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Positive sleep state misperception – A new concept of sleep misperception

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Abstract

Objectives: To better define the concept of sleep misperception and analyse a category of patients who overestimate their sleep. At present, a condition of underestimation of sleep is classified as paradoxical insomnia. Overestimation of sleep has also been reported in the past, with no clear reference to corresponding polysomnographic (PSG) findings or its clinical significance.
Patients and methods: Patients were recruited from the general population undergoing a PSG assessment for a cross-sectional retrospective study in a sleep clinic affiliated with a tertiary health center.
Results: A group of patients who overestimated their sleep had mostly non-discriminating PSG findings when compared to patients who underestimated their sleep, and correct estimators. The only parameters that were significantly different were objective sleep duration and efficiency, and, importantly, respective multiple sleep latency test (MSLT) results. The patients who overestimated their sleep had a mean MSLT result of 7.8 min, which indicates moderate daytime sleepiness. Patients who underestimated their sleep and correct estimators had the respective MSLT results of >10 min, making a statistically significant difference.
Conclusion: The authors identified a condition opposite the previously described sleep underestimation, and named it 'positive sleep state misperception' (PSSM). The condition is characterised by a gross overestimation of sleep. Inadequate sleep results in a clinically significant excessive daytime sleepiness, which patients were not able to predict. The authors propose a new model that incorporates both ends of the sleep misperception spectrum.

Keywords: Sleep; Sleep state misperception; Paradoxical insomnia; Daytime sleepiness; MSLT

1. Introduction

While progressively advancing on many fronts, the field of sleep medicine has also been blessed with several conditions which defy clear conceptualisation. One of these conditions was formerly known as 'insomnia with no objective findings' [1] or 'sleep state misperception' (SSM) [2], recently renamed 'paradoxical insomnia' [3]. Paradoxical insomnia is now defined as a condition with a complaint of 'severe insomnia that occurs without evidence of objective sleep disturbance' and without a significant impairment of daytime function. Whether SSM merits being recognised as a diagnostic entity separate from other primary insomnias has been repeatedly questioned [4–6] and defended [6,7]. Some researchers have taken the position that SSM represents a subtype of another primary insomnia, while others view it as a prodromal state eventually leading to a psychophysiological insomnia [8,9].

The bulk of available information describes only one facet of SSM – a situation of subjective sleep underestimation, observed mainly in patients with insomnia. On

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the other hand, data describing subjects who underestimate their sleep in relation to other sleep disorders, or who overestimate their sleep, was largely ignored. There were several studies which identified an opposite side of the spectrum – individuals who overestimated their sleep [10–13]. Mercer et al. [14] observed mild overestimation of sleep in their 'good sleeper' group versus the 'insomnia group,' which showed underestimation of total sleep time. Aside from being referred to as 'good sleepers,' these patients were described as having a 'wake–sleep misperception' [11] or 'reverse sleep state misperception' [13]. There is no systematic research of this group of patients as yet, or evaluation of the significance of this variant of sleep misperception.

The purpose of our study was to define this medical condition and assess its medical impact. Considering that these patients have less sleep than reported, and possibly below the threshold necessary to maintain a normal level of daytime alertness, it was expected that their multiple sleep latency test (MSLT) assessment would show higher levels of daytime sleepiness. A secondary aim was to propose a new concept, which would integrate different aspects of sleep misperception.

