The Association Between EEG and Sleep Perception During MSLT Naps on Subjects With Excessive Daytime Sleepiness

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This study investigated the relationship between EEG indexes and perception of sleep depth (DEPTH) during Multiple Sleep Latency Tests (MSLT). Participants were five males (X=41.6 years) and six females (X=36.8 years) with clinical complaints of excessive daytime sleepiness. Each subject had five nap opportunities. Subjects completed the Stanford Sleepiness Scale (SSS) before each nap and completed a "0-5" point scale to indicate DEPTH of sleep (DEPTH "0" indicated awake and DEPTH "5" indicated deep sleep) after each nap. Only naps in which EEG sleep occurred were used for data analysis. Recordings were scored for standard sleep parameters and SS density. Total sleep time (TST) was positively correlated with DEPTH. Analysis of variance (ANOVA) showed that TST was significantly less for DEPTH "0" compared to DEPTH "1-4". SS density was positively correlated with TST but not with DEPTH. ANOVA showed SS density was significantly lower for DEPTH "0" and DEPTH "4" compared with DEPTH "1-3". SSS scores were unrelated to TST and DEPTH scores. These results indicated that TST was associated only with the subjective experience of being awake versus being asleep. SS density was related to the perception of intermediate DEPTH levels but not to the deepest level (DEPTH "4"). Decreased SS density at DEPTH "4" indicated either that SS is not sufficient for accurate sleep perception or that all sleep states are not homogenous in terms of subjective experience. (Sleep and Hypnosis 2001;3(2):84-92)

Key words: sleep spindle, multiple sleep latency test, sleep onset latency, sleep perception, excessive daytime sleepiness

INTRODUCTION

Discrepancy between objective and subjective sleep, referred to as sleep misperception, is common in normal sleepers but is most evident in insomniacs (1). Sleep and wake stages are typically defined by electroencephalographic (EEG) patterns. EEG is only one neurophysiological aspect of the sleep state and researchers have tried to correlate other factors with EEG sleep/wake patterns. These factors have included subjective reports of sleep onset, sleep quality and sleep depth (2-9); auditory arousal thresholds (AAT) (4,5,10-12); event related potentials (13-16); and button pressing paradigms to indicate behavioral wakefulness (17-20).

Polysomnographic (PSG) variables such as sleep stage percentages (4,8), sleep onset latency (SOL) (12,21), total sleep time (TST) (2,3,9,11), and EEG frequency analysis (15,22) have also been studied in relation to sleep perception. No single factor or combination of factors has unequivocally been found to relate EEG, behavioral and subjective indexes of sleep.

For example, AAT does not reliably correlate with self-reports of sleep depth/quality taken either at the end of the sleep period or following awakenings from particular sleep stages (4,5,10-12). Secondly, even though AAT is usually greatest in

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Accepted September 26, 2000

slow wave sleep (SWS), an inverse relationship between subjective sleep depth and SWS percentage was found in normal sleepers (8). Similarly, an inverse relationship between sleep quality reports and SWS percentage was demonstrated in insomniacs (4). Sewitch (9) found that normal subjects reported being awake in 26 percent of awakenings from REM, 56 percent from stage 2 and 77 percent from stage 4. Mendelson (5) showed that, when awakened from stage 4 sleep, insomniacs reported having been awake 50 percent of the time as compared to 40 percent during stage 2, 7 percent during REM, 87 percent five minutes after lights out and 57 percent during wake following the first REM episode. Discrepancies for sleep perception during all stages of sleep were described in earlier studies, as well (23,24).

Other studies have looked at the role of TST on sleep perception. Sleep perception has been shown to improve with increased stage 2 sleep time and with decreased sleep fragmentation (3,9-11). Sleep time is not sufficiently predictive of subjective experience, however, since in all studies, a certain percentage of subjects reported wakefulness during stage 2 sleep. Furthermore, a higher percentage of wakefulness was reported from stage 4 awakenings than from stage 2 (5,9,25). These findings do not support the TST hypothesis, since SWS occurs after stage 2 in the normal sleep cycle. These findings suggest that some other variable(s) aside from, or in addition to, stages and stage percentages is related to sleep perception.

