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Original Article

Electroencephalographic slow waves prior to sleepwalking episodes

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ABSTRACT

Objective: Recent studies have suggested that the onset of sleepwalking episodes may be preceded by fluctuations in slow-wave sleep electroencephalographic characteristics. However, whether or not such fluctuations are specific to sleepwalking episodes or generalized to all sleep–wake transitions in sleepwalkers remains unknown. The goal of this study was to compare spectral power for delta (1–4 Hz) and slow delta (0.5–1 Hz) as well as slow oscillation density before the onset of somnambulistic episodes versus non-behavioral awakenings recorded from the same group of sleepwalkers. A secondary aim was to describe the time course of observed changes in slow-wave activity and slow oscillations during the 3 min immediately preceding the occurrence of somnambulistic episodes.
Methods: Twelve adult sleepwalkers were investigated polysomnographically during the course of one night.
Results: Slow-wave activity and slow oscillation density were significantly greater prior to patients' somnambulistic episodes as compared with non-behavioral awakenings. However, there was no evidence for a gradual increase over the 3 min preceding the episodes.
Conclusions: Increased slow-wave activity and slow oscillation density appear to be specific to sleepwalking episodes rather than generalized to all sleep–wake transitions in sleepwalkers.

1. Introduction

Sleepwalking, also known as somnambulism, is a non-rapid eye movement (NREM) parasomnia involving behaviors of varying complexity, usually initiated during arousals from N3 sleep, also known as slow-wave sleep (SWS) [1,2], during the first sleep cycle of the night [2,3]. The symptoms and manifestations that characterize sleepwalking can vary greatly both within and across patients, but most episodes are characterized by misperception and relative unresponsiveness to the environment, impaired judgment, perceived threat or agitation, and variable retrograde amnesia [4].

Whereas sleepwalkers' overall sleep architecture and cycling among sleep stages is essentially the same as that of controls [2,3,5], sleepwalkers show an unusually elevated number of spontaneous awakenings and electroencephalogram (EEG) arousals occurring out of SWS, even on nights without episodes [3,6,7]. Furthermore, sleepwalkers' increased number of arousals is limited to SWS as they do not show a greater number of awakenings from other sleep stages in comparison with controls [3]. Other documented abnormalities in sleepwalkers' SWS include disturbances in sleep intensity as measured quantitatively by slow-wave activity (SWA: spectral power between 0.5 and 4.5 Hz) [3,5] as well as atypical patterns in the cyclic alternating pattern rate, a measure of NREM sleep instability [8–10]. Taken together, these findings suggest that somnambulism could be due to a dysfunction in SWS regulation (see [2] for a review).

Although a majority of polysomnographic (PSG) studies of sleepwalkers have examined general all-night sleep characteristics, increasing attention has been paid to the study of sleep EEG variables immediately preceding the onset of somnambulistic episodes. To date, the study of SWA and slow oscillations (SO; EEG waves >75 μV, <4 Hz) prior to episode onset appears to be the most promising in advancing our understanding of pathophysiological mechanisms underlying this parasomnia. One study of 11 patients with sleepwalking and/or sleep terrors (six with sleep terrors only) found that SWA during the 2 min immediately preceding a parasomniac episode is greater than SWA measured 10 min prior to the parasomniac episode [6]. SWA during the 2 min prior to a parasomniac episode was also greater than that during the 2 min preceding an arousal without behavioral manifestations. However, nine of the 15 episodes analyzed in this study were sleep terrors and there was no indication as to how many of the 15 episodes and 150 arousal reactions analyzed came from each of the 11 subjects investigated. It is thus possible

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Table 1
Patient characteristics.

Patient	Gender	Age at recording	Episode frequency	Presence of concomitant sleep terrors	Presence of a positive family history of somnambulism
1	F	25.3	1/month	Possible	Yes
2	F	33.5	±daily	No	No
3	M	22.3	Daily	Nil	No
4	F	19.4	Daily	Yes	Possible
5	F	18.3	Two times per week	No	No
6	F	20.5	Daily	No	Yes
7	M	39.9	±Daily	Yes	Possible
8	F	32.1	Few times/month	No	No
9	F	35.2	Few times/week	No	No
10	M	19.2	Three or four times/week	No	Yes
11	F	22.2	Two times/week	No	Yes
12	F	40.5	Four or five times/week	No	Yes