2. Methods

2.1. Subjects

A retrospective cross-sectional study identified patients who overestimated their sleep after undergoing an overnight sleep assessment. Subjects were selected from the initial pool of 1250 active records (patients undergoing a sleep assessment, or requiring follow-ups), using the following selection criteria: (1) completed overnight sleep [polysomnographic (PSG)] study, (2) completed set of pre- and post-sleep questionnaires (questions related to sleep-self assessment), and (3) completed MSLT. A total of 570 records met such inclusion criteria. From this pool of records, three subgroups were identified based on their sleep perception. The first group of subjects (Ss) were all those who overestimated their sleep by at least two hours when compared to their respective objective data. A total of 27 subjects (17 males, 10 females, age 47.2 ± 14.7) were identified meeting these criteria, and they were referred to as the 'positive sleep state misperception' (PSSM) group. A second group of patients who underestimated their sleep by at least two hours ($n = 59$, 37 males, 22 females, age 45.2 ± 13.5), and a group of patients who were correct in estimating their sleep within an hour ($n = 50$, males 24, females 26, age 41.9 ± 12.9), were randomly selected from the same pool, until matching the size of the first group. Conversely, the former group was referred to as the 'negative sleep state misperception' (NSSM) group, while the latter was referred to as the 'Correct Estimator' (CEst) group. The groups were aggregated in this way based on the reference studies showing that two hours of sleep loss produced significant daytime effect in terms of performance and level of sleepiness. The inability to perceive a significant loss of sleep was hypothesised to result in a (objective) daytime sleepiness, while misperception of sleep loss was expected not to have such effect. The only exclusion criteria in our study were age (17 and younger) and mental retardation or mental/cognitive impairment that may have influenced subjective sleep estimation. After selection, there was no significant difference between groups with regard to reason for referral. Patients from all three groups were selected from the same pool of patients who required MSLT assessment based only on their perception of sleep. All major sleep disorders (or suspicion thereof) were represented in each group, with exception of circadian rhythm disorders being absent from the PSSM group.

2.2. Subjects – Group characteristics

In order to determine whether there was an intergroup bias towards any specific disorder, a statistical ad hoc group analysis was performed using a chi-square method. The sleep conditions were nominally divided into seven groups (Table 1), with some of the patients being referred with several provisional diagnoses, and a relatively small number of patients being referred with 'unknown' or 'multiple unknown diagnoses.'

The results show that there was no statistically significant relationship in the distribution of cases between the three groups (chi-square = 13,944, df = 12,

Table 1
Reason for referral (PLMS – periodic leg movements in sleep, RLS – restless legs syndrome)

Condition	CEst ($n = 50$)	NSSM ($n = 59$)	PSSM ($n = 27$)
1. Excessive sleepiness, narcolepsy	17 (34%)	22 (37.3%)	12 (44.4%)
2. Respiratory d/o	25 (50%)	21 (35.6%)	15 (55.6%)
3. Insomnia, psychiatric d/o	22 (44%)	24 (40.7%)	8 (29.7%)
4. PLMS, RLS, movement d/o	13 (26%)	12 (20.4%)	7 (25.9%)
5. Parasomnia, seizures	6 (12%)	9 (15.3%)	2 (7.4%)
6. Multiple unknown, unknown, other	5 (10%)	15 (25.4%)	4 (14.8%)
7. Circadian rhythm d/o	6 (12%)	2 (3.4%)	0 (0%)

$p = 0.304$). The degree of relationship and association of dependence between the groups was low (Contingency Coefficient = 0.231).

2.3. Data collection

Data collection included a clinical interview prior to the diagnostic PSG assessment, PSG assessment and standard MSLT assessment. The PSG study utilised either a standard montage (C3A2, C4A1, O1A2, O2A1, electro-oculogram (EOG), electromyogram (EMG) m. submentalis, electrocardiogram (EKG), oro-nasal pressure, oro-nasal flow, thoracic and abdominal respiratory effort, O_2 saturation, body position, snoring, EMG mm. anterior tibialis) or a full-EEG montage (standard montage with additional electroencephalogram (EEG) leads). The pre-sleep questionnaire included a seven-item Stanford Sleepiness Scale [15] (SSSpm), which measures acute sleepiness (1 – 'no sleepiness' to 7 – 'inability to stay awake') and a 20-item Toronto Alexithymia Scale (TAS) [16], which measures the level of emotional connectedness and ability to recognise and convey physical symptoms (scores below 51 on this scale are normal). Patients with high alexithymia score have difficulty understanding physical sensations and reporting their symptoms, and often end up undergoing unnecessary or inappropriate medical assessments, while their root problem might remain unresolved. The post-sleep questionnaire, included a morning self-assessment on the Stanford Sleepiness Scale (SSSam) and a brief questionnaire asking patients to evaluate, among other parameters, time they have spent sleeping and sleep onset latency. The SSS served as a measure of subjective, and the MSLT of objective sleepiness.