The appearance of sleep spindling (SS) and/or K-complexes have been used to indicate unequivocal EEG sleep (26-28). SS has not been systematically studied in relation to sleep perception. SS were shown to promote the initiation and initial descent of EEG from stage 1 into SWS (29). Epochs in which SS occurred had significantly less EEG arousals than epochs in which no SS or in which an isolated K-complex occurred (31,32). These results suggest that SS are related to improved sleep consolidation and decreased likelihood of arousals. Improved sleep perception was reported in subjects with low arousal indexes (10) and with increasing sleep time following the first SS (9,11).

Two experimental paradigms have predominantly been used to obtain self-reports of sleep/wake state. One method is to awaken subjects at the end of the sleep period and to collect subjective reports about the quality and depth of sleep. Another experimental paradigm is to awaken subjects (verbally or with auditory tones) at various times from different sleep stages to collect self-reports. This study was conducted to investigate the relationship of EEG indexes and sleep perception during Multiple Sleep Latency Test (MSLT) naps in patients with excessive daytime sleepiness (EDS), but otherwise normal sleep parameters. The MSLT was chosen because scoring criterion (32) allows only 15 minutes of TST before termination of the nap and because SWS and REM are unlikely to occur. One report (11) found that sleep perception was most accurate after 16 minutes of sleep, therefore, the MSLT provides a natural control for maximal TST. It was expected that using patients with EDS would optimize the chance of obtaining EEG sleep during the naps. MSLT naps allow for multiple data collection opportunities and the collection of sleep reports close to the sleep onset process instead of at the end of many hours of sleep. We hypothesized a positive correlation between SS density and subjective sleep depth reports.

METHOD

Subjects

Subjects consisted of eleven patients with clinical complaints of EDS (5 males and 6 females) between the ages of 20 and 55 (X = 41.6 years for men; X= 36.8 years for females). Subjects were previously scheduled for an all-night polysomnogram (PSG) and a following day MSLT. Prior to the nocturnal PSG recordings, each subject signed a consent form, approved by the Washington University Institutional Review Board, for permission to use the PSG and MSLT data for study purposes.

Inclusion criteria: Subjects were (1) age 20 to 55 years; (2) on a nocturnal sleep schedule; (3) already scheduled for PSG with following day MSLT as part of clinical diagnostic testing; (4) chosen based on clinical complaints of EDS.

Exclusion criteria: (1) previous diagnosis of obstructive sleep apnea (OSA; index>10/hr.), periodic leg movements (PLM; index>5/hr.), narcolepsy, insomnia, parasomnia or any disorder discovered during the current PSG/MSLT testing (33); (2) sleep schedule other than nocturnal; (3) medications known to alter sleep architecture that could not be withdrawn for two weeks prior to the PSG/MSLT; (4) use of caffeine or alcohol within 12 hours of the PSG; (5) less that 60 percent sleep efficiency index on the PSG.

Apparatus

The nocturnal PSG consisted of EEG scalp elec-

trode placement according to the International 10-20 System (34). Left and right electrooculogram (EOG), submental electromyogram (EMG), intercostal EMG and left and right anterior tibialis EMG were monitored. Snoring, airflow, EKG and arterial oxygen saturation were monitored. Thoracic and abdominal effort were monitored by plethysmography. PSG and MSLT data were collected on paper recordings using a Nihon Kohden Neurofax machine or on computer using the Healthdyne Corporation sleep analyzing program (Alice III).

The MSLT included central (C3 and C4) and occipital (O1 and O2) EEG [sensitivity (S)=5, high frequency filter (HFF)=35, low frequency filter (LFF)=.3]. Left and right EOG electrodes (S=5, HFF=35 and LFF=.3) were placed one centimeter above the outer canthus of the left eye and one centimeter below the outer canthus of the right eye. This allowed recording of horizontal and vertical eye movements. EMG (S=2, HFF =90 and LFF=10) were placed below the chin to record muscle tension and loss of muscle tone. A snoring microphone and airflow monitor were used to record changes in respiratory rate or volume. On the day following the PSG, MSLT naps were performed at 10:00, 12:00, 14:00, 16:00 and 18:00. For each nap, the subject remained in bed in a quiet, dark room, and was instructed to allow him/herself to fall asleep. Naps were terminated following 20 minutes of continual wakefulness or 15 minutes after the first epoch of sleep (32).

