleminault et al., 2006; Burns et al., 2008; Okura et al., 2008; Stone et al., 2008). We conducted the present study to appraise, in a large sample of patients referred to a sleep clinic, the correlation of the intensity of alpha–delta sleep with light sleep sensation and sleep time estimation.

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2. Methods

An observational and prospective study was conducted in 5764 consecutive patients (3885 male (67%) and 1879 female) referred to a university-affiliated sleep clinic for PSG. Inclusion criteria were: (1) age above 18 years; (2) a complaint of sleep-disordered breathing (SDB) or insomnia; (3) consenting for the use of the data. Exclusion criterion was diagnosis of any debilitating medical condition (cardiovascular, pulmonary, rheumatologic, or neoplastic).

PSG was carried out at the sleep laboratory using a 36-channel polysomnograph (BrainNet, Emsa, Rio de Janeiro, Brazil) in accordance with standard methods as previously described (Lenz and Martinez, 2007). Briefly, we, recorded electroencephalograms (C3–A2 and C4–A1), electro-oculograms, electromyograms, and electrocardiogram, airflow by a nasal cannula connected to a pressure transducer (Ultima, Braebon, Canada), respiratory inductance plethismography (Q-RIP, Braebon, Canada), and oxygen saturation by a pulse oximeter (BCI, USA). Sleep and respiratory events scoring followed the standard rules of the American Academy of Sleep Medicine (Iber et al., 2007).

We measured sleep latencies from lights out to the first epoch of stage NREM1 (LatN1), NREM2 (LatN2) and from the first epoch of stage N2 to the first epoch of stages NREM3 (LatN3) and REM (LatREM). Sleep efficiency (SEff) was calculated as the percentage of time asleep over total procedure time. Five-minute or longer periods of wakefulness were counted as awakenings. Arousal index (AI), periodic limb movement index (PLMI), and apnea–hypopnea index (AHI) were calculated dividing number of events per hours of sleep.

Delta sleep, stages 3 and 4, or NREM3 (Iber et al., 2007) was scored when epochs contained 20% or more of slow wave activity with frequency ranging from 0.5 to 2 Hz and peak-to-peak amplitude >75 mcV. Alpha–delta activity was qualitatively assessed based on the density and duration of alpha activity and aided by visualization of the power spectral density. The subjective scale ranged from 1 to 4 points based on a visual template (Fig. 1) In this scale, 1 represents 0–20% alpha intrusion during N3 sleep; 2, 21–40%; 3, 41–60%; and 4, alpha intrusion during 61% or more of N3 sleep time. To verify the interobserver agreement of the A–DS classification, a board certified sleep physician and two technicians examined 109 randomly selected PSGs obtaining a kappa of 0.773 and a weighted kappa of 0.899. In 374 cases with no stage N3, alpha activity was scored during NREM sleep.

We used the frequency analysis module of the scoring program (Poliwin, Revolution Software, Sao Paulo, Brazil) to confirm the existence of an alpha activity band simultaneous with the delta band. The software generates a color display where one can visualize the spectrum of brain activity during the night. To create this display, raw signal is conditioned using a Hanning window and then processed using real Fast Fourier Transforms extracted for the whole night at intervals of 1024 points, representing 10 s of the EEG channel at a sampling rate of 100 Hz. EEG power in the bands determined by the software (delta, theta, alpha, and beta) showed significant difference in percentage among the four A–DS groups only for alpha ($n = 90$; ANOVA; $F = 34$; $p < 0.000001$) and delta ($F = 19.1$; $p < 0.000001$) power bands.