2.4. Data analysis

The PSG records were scored by experienced scorers, with inter-scorer ratings of reliability of $0.87 \geqslant$ (kappa), and according to accepted criteria (Rechtschaffen–Kales). The criterion for objective sleep latency (SLo) was an interval between lights-off time and the first epoch in an uninterrupted series of four 30-s epochs of stage 2 sleep, slow wave sleep (SWS) or rapid eye movement (REM) sleep. The subjective sleep latency (SLs) was a self-estimated period between lights-off and perceived onset of sleep. The objective sleep duration (DURo) was defined as interval of aggregated sleep time, not including pre-sleep, post-sleep or intervening wakefulness. Conversely, the subjective sleep duration (DURs) was a self-estimated period of sleep time, less wakefulness (the questionnaire provided for a separate self-assessment of pre-sleep and intervening wakefulness). All of the PSG sleep variables were separately analysed in order to identify those that differentiate subjects with misperception of sleep.

3. Results

All data analyses were performed using SPSS version 13.0 (SPSS Inc., Chicago, IL). One-way analysis of variance (ANOVA) was performed for variables that fulfilled the assumption of normal distribution and homogeneity of variance. The Kruskal–Wallis one-way ANOVA on ranks was performed for variables where normality of distribution and homogeneity of variance was violated. For variables with significant ANOVA F, we performed post hoc pairwise contrasts to determine the source of the differences. For variables with significant Kruskal–Wallis χ^2, we performed a post hoc Dunn's multiple comparison test to determine the source of the differences. Alpha error level in this study was set to $p = 0.05$.

3.1. Sleep duration

Results of one-way ANOVA indicate a statistically significant difference among the three groups of patients in sleep duration – subjective (DURs), $F(2, 133) = 100.20$, $p < 0.001$. Table 2 shows that the mean DURs is 3.16 h (189.6 min) for the NSSM group, 7.66 h (459.6 min) for the PSSM group and 5.78 h (346.8 min) for the CEst group. Pairwise contrasts for one-way ANOVA indicate that the mean DURs in the PSSM group was significantly higher than in the NSSM group ($p < 0.001$) and in the CEst group ($p < 0.001$). In addition, the NSSM group had a significantly lower mean DURs than the CEst group ($p < 0.001$) (Table 3).

In contrast, results of one-way ANOVA indicate a statistically significant difference among the three groups of patients in sleep duration – objective (DURo),

Table 2
Means [hours (minutes)] and standard deviations of sleep duration – subjective in three groups of patients

	n	M	SD	min	max
NSSM	59	3.16 (189.6)	1.44	0.0	6.0
PSSM	27	7.66 (459.6)	1.43	4.3	10.0
CEst	50	5.78 (346.8)	1.47	2.0	8.3
Total	136	5.02 (301.2)	2.28	0.0	10.0

Table 3
One-way analysis of variance summary table comparing three groups on sleep duration – subjective

Source	df	SS	MS	F	p
Between groups	2	422.27	211.13	100.20	<.001
Within groups	133	280.24	2.11		
Total	135	702.50			

Table 4
Means [hours (minutes)] and standard deviations of sleep duration – objective in three groups of patients

	n	*M*	SD	min	max
NSSM	59	6.07 (364.2)	1.20	3.0	8.2
PSSM	27	4.87 (292.2)	1.65	1.8	7.0
CEst	50	5.75 (345)	1.44	2.2	7.7
Total	136	5.71 (342.6)	1.45	1.8	8.2

$F(2,133) = 6.95$, $p = 0.001$. Table 4 shows that the mean DURo is 6.07 h (364.2 min) for the NSSM group, 4.87 h (292.2 min) for the PSSM group and 5.75 h (345 min) for the CEst group. Pairwise contrasts for one-way ANOVA indicate that the mean DURo in the PSSM group was significantly lower than in the NSSM ($p = 0.001$) and CEst ($p = 0.009$) groups. The NSSM and the CEst group did not differ significantly with respect to mean DURo ($p = 0.238$) (Table 5).

The results showed a statistically significant difference between the PSSM and NSSM, and the PSSM and CEst subgroups. The average difference between objective and subjective sleep duration was (+)2.9 h for the PSSM group, (−)2.8 h for NSSM, and no difference (0 h) for CEst group (Fig. 1).

3.2. Sleep efficiency

Results of the Kruskal–Wallis test indicate a statistically significant difference among the three groups of patients in sleep efficiency (SE), χ^2 (2) = 12.55, $p = 0.002$. A post hoc Dunn's multiple comparison test indicated that the SE in the PSSM group was significantly lower than in the NSSM group, $z = -26.84$, $p < 0.05$, or the CEst group, $z = -32.35$, $p < 0.01$. However, the NSSM group and the CEst group did not differ significantly from each other in terms of SE, $z = -5.50$, $p > 0.05$. The results are graphically represented in Fig. 2 (Table 6).