Procedure

On the morning following the PSG, the records were reviewed for OSA, PLM, insomnia, sleep efficiency, and parasomnias. Sleep stages were scored in 30 second epochs according to Rechtschaffen and Kales and standard diagnostic criteria were used to assess sleep disorders (33,35).

Prior to each nap, each subject completed a Stanford Sleepiness Scale (SSS), to indicate the level of subjective sleepiness prior to the nap (36). Upon awakening from each nap, each subject was asked to rate the depth of sleep on a scale from 0-5. "0" reflected no sleep/awake throughout the entire nap and "5" indicated that deep sleep was achieved. No criteria were given to subjects regarding how to define subjective wakefulness and deep sleep. Between naps, the subjects were allowed to stay in the bedroom, to sit in the television room or to take a walk in the hallways close to the sleep laboratory. Subjects were monitored to ensure that they did not sleep between MSLT naps.

Data Analysis

Each subject had 5 nap opportunities. Only naps in which objective sleep appeared were used for data analysis. Of fifty-five naps obtained from eleven subjects, five were excluded from the study because EEG sleep did not occur. For statistical purposes, each nap was considered an independent data point.

The MSLT naps were scored for percentages of stages wake, 1, 2, 3, 4 and REM. Sleep stage percentage was derived by dividing the minutes of a particular stage by minutes of TST. Sleep onset latency constituted the number of minutes from lights out to the first epoch of stage 1. In addition, sleep efficiency, minutes of wake after sleep onset (WASO) and arousal index (AI) were determined. Sleep spindles were scored from the central (C4-A1, C3-A2, C3-O2 and / or C4-O1) EEG scalp areas. A SS was defined, by visual scoring, as a 12-15 Hz synchronous burst in the EEG lasting .5 to 2 seconds, which was at least 20 microvolts in amplitude. Sleep spindle density was calculated for each nap by dividing the number of SS by the number of minutes scored as stage 2. EEG microarousals were scored when the sleep EEG was interrupted by 3-14 seconds of continuous low-voltage, mixed-frequency activity.

A multiple regression analysis was run to determine which independent variables predicted sleep depth reports. One-way analysis of variance (ANOVA) was run to clarify the results of the multiple regression. Scheffe post-hoc tests were used when the ANOVA indicated significance. Two-tailed tests were run at a significance level of $p<.05$ for all analyses.

RESULTS

Fifty-five MSLT naps from a total of 11 subjects were recorded. Five naps were excluded from the study because electrophysiological sleep was not attained. Of the fifty naps in which objective EEG sleep was recorded, 43 (86%) were subjectively perceived as sleep. Sleep depth ratings will be referred to as "DEPTH". Seven naps were scored DEPTH "0", twelve scored DEPTH "1", sixteen scored DEPTH "2", nine scored DEPTH "3", six scored DEPTH "4" and no subjects scored DEPTH "5". Table 1 provides descriptive statistics for each DEPTH category.

Correlations with SS density

Five variables were significantly correlated with

Table 1. Mean values (S.D.) for dependent variables in each DEPTH category

Variable	DEPTH 1	DEPTH 1	DEPTH 2	DEPTH 3	DEPTH 4
N	7	12	16	9	6
AI	1.31(.54)	.65(.36)	.63(.24)	.43(.24)	.48(.32)
SOL	9.93(5.61)	7.04(4.73)	5.41(3.55)	8.17(6.69)	6.67(4.94)
SSD	.37(.63)	3.37(1.32)	2.73(1.69)	2.69(1.27)	1.88(.38)
SSS	2.00(.82)	2.83(.94)	3.06(1.24)	2.78(1.39)	3.17(2.04)
ST1MIN	2.14(.75)	4.75(3.34)	5.34(3.76)	3.30(2.70)	4.00(2.64)
ST2MIN	.86(1.49)	8.25(2.97)	9.59(2.87)	11.28(2.36)	9.33(3.76)
ST2PER	.16(.23)	.64(.21)	.63(.13)	.76(.14)	.67(.20)
TST	3.00(1.78)	13.17(2.96)	15.13(2.26)	15.00(2.06)	13.75(1.84)
WASO	9.79(7.57)	1.67(1.85)	1.66(2.37)	2.83(2.56)	1.50(1.00)

N= sample size; AI = arousal index; SOL = sleep onset latency; SSD = sleep spindle density; SSS = Stanford Sleepiness Scale; ST1MIN = minutes of stage 1; ST2MIN = minutes of stage 2; ST2PER = percentage of stage 2 based on total sleep time; TST = total sleep time; WASO = minutes of wake after sleep onset

SS density. Positive correlations occurred with TST (r= .36, p= .011) and minutes of stage 2 sleep (ST2MIN) (r= .44, p= .001). Negative correlations occurred with AI (r = -.33, p=.017), WASO (r = -.44, p= .001) and SOL (r= -.38, p=.006).

