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Research Report

Actigraphic and Self-reported Sleep in Traffic Accident Victims

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Abstract.
Background: Some accident victims report poorer sleep during the months after the trauma, which may double the risk for and is a mediator of the development of a PTSD. Furthermore, subjective and objective sleep measures are often discrepant in PTSD-patients, which is why a 'sleep state misperception' of PTSD patients is often hypothesized.
Objective: The goal of this study is to assess differences in sleep quality in victims of a traffic accident compared to healthy participants without an accident history as well as differences between objective and subjective sleep quality measures.
Methods: We recruited 25 hospitalized accident victims within ten days of an accident and 31 age and sex-matched controls without an accident history. Three months later, participants were given a structured clinical interview (SCID), they completed the Pittsburg Sleep Quality Index (PSQI) for the previous two weeks, wore a wrist actigraph, and kept a sleep log for two consecutive nights.
Results: At the three-month follow-up, none of the victims met the criteria for any kind of mental disorder, but scored higher on the Posttraumatic Diagnostic Scale. On the PSQI they reported slightly worse sleep than controls for the previous two weeks, although sleep log and actigraphy measures on the two recording nights showed no group differences. Actigraphy measures showed shorter sleep onset latencies compared to log measures.
Conclusions: The accident victims suffered only minimal sleep disturbances three months later. The assumption of a 'sleep state misperception' in traffic accident victims is questioned by these results.

Keywords: Sleep, traffic accident, actigraphy, PTSD

INTRODUCTION

Approximately 2 million traffic accidents are reported to the police every year [1]. Even though traffic accident fatalities have decreased 25% from 2005 to 2014 [2], the number of severely injured victims increased by 10.2%, and the number of mildly injured by 4.8% from 2011 to 2012 [1]. Traumatic events have been increasingly recognized as important precipitants of sleep disturbances such as insomnia. Due to its sustained neurobiological response the normal sleep-wake regulatory mechanism gets disrupted by sensitizing the central nervous system's arousal centers. This leads to central and physiological hyperarousal, which is linked to both the pathogenesis of insomnia and to neurobiological changes in the aftermath of traumatic events [3] impacting the physical recovery of the patients [4].

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Sleeping disturbances have been estimated to occur in 70% of people suffering a traumatic event [5]. Patients ten days after traffic accidents, poor sleep was reported on the Pittsburg Sleep Quality Index (PSQI) and was still evident one month later [6]. The more psychological symptoms of an acute stress disorder are reported, the more often disturbed sleep is reported on the PSQI [7]. They do not sleep as long [8] and have longer periods of wakefulness after first falling asleep (WASO) than controls without traumatic events do [9].

One year after the accident victims did not differ in self-reported sleep quality, either because their sleep had normalized or because it was perceived differently [10]. Fragmented sleep in trauma victims may double the risk for, as well as being a mediator of, the development of a psychological disturbance [11, 12]. In line, elevated scores in the PSQI one month after the accident predicted the development of a chronic PTSD [6].

Sleep logs and sleep questionnaires provide subjective sleep data. Actigraphy, however provides an objective measure, is cost effective, easy and non-demanding to the subject. It is a well-established method to objectively measure sleep over the course of multiple nights in the patients home-sleep environment. Despite its advantages it is known, that sleep actigraphy in contrast to gold standard polysomnography (PSG) has limitations, i.e. a low specificity for sleep by misclassifying wake periods with little wrist movement as sleep [13]. Furthermore, subjective and objective sleep measures are often discrepant, while perceived sleep quality is mainly determined by self-reports rather than actigraphy. For instance in PTSD-patients, discrepancies between subjective and objective (actigraphic) sleep reporting have been reported [14–16], for example women with PTSD underreported their sleep onset latency and WASO compared to actigraphic measurements [17]. One explanation for the failure of objective and subjective sleep measures to match might be that patients with PTSD experience 'sleep state misperception' [18]. Such discrepancies occur also in subjects without trauma exposure or PTSD [8]. Therefore, the discrepancy between subjective and objective sleep measure has to be explored more in detail, especially in patients after a traffic accident.

Initial differences of sleep quality between motor vehicle accident survivors with and without a later PTSD were found to widen in the first three months after a traffic accident [6]. Based on this, we hypothesized that three months after the accident, victims would report poorer sleep for the previous two weeks than would matched controls, which would be corroborated by sleep logs and actigraphic measures, but suspecting that self-reported sleep might be affected more by the accident than actigraphically-measured sleep, we tested for discrepancies between these two kinds of measures. In contrast to past studies [10], we assessed objective and subjective sleep quality during the same nights.

METHOD

Participants

Patients involved in a traffic accident in the previous two weeks were recruited at the University Hospital in Dresden, Germany, along with healthy age and sex-matched controls who had not been involved in a traffic accident in the previous three months. All participants were between 18 and 65 years old and smoked fewer than ten cigarettes per day. In both the experimental and the control group, individuals were excluded who had had another severe trauma less than three months prior to recruitment or a DSM-IV Axis I Disorder before and at the time of the accident assessed by using the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-IV). Additionally, prior to the traffic accident, included participants did not show any sleep disorders, did not use medication known to influence sleep or had any neurological disorder. Further exclusion criteria were the use of continuous positive airway pressure during the night, or those working night shifts.