Table 5
One-way analysis of variance summary table comparing three groups on sleep duration – objective

Source	df	SS	MS	*F*	*p*
Between groups	2	26.76	13.38	6.95	.001
Within groups	133	256.16	1.93		
Total	135	282.92			

3.3. Sleep latency

Results of the Kruskal–Wallis test indicate a statistically significant difference among the three groups of patients in subjective sleep latency (SLs), χ^2 (2) = 11.87, $p = 0.003$. A post hoc Dunn's multiple comparison test indicated that the SLs in the NSSM group was significantly higher than in the PSSM group, $z = 27.27$, $p < 0.01$, or in the CEst group, $z = 17.60$, $p < 0.05$. However, groups PSSM and CEst did not differ significantly from each other in terms of SLs, $z = -9.67$, $p > 0.05$ (Table 7).

When compared between the objective and subjective latencies, NSSM patients grossly overestimated their sleep onset latency, while PSSM patients made a slight

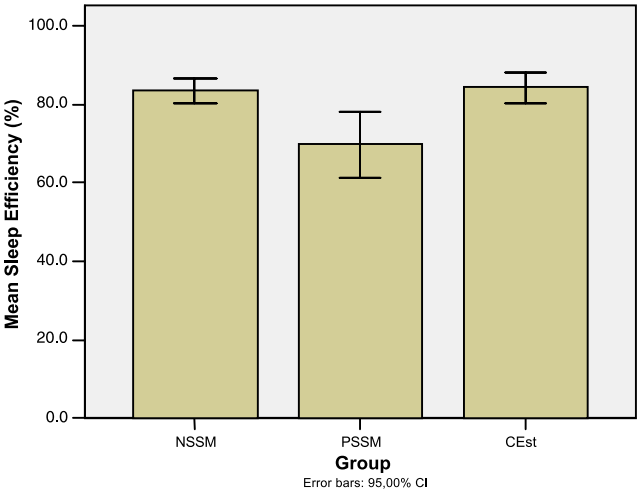

Fig. 2. Mean sleep efficiency.

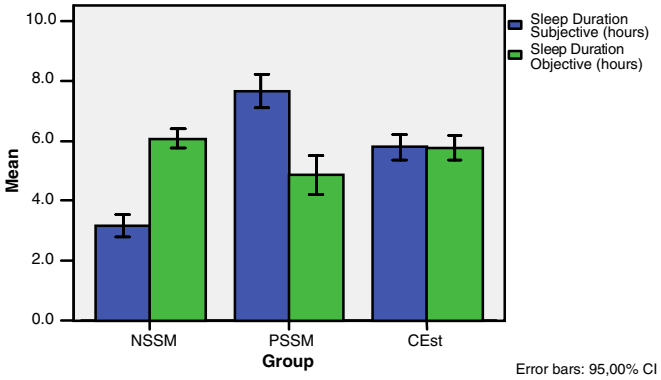

Fig. 1. Sleep duration.

Table 6
Means and standard deviations of sleep efficiency in three groups of patients

	N	M	SD	min	max
NSSM	59	83.51	11.75	51.7	99.2
PSSM	27	69.76	21.29	25.4	97.2
CEst	50	84.36	13.80	34.8	98.0
Total	136	81.10	15.74	25.4	99.2

Table 7
Means and standard deviations of subjective sleep latency in three groups of patients

	N	M	SD	min	max
NSSM	44	92.02	104.19	3.0	480.0
PSSM	25	28.50	24.16	1.0	90.0
CEst	48	50.10	63.99	1.0	300.0
Total	117	61.25	80.29	1.0	480.0

underestimation. Objective sleep latencies did not differ significantly between the groups (Fig. 3).

3.4. MSLT

As expected, there was a statistically significant difference in the MSLT results between groups.