Correlations with perceived sleep depth

Four variables were significantly correlated with DEPTH. Total sleep time (r= .45, p=.001), ST2MIN (r=.53, p=.000) and percentage of stage 2 sleep (ST2PER) (r=.46, p=.001) were positively correlated with DEPTH. The AI was negatively correlated with DEPTH (r=-.44, p=.001).

A negative correlation between AI and SS density (r=-.33, p=.017) and between SS density and WASO (r=-.44, p=.001) indicated that arousals and awakenings decreased with increased SS. However, a relationship between SS density and DEPTH was not found (r=.17, p=.244).

Correlations with TST

There were nine correlations with TST that reached significance. TST was positively correlated with DEPTH (r=.45, p=.001), ST2MIN (r=.72, p=.000), ST2PER (r=.39, p=.005), SS density (r=.36, p=.011), and SSS scores (r=.38, p=.006). TST was negatively correlated with SOL (r =-.34, p=.015), AI (r=-.42, p=.003) and WASO (r= -.51, p=.000).

SSS scores were negatively correlated with SOL (r= -.42, p=.002). SSS did not correlate with DEPTH scores (r=.17, p=.231). Due to colinearity among variables, additional analyses were performed to interpret the correlations and to determine which variables were predictive of DEPTH.

Multiple regression analyses

First, a multiple regression analysis was performed to determine which independent variable(s) from the above correlations best predicted DEPTH. TST, ST2MIN, AI, SS density and SOL values were entered into the regression as independent variables and DEPTH was entered as the dependent variable. TST was the only variable to significantly predict DEPTH (DF=1, F=24.38, p=.000). Arousal index, SS density, SOL and ST2MIN did not provide additional significant predictive value over TST. This meant that the significant correlations between ST2MIN and AI to DEPTH were accounted for by colinearity of these variables with TST. Any predictive value of ST2MIN on DEPTH could be accounted for by the strong correlation between ST2MIN and TST.

A second multiple regression was performed that excluded TST and used ST2MIN, SSS, WASO, SS density and minutes of stage 1 (ST1MIN). The purpose was to test whether ST2MIN would be entered into the regression equation first and if any variables not tested in the first multiple regression would be entered. This time, ST2MIN was the only variable to significantly predict DEPTH (DF=1, F=24.38, p=.000). These findings showed that TST was the only variable which significantly predicted DEPTH and other variables correlating with DEPTH were colinear with TST.

Analysis of variance

ANOVA was performed to determine between which DEPTH values (0-4) TST significantly differed. DEPTH was divided into five levels which corresponded to the five response values reported on the sleep depth scale (0-4). Mean TST values were calculated for each level. Mean TST for DEPTH "0" (X=3.0±1.78), was significantly less than DEPTH "1" (X=13.17±2.96), DEPTH "2" (X=13.75±.26), DEPTH "3" (X=15.0±2.06) and DEPTH "4" (X=15.13±1.84). The only significant difference of the post hoc analysis was between DEPTH "0" and all other DEPTH levels.

A second ANOVA was performed to determine between which DEPTH values (0-4) SS density significantly differed. DEPTH was divided into five levels which corresponded to the five response values reported on the sleep depth scale (0-4). SS density was significantly less for DEPTH "0" (X=.37±.629) and DEPTH "4" (X=1.88 +/- .38) compared with DEPTH "1" (X=3.37±1.32), DEPTH "2" (X=2.73± 1.69) and DEPTH "3" (X=2.69 +/- 1.37).