In the morning, patients replied to the questions "How many hours do you think you slept last night?", "How long do you think it took for you to fall asleep last night?", "Last night your sleep quality was: worse than usual (1), like the usual (2), or better than usual (3)". We calculated PSG total sleep time minus patient-reported sleep time (DiffSleep) and LatN2 minus patient-reported sleep latency (DiffLat). Patients also marked a number ranging from 0 to 10 in Likert-type scales of the following sensations during sleep: pleasant (0) to unpleasant (10) dreams; "deep" (0) to "light" (10) sleep; "no thoughts" (0) to "many thoughts during sleep" (10); "no awakenings" (0) to "lots of awakenings" (10). Likert-type scales also assessed sensations at wake up: "fully rested" (0) to "very tired" (10); "wake up easily" (0) to "extremely difficult to wake up" (10); "no pain" (0) to "lots of pain" (10), in eight loca-

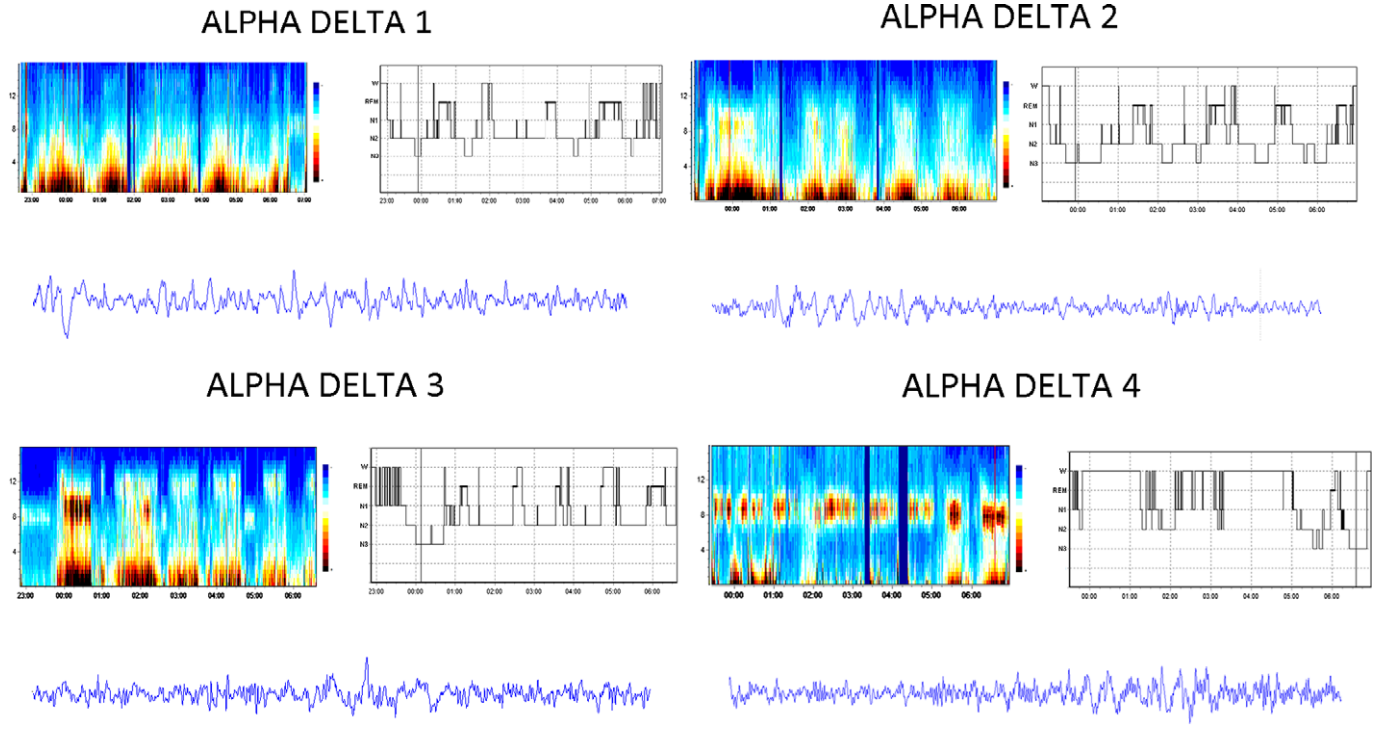

Fig. 1. EEG tracings, hypnograms, and spectral arrays in four different patients whose alpha–delta sleep was classified in categories 1–4, according with the power of alpha activity during delta sleep. EEG tracings in the four categories are 30-s epochs. In the whole night spectral arrays, darker segments indicate higher power in each frequency band: delta, up to 3 Hz; theta, up to 8 Hz; alpha, up to 12 Hz. Vertical lines in spectral arrays and hypnograms indicate epoch from which the EEG record was obtained.