Results of one-way ANOVA indicate a statistically significant difference among the three groups of patients on MSLT, $F(2,133) = 3.88$, $p = 0.023$. Table 8 shows that the mean MSLT is 10.81 for the NSSM group, 7.79 for the PSSM group and 10.21 for the CEst group. Pairwise contrasts for one-way ANOVA indicate that the mean MSLT in the PSSM group was significantly lower than in the NSSM group ($p = 0.007$) and the CEst group ($p = 0.034$). However, groups NSSM and CEst did not differ significantly from each other in terms of the mean MSLT ($p = 0.508$). Aside from the statistical significance, based on the normative data, the PSSM patients also have clinically more significant MSLT results, falling into the 'moderately sleepy' group, while the NSSM patients and CEst patients have results indicating only mild (or minimal) daytime sleepiness. The results are graphically represented in Fig. 4 (Table 9).

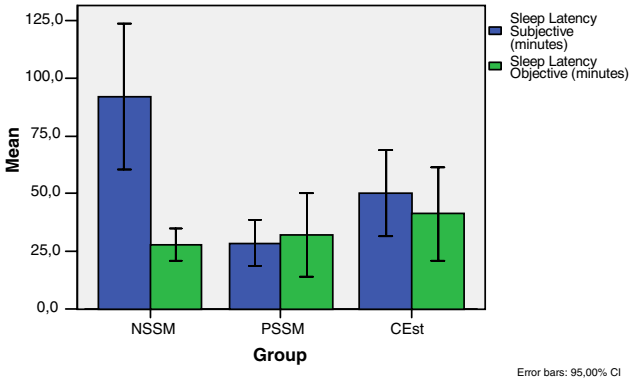

Fig. 3. Composite sleep latencies.

Table 8
Means and standard deviations of multiple sleep latency test in three groups of patients

	n	M	SD	min	max
NSSM	59	10.81	4.76	1.5	19.8
PSSM	27	7.79	4.10	1.4	17.4
CEst	50	10.21	4.93	3.0	20.0
Total	136	9.99	4.80	1.4	20.0

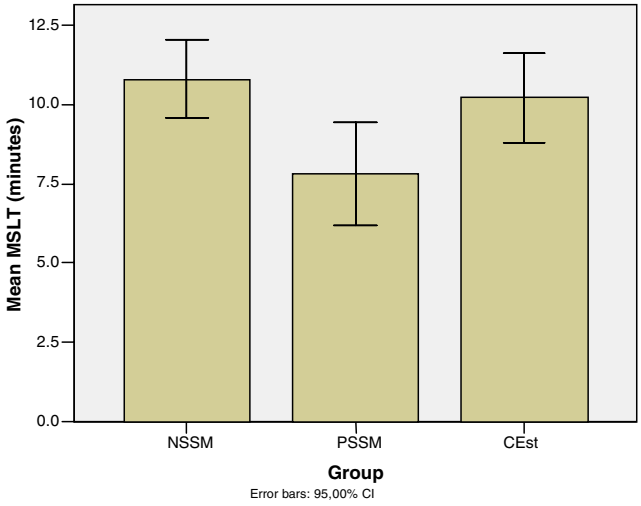

Fig. 4. MSLT results.

Table 9
One-way analysis of variance summary table comparing three groups on multiple sleep latency test

Source	df	SS	MS	F	p
Between groups	2	171.98	85.99	3.88	.023
Within groups	133	2945.02	22.14		
Total	135	3117.00			

4. Non-significant PSG and other parameters

Other tested variables did not show statistically significant differences. Most importantly, there was no indication of awareness of residual sleepiness in PSSM patients as judged by the morning administration of the Stanford Sleepiness Scale. Patients with PSSM also have slightly higher arousal, respiratory disturbance (apnoea/hypopnoea) and periodic leg movement (PLM) indices (not reaching statistical significance) (Table 10).

As to the use of medication, while this may certainly have an impact on one's sleep perception, no clear differ-