DISCUSSION

This study investigated the relationship between EEG indexes and subjective sleep perception during MSLT naps. Subjective DEPTH ratings were positively correlated with TST and ST2MIN and negatively correlated with AI. Multiple regression analysis showed that only TST significantly predicted DEPTH. The correlations of ST2MIN and AI with DEPTH were due to high colinearity with TST. Therefore, in this study, TST was the best predictor of sleep DEPTH. The hypothesis that SS density would be positively correlated with perceived DEPTH was not directly supported. However, it was observed that toward the end of naps with longer TST, delta activity began to increase. It is established that the appearance of SS and delta frequencies are inversely related. The non-significant correlation between SS density and DEPTH may have been due to reduced SS in naps with high TST. Therefore, it is possible that sleep perception is regulated differentially during stage 2 and SWS. The following is a more detailed discussion of the results.

Bonnet (11) reported that in normal sleepers, 4-8 minutes and 16 minutes following the first SS, sleep perception accuracy was about 60 percent and 90 percent, respectively. Sleep perception improved with increased sleep time and was unrelated to AAT levels. In normal sleepers, TST is positively correlated with sleep perception accuracy for stage 2 awakenings but not for REM awakenings (9).

Performance tasks have been used as indicators of sleep onset. For example, lapses in continuous finger tapping (19), reduced reaction times to auditory stimuli (37, 38), alterations in thoracic and abdominal respiratory activity (28) and changes in event related potentials were consistently associated with stage 2, but less reliably with stage 1 (alpha attenuation) (22).

While sleep perception accuracy and behavioral changes are more reliable in stage 2 compared to stage 1, a point of convergence between subjective, behavioral and EEG measure has not been identified. Even the subjective state of sleepiness, as measured by the SSS and the Visual Analog Scale, does not reliably correlate with objective measures such as the MSLT, Maintenance of Wakefulness Test or the behavioral measures indicated above (39-41). In this study, there was no correlation between SSS and EEG sleep onset latencies on the MSLT. Furthermore, there was no correlation between SSS and DEPTH scores. Therefore, subjects did not use subjective sleepiness levels prior to the naps to determine whether or not they slept.

Because most studies have collected sleep reports from stage 2 and not from stage 1, it is difficult to differentiate the effects of TST from the onset of phasic events such as SS and K-complexes. For example, would ten minutes of stage 1 sleep be perceived the same as five minutes of stage 1 followed by 5 minutes of stage 2? This type of control is very difficult to reliably exert across subjects since sleep stages follow a natural architecture. Because it takes longer to reach what has traditionally been considered "deeper" stages of sleep (SWS), it is virtually impossible to separate effects of TST from isolated sleep stages.

Stage 2, as defined by the appearance of SS and K-complexes, has represented unequivocal sleep for stage scoring purposes (26,45). Our results indicate that all naps with less than six minutes of TST (14%) were perceived as wakefulness (DEPTH "0") whereas all naps with greater than six minutes of sleep (86%) were related as DEPTH "1", "2", "3" or "4". While the correlation between DEPTH and TST was significant, ANOVA showed that the only difference was less TST for DEPTH "0" compared to all other groups (DEPTH "1-4"). The fact that there were no differences in TST between DEPTH "1-4", suggests that something(s) other than TST accounted for variations in DEPTH ratings. Both stage 1 and stage

2 times were significantly less in DEPTH "0" compared with DEPTH "1-4" but were not different between DEPTH "1-4". Of the seven naps reported as wake (DEPTH "0"), SS appeared in two and stage 2 was scored in 3 naps, so the absolute appearance of stage 2 is not a sufficient EEG correlate of sleep perception. Stage 2 and SS occurred in 100 percent of the naps rated as DEPTH "1-4".

One might expect that "deeper" sleep, stages 3 and 4, would be more accurately perceived than "lighter" sleep, stages 1 and 2. Arousal thresholds are normally higher in SWS than other stages and SWS occurs with increasing TST. However, an inverse relationship between SWS and sleep perception has been shown. Stage 4 percentage was inversely correlated with reports of sleep quality obtained in the morning following a full night of sleep (4,8). A trend for the perception of wakefulness following EEG stage 4 awakenings in normal sleepers (9). Similarly, higher percentages of "wake" reports followed stage 4 awakenings compared to stage 2 and REM in insomniacs (5).