that data from some subjects were given a disproportionate weight in comparison with others. A subsequent study [5] analyzed spectral power in delta (2.25–4 Hz) and in slow delta (0.75–2 Hz) bandwidths during the 32 s immediately preceding somnambulistic episodes in 12 adult sleepwalkers. They found an increase in slow delta power density during the 4–16 s (12 s total) preceding episode onset as compared with the 28–32 s segment preceding an episode. However, the statistical analyses focused only on the 4–16 s time window before the episodes, leaving out the 16–28 s time period. Moreover, analyses of SWA beyond 32 s prior to an episode may be necessary to detect more gradual changes in EEG signals. More recently, Jaar et al. [11] investigated the sleep EEG prior to somnambulistic episodes recorded out of SWS during daytime recovery sleep following 25 h of sleep deprivation, finding an increase in SWA during the 20 s prior to episode onset. This study was also the first to investigate SO in sleepwalkers. It revealed an abrupt increase in SO density in the 20 s immediately preceding episode onset. However, the specificity and generalizability of the study's findings were limited by the fact that the data were collected during daytime recovery sleep following 25 h of sleep deprivation and that no comparable control periods were investigated.

The aim of the present study was to investigate patterns of SWA and SO density prior somnambulistic episodes recorded during normal sleep in comparison with patterns observed prior to non-behavioral awakenings collected from the same subjects. PSG data collected during normal overnight recordings from adult sleepwalkers were used to compare EEG patterns observed during the 3 min preceding episode onset (a longer time window than previously investigated the literature) with those observed from normal awakenings without behavioral manifestations while focusing on fluctuations in the spectral power of SWA (0.5–1 Hz), delta (1–4 Hz) and slow delta (0.5–1 Hz) bandwidths and on SO density. It was hypothesized that SWA, delta, slow delta, and SO density would be greater before somnambulistic episodes than before non-behavioral awakenings collected from the same sleep stage and NREM sleep cycle. Since postulated increases in SWA may occur gradually, the time course of observed changes in SWA and SO during the 3 min preceding somnambulistic episodes was also investigated.

2. Methods

2.1. Subjects

Subjects were 12 adult sleepwalkers (three men, nine women; mean age, 27.4 years; SD, 8.4) referred to the Sleep Disorders Clinic of the Hôpital du Sacré-Coeur by their physician for suspected somnambulism. All patients reported a clinical history (including over the previous 6 months) of somnambulism that was not of a traumatic, neurological, or medication-induced origin, and received a final diagnosis of SW according to the International Classification of Sleep Disorders [4]. Exclusion criteria consisted of: (1) the presence of another sleep disorder [4] or an index (number per hour of sleep) >5 for respiratory events (apnea–hypopnea index) or >10 for periodic leg movements during sleep; (2) a history of neurological or psychiatric disorders; (3) a history of drug addiction or abuse; and (4) the use of medications that could influence the sleep EEG, sleep architecture, motor activity during sleep, or daytime vigilance. The 12 patients included in the present study were selected on the basis of having experienced, while undergoing a whole-night PSG in the sleep laboratory, at least one spontaneous somnambulistic episode in addition to one non-behavioral awakening during the same sleep stage within the same NREM period with a minimum of 5 consecutive minutes of sleep separating the two events. The study was approved by the hospital's ethics and scientific committee, and informed consent was obtained from each patient. Table 1 presents the clinical characteristics of these 12 patients.

2.2. Materials

PSG recordings were conducted on a 32-channel Grass polygraph (sensitivity, 7 μV/cm; bandpass, 0.3–100 Hz). Signals were digitized at a sampling rate of either 256 Hz using commercial software (Harmonie, Stellate Systems, Montréal, QC, Canada). EEG recordings and electrode placement were performed according the 10–20 system (Fp1, Fp2, F3, F4, F7, F8, C3, C4, P3, P4, O1, O2, T3, T4, T5, T6, Fz, Cz, Pz; linked ears), with left and right electro-oculogram, chin EMG, pulse oxymetry, nasal/oral thermistor, and electromyogram leg electrodes. All patients were continuously videotaped during sleep assessment and sleep stage data scored according to established criteria [12].

All behavioral manifestations arising out of patients' SWS (stage N3) were visually inspected on the accompanying time-synchronized video recordings and attention paid to behavioral episodes characterized by clumsy, stereotyped or repetitive movements, confusion, agitation or disorientation during the event, and episodes accompanied by (but not limited to) somniloquy. The selected somnambulistic episode occurred during the first NREM period for nine participants and in the second NREM period for the other three subjects. For each patient, one non-behavioral awakening was selected that matched the patient's episode occurrence in terms of sleep cycle and sleep stage (with the restriction that a minimum of 5 min of continuous sleep separated the two events). Non-behavioral awakenings were defined as a transient interruption of sleep, identifiable when ≥50% of an epoch contained alpha (8–13 Hz) activity or low-voltage, mixed (2–7 Hz) frequency activity [12]. In five cases the somnambulistic episode occurred before the arousal, and in seven cases the order was reversed.