Table 10
Sleep variables not reaching statistical significance

Variable	Group	*n*	*M*	SD	*p*
Age	NSSM	59	45.25	13.49	.227
	PSSM	27	47.15	14.69	
	CEst	50	41.94	12.94	
Alpha	NSSM	47	1.80	.77	.901
	PSSM	26	1.81	.85	
	CEst	49	1.86	.76	
Arousal Index	NSSM	59	17.54	12.89	.483
	PSSM	26	23.59	20.69	
	CEst	50	19.32	10.21	
PLMI	NSSM	59	8.97	15.52	.881
	PSSM	27	13.11	22.07	
	CEst	50	6.84	12.18	
RDI	NSSM	59	7.50	15.52	.955
	PSSM	27	12.44	21.89	
	CEst	50	6.42	9.45	
S1	NSSM	48	7.68	4.14	.511
	PSSM	26	8.64	6.43	
	CEst	50	7.01	3.90	
SLo	NSSM	48	23.39	22.57	.364
	PSSM	26	32.65	42.96	
	CEst	50	39.91	68.11	
SSSam	NSSM	57	3.86	1.53	.095
	PSSM	27	3.11	1.37	
	CEst	50	3.50	1.66	
SSSpm	NSSM	43	3.47	1.55	.536
	PSSM	25	3.56	1.58	
	CEst	49	3.18	1.48	
SWS	NSSM	48	10.36	6.48	.181
	PSSM	26	8.26	7.07	
	CEst	50	12.28	8.92	
TAS	NSSM	42	51.93	14	.142
	PSSM	20	50.80	12.55	
	CEst	45	46.31	13.71	

'Age,' patient's age, 'Alpha,' alpha EEG activity, 'Arousal Index,' number of arousals per hour of sleep, 'PLMI,' periodic leg movement index in sleep, 'RDI,' Respiratory Disturbance Index (apnoea/hypopnoea index), 'S1,' stage 1 sleep %, 'SLo,' objective sleep latency, 'SSSam,' Stanford Sleepiness Scale in the morning, 'SSSpm,' Stanford Sleepiness Scale in the evening, 'SWS,' slow-wave sleep %, 'TAS,' Toronto Alexithymia Scale.

ences between the groups were found. At the same time, patients from all three groups had high use of antidepressant medication (NSSM 47.6%, CEst 40% and PSSM 40.7%) and analgesics, including acetylsalicylic acid (ASA) (NSSM 28.8%, CEst 28%, PSSM 25.9%). In addition, there was no significant difference in the number of patients who were not using any medication (NSSM 20.3%, CEst 16% and PSSM 14.8%).

5. Discussion

The results of this study suggest that the amount of sleep received determines the level of daytime sleepiness on the following day, in spite of the perception of sufficient or insufficient sleep. Since we identified individuals who misperceive their sleep at both ends of the spectrum (under and overestimation), there is a need to revise the concept of the SSM as being a variant of primary insomnia. Patients with negative sleep misperception by and large complain of insufficient sleep. There are also individuals who do not necessarily complain about having insufficient sleep but do underestimate, when asked, the amount of sleep they have. At the other end of the spectrum are individuals who overestimate their sleep. Generally, they do not complain about having insufficient sleep; notwithstanding, in this case the absence of complaint equaled the presence of a problem. Some of these patients report symptoms that may bring them for assessment, such as sleepiness, fatigue, tiredness, snoring or some other complaint implying the impairment of daytime performance, but the majority deny significant sleep disruption and its daytime consequences. In some of the cases, a patient's spouse was key in the patient coming in for assessment. The PSSM patients have sufficient time spent in bed (well within the normal range), but also have lower sleep efficiency, which makes it difficult to establish the diagnosis based on a self-report tool such as a sleep diary. The fact that they assess their post-sleep sleepiness at the same level as the patients who have objectively received more sleep compounds the problem. The administration of the Toronto Alexithymia Scale was not helpful in making a clear distinction either, as the PSSM and NSSM patients also had similar scores on this scale.

Considering the results of this study, we propose a new concept of SSM that would encompass both ends of the spectrum (Fig. 5). We introduce terms 'positive' (PSSM) and 'negative' (NSSM) sleep state misperception to describe a spectrum of SSM.

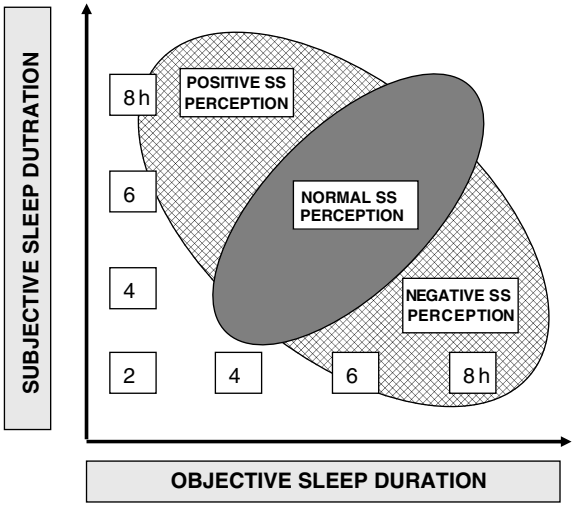

Fig. 5. Dichotomic concept of sleep state misperception.