Auditory arousal thresholds, which are highest during SWS, were not related to reports of sleep quality or depth (2,11,12). Triazolam, which increased AAT in stages 2 and REM sleep, did not significantly improve sleep perception in these stages (5). Triazolam increased perception accuracy in SWS despite no significant increase in AAT during this stage. These results challenge the notion that EEG stages define behavioral states. The lack of correspondence between general sleep stages and subjective sleep reports suggests that some other neurophysiological correlate(s) to sleep perception may exist. The difference between obtaining sleep reports upon awakenings from specific sleep stages as compared to the end of a full night of sleep may be clarified in future studies. Also, the relationship between subjective reports of sleep quality, sleep depth and sleep/wake state may be further investigated.

Several studies have indicated that SS is important for EEG consolidation and normal sleep stage progression. During the onset of sleep, auditory tones presented at the occurrence of SS were less disruptive to sleep continuity than were tones presented randomly (29). During nocturnal sleep, arousals are significantly less frequent in epochs following SS than during epochs not including SS (30,31). Increased SS interfered with morning arousal levels in a group of patients with idiopathic hypersonic (46). The hallmark of benzodiazepines, which improve sleep quality reports, and in some cases sleep perception, is increased SS density/sigma power and often decreased delta power (47).

In our study, AI, a measure of sleep fragmentation, was inversely correlated with SS density, TST and DEPTH, which reflected previous findings. AI was positively correlated with ST1MIN which indicated an association between stage 1 and sleep fragmentation. Johnson (26) proposed that sleep perception relies upon consolidated sleep, and that stage 2 indicates unequivocal sleep. Therefore, it is likely that a neurophysiological event, such as SS or K-complexes, is related to perception. However, we did not find a significant correlation between SS density and DEPTH ratings, which indicated that SS was not related to DEPTH in this subject sample. However, SS density was significantly less in DEPTH "0" and DEPTH "4" compared to DEPTH "1-3". It seemed paradoxical that SS density was lowest for subjects that reported being awake and also for those who reported the deepest sleep. The low SS density for DEPTH "0" was probably due to the small amount of stage 2 sleep in this group. However, the low density in DEPTH "4" may be consistent with previous findings that the occurrence of peaks in the sigma power spectrum are inversely related to peaks in delta power (48). The transition from stage 2 sleep to SWS is not sudden but constitutes a gradual increase in delta waves over a period of time. Unfortunately, delta and sigma power were not quantitatively measure in our study but absolute counts of SS and sleep stage epochs were made. In the present sample, visual inspection suggested that in the longer MSLT naps with DEPTH "3" and "4" ratings, delta wave activity was increased, although the stage 3 scoring criterion was not met. Admittedly, this was not a quantitative measure, but the trend for increased delta waves with increased sleep time, and the reduction in SS density is reflective of quantitative reports (48). The reduced SS density in DEPTH "4" may have precluded a significant overall correlation between SS and DEPTH. The correlation between SS density and DEPTH "1-4" was .17 ($p<.244$) and the correlation between SS density and DEPTH "1-3" was .28 ($p<.067$), which approached significance. The ANOVA showed no significant difference in SS density between individual DEPTH "1-3" levels. However, the trend for higher SS densities at DEPTH "1-3" and lower SS densities at DEPTH "4", suggests that stage 2 and delta sleep may represent different mechanisms underlying sleep perception. Because sleep perception has not been evaluated in the context of SS, these speculations may provide a basis for future

investigation.

The trend that DEPTH "4" scores were accompanied by increased delta activity and increases TST was different from previous reports in which wake reports following arousals from stage 4 sleep were more frequent than from stage 2 and REM arousals (5,25). One likely reason for the discrepancy between studies is methodological differences. Studies investigating sleep perception use many different research protocols, subject populations, measurement tools, awakening paradigms and pharmacological agents. The following is a discussion of how the methodology in our study could have influenced the results.

We initially expected that, due to the short duration of sleep allowed on MSLT naps, subjects would make frequent errors in sleep perception. However, 86% on the naps in which EEG sleep occurred were perceived as sleep. Our sample consisted of patients with complaints of EDS with no other sleep complaints or sleep disorders. Some studies have used normal sleepers (9,11), while others have used insomniacs with the intent of testing the effects of hypnotics on sleep perception (5,25). Because our sample differed clinically from insomniacs and normal sleepers without EDS, the comparison of results between studies cannot be made directly. Also, since relatively little is known about neurophysiological mechanisms of insomnia and EDS, it is not possible to generalize results from these studies to explain mechanisms of normal sleep.

We expected that subjects would sleep approximately the full 15 minutes during MSLT naps and that TST would be held constant between naps and subjects. This was not the case, and TST ranged from 1.5 minutes to 20 minutes. More than 15 minutes of sleep occurred on a few naps due to difficulty in determining sleep onset at the time of testing. While the high correlation between TST and DEPTH in instructive, it was hoped that SS and AI could be less ambiguously studied in relation to DEPTH. Colinearity between variables made it difficult to interpret the effects of individual variables.

Because SWS did not occur during the MSLT naps, we had no quantitative data regarding the role of delta waves in sleep perception and the nature of the relationship between SS and SWS. EEG power spectrum may provide useful quantitative data regarding relationships between these variables. The MSLT may be considered and further validated as an experimental paradigm to study sleep perception (49). If sleep architecture during MSLT naps is reflective of the first nocturnal sleep cycle, the MSLT would be an efficient data collecting method due to the repetitive number of naps taken by each subject. Another instructive study may be to use the MSLT paradigm to awaken subjects at predetermined times after sleep onset, such as immediately after stage 1 onset, the first K-complex and SS, and SWS onset. Such a design may help to more clearly determine the individual contribution of these events in sleep perception.

It is unknown what internal or behavioral cues are used to perceive sleep or to determine sleep depth. REM mentation is a reliable cue for subjectively perceiving REM sleep. In the present study, REM sleep did not occur in any of the naps. As discussed, sleep time estimation, AAT, sleep stages and perceived sleep quality have inconsistent relationships to perceived depth. One study found that sleep perception varied according to time of day (21). Subjects reported sleep significantly more accurately during the first three MSLT naps than during the fourth nap. Johnson (39) found more consistent correlations between objective and subjective sleep during the first MSLT naps (06:00) but not on subsequent naps. In contrast, another study showed no differences in TST and sleep perception as a function of time of night for REM and NREM (9). A future study might look at sleep perception during different sleep stages across the entire night in other populations such as sleep maintenance insomniacs and hypersomniacs.

Variables that were not considered in this study may have contributed to DEPTH ratings. For instance, we did not consider whether subjects were already awake at the end of the nap or if the experimenter awakened them prior to collecting subjective reports. The knowledge of having been awakened could have influenced subjects perceptions. Most studies have used auditory tones to awaken subjects instead of waiting for endogenous arousals. In our study, WASO was not significantly correlated with DEPTH ratings. The placement of wakefulness during the naps did not appear to influence DEPTH reports.

In this study, there was no correlation between SSS scores and DEPTH which suggested that subjects did not use pre-nap subjective experiences of sleepiness as a cue for evaluating DEPTH. There was a significant correlation between SSS and MSLT sleep onset latencies. Others did not find a relationship between subjective and electrophysiological sleepiness (40). Another self-report measure, the Epworth Sleepiness Scale (ESS) (50) is used to measure the general level of daytime sleepiness across many commonly encountered situations. In contrast

to our results of a non-significant correlation between SSS and DEPTH, ESS scores and SOL have been positively correlated with the accuracy of perceiving sleep (21). The use of different scales, report measures and statistics may account for the contrasting results. The literature on sleep perception contains a variety of methodologies such as the use of self-report measures (sleep quality, sleep depth, wake versus sleep, awakenings from sleep, end of night reports), EEG analysis techniques (EEG sleep staging, power spectrum analysis), sleep paradigms (MSLT versus all-night PSG) and subject samples (normal sleepers versus insomniacs, young versus old). The significance of these differences may be elucidated in future studies.

CONCLUSION

In our sample of patients with complaints of EDS with no other identified sleep problems, TST was most significantly associated with the perception of sleep depth. Naps with less than 6 minutes of either stage 1 or 2 sleep were perceived as wake and naps with greater than 6 minutes of sleep were perceived as ranging from "light" to "deep" sleep. The overall correlation between SS density and DEPTH was not significant, however, reduced SS density in the "deepest" perceived naps and the observation of increased delta activity, suggests that EEG sleep stages may be heterogeneous with respect to the neurophysiological mechanisms underlying sleep perception.

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