It is difficult to establish what type of an intrinsic problem is the root of SSM, but some of the evidence points away from the simple inability to estimate time [17]. Patients in both the PSSM and NSSM groups on one hand, and correct estimators on the other, all had comparable arousal indices, which makes the previously suggested explanation of the arousal effect influencing sleep estimation (as suggested for NSSM patients) difficult to apply [18]. There is some evidence of spectral EEG differences in patients along the 'good sleeper'-to-insomnia range. Good sleepers were shown to have less recollection of wakefulness preceding and during the sleep period. At the same time, the patients in the PSSM group were (by definition of sleep efficiency and continuity) closer to insomnia patients. The insomnia patients showed *increased* wake recall, coupled with an increase in higher frequencies on EEG patterns. While the theory of aberrant EEG substrate in the absence of a gross PSG change is plausible, none of the previous NSSM studies were able to clearly correlate a change in a spectrum of frequencies with SSM [11,19,20] (notwithstanding, changes in beta/gamma range were found in the insomnia group as a whole). We did not find any difference in alpha range activity between our study groups; further research should focus on investigation of beta and gamma range changes, and potential attenuation of these in PSSM patients. While it is shown that the increase in beta and gamma frequencies accounts for a sleep misperception phenomena demonstrated through increased information processing and formation of long-term memory [21,22], the simple analogy with regard to PSSM patients was not possible, since these patients seem to have attenuation of 'mesograde' amnesia of wakefulness rather than that of sleep. It is not yet clear whether the PSSM and NSSM have the same substrate, possibly in the sphere of sleep frequencies shift, which may cause an aberrant perception of sleep and wakefulness, or whether we see a dichotomous phenomenon with different pathophysiological mechanisms.

One of the issues in dealing with SSM is that sleep specialists by and large rely purely on EEG criteria. There are many other factors which could influence the quality and the perception of sleep, such as oxygen consumption, temperature level and melatonin release amongst others. It is, therefore, important to always bear in mind, in treating these patients, that, although our objective and the subjective might mismatch, it may be because we are limited in what objective measures we are using [23–25].

The study also confirmed previous findings regarding NSSM: inherently normal sleep onset latency, sleep duration and sleep efficiency in the absence of excessive daytime sleepiness (EDS). When compared to other variants of sleep perception, there was no significant correlation between the sleep variables that were analysed and the NSSM.

The shortcomings of the present study include the very selection of subjects. Our sample was not pooled from the general population, but rather came from a general pool of sleep patient population, who either presented with a sleep complaint or were in need of a sleep assessment. At the same time, it is difficult to believe that individuals in the general population who have an underestimation of sleep and objectively receive less than optimal amount of sleep would not suffer from resulting EDS. Studies of sleep deprivation in a normal population show a direct correlation between the amount of sleep and levels of daytime sleepiness [26]. These studies also showed that the threshold for impaired daytime function and increased sleepiness is an average of 5–6 h of sleep over a prolonged period (amount of sleep seen in PSSM patients) [27–29]. Another potential bias is selection of patients who all underwent the MSLT assessment. This group of patients is more likely to suffer from daytime sleepiness, in spite of the fact that the MSLT test was widely available locally and not completely restricted to a specific group of patients. In our clinic, the MSLT was commonly administered to both patients who complained of EDS, and also to patients in whom EDS was suspected or expected, who complained of fatigue or tiredness, or had any decrement in daytime function. The spectrum of the provisional diagnoses in our sample encompassed all of the major sleep disorders, with the small bias towards sleep disorders featuring EDS. The last of the major shortcomings is a lack of complete psychometric testing, which could potentially help determine a psychological profile of SSM patients. This remains a goal for future research.

In conclusion, this study provides information that should help us better understand and define sleep misperception. More importantly, it identifies a group of individuals who may present a clinical challenge for a sleep clinician. While in most cases patients were only mildly sleepy during the day, there were patients who exhibited significant hypersomnolence (MSLT of <8 min) after they had subjectively assessed their overnight sleep as sufficient. A sleep clinician should put emphasis on objective testing in case of a mismatch between the daily functioning and perception of sleep.

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