Materials and procedure

Participants were asked about their medical and medication history and filled out the Global Severity Index (GSI) of the Brief Symptom Inventory (BSI-18) [19], which consists of three six-item subscales: somatization (SOMA), anxiety (ANX), depression (DEPR). A global score is calculated as the sum of all the six-item subscale scores. It ranges between 0 and 72 and the three subscales range between 0 and 24. None of the participants reached global scores above 62.

Three months after the recruitment, ex-patients (none hospitalized at this time) were examined by a trained clinical psychologist by using the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-IV). None was given a current or past DSM-

IV Axis I diagnosis. Participants rated themselves on the Posttraumatic Diagnostic Scale (PDS) [20], a self-report questionnaire for PTSD symptom severity. They rated how much they experienced each of the DSM-IV PTSD symptoms on a scale from 0 (not at all or only one time) to 3 (five or more times a week / almost always) and indicated which areas of life were impaired, e.g., household, occupation, leisure time, or sexuality. Additionally, the patients' Injury Severity Score (ISS) was calculated based on the injuries patients suffered of. It is an established medical score to assess trauma severity and correlates with mortality, morbidity and hospitalization time after trauma [21].

Actigraphy data were recorded on four consecutive nights with the Motionlogger activity watch (Ambulatory Monitoring Inc, Ardsley, NY) [22] set to store data at ten second intervals. The watch houses a tri-axial accelerometer and a light sensor, and has channels that detect periods when the device has been removed from the wrist. Participants were told to start wearing the watch before going to bed and to take it off when they got up in the morning. They were to press the watch's event marker button once when they first lay down intending to go to sleep, whenever they woke up during the night, and once when they got up in the morning. Participants could use alarm clocks and follow their regular sleeping schedule.

Nights that ended on holidays or weekends were excluded from the data, but not those that started on a holiday or a Sunday. Except for four patients and three controls, this rule resulted in three recordings being from consecutive work days. The sleep data of 25 patients and 31 controls were included in the calculations for nights one and two. In addition, 17 patients and 30 controls provided sleep data for a third night. Shortly before the recordings, participants filled out a Pittsburgh Sleep Quality Index (PSQI, German version) about their sleep in the previous two weeks. Scores range from 0 to 21 with higher scores indicating poorer sleep [23]. Scores higher than 5 indicate that a subject is having severe difficulties in at least two sub-scores [23]. Before and after each recording night, participants completed a log sheet which asked about their daytime activities and whether they had been exhausted or had trouble concentrating the previous day. Each morning they estimated their total sleep time (TST), time to fall asleep (sleep onset latency-SOL), sleep quality (from 1-10), reasons for waking up during the night and how long they were awake (WASO), use of sleep medication, whether they were sharing the bed or the bedroom, and whether they had used CPAP on that night. On the log sheet, 36% of the patients and 69% of the controls indicated that they were working regularly when the data were collected.

Actigraphic data were scored by the ActionW2 program (Ambulatory Monitoring Inc.) using "proportional integration mode" activity and the USCD-algorithm [13]. Raters established "down intervals" defining the subjects' time in bed with the intention to sleep, following a decision tree in order to promote reliability. Most weight was given to the event marker, followed by light, temperature, and activity level. The result was verified by the log sheets. The actigraphic measures chosen were those identical to ones that could be established from the sleep log: time in bed (TIB), total sleep time (TST), sleep onset latency (SOL), and time awake after sleep onset (WASO).

All procedures involved with the study were reviewed and approved by the Ethics Committee of the Medical Faculty of the Technische Universität Dresden, Germany (EK 214072010).

Statistical analysis

SPSS (IBM, Armonk, NY) with an alpha level of .05 was used for all analyses. PSQI scores were distributed normally (Kolmogorov-Smirnov test) and had homogeneous variance (Levene test) so group differences were analyzed with a one-way ANOVA. Spearman correlations were calculated for GSI and sleep parameters from the log sheets. Actigraphy measures with inhomogeneous variance by the Levene test were log transformed before analyzing them by repeated-measures ANCOVAs with the not-repeated factor Group (patients, controls), and the repeated factors Method (actigraphy, log) and Night (night 1, night 2), along with their interactions (see Kobayashi et al., 2012 for a similar analysis). Work status was included as control variable as it was found to differ significantly between groups ($\chi^2 = 11.565$, $p = 0.001$).

RESULTS

A total of 29 men (14 patients, 15 controls) and 27 women (11 patients, 16 controls) participated in the study. Patients (P) and controls (C) did not differ in age: $t(54) = 1.12$, $p = 0.27$: P-M = 41.0 ($SD = 11.1$), C-M = 37.3 ($SD = 12.9$). Patients' ISS varied from 0 to 34. 88% had an ISS of lower than three, indicating at least one moderate injury. All patients had to

Table 1
Pittsburg Sleep Quality Inventory (PSQI), past 2 weeks. Means (M) and standard deviations (SD) are listed

	Patient *M (SD)*	Control *M (SD)*	*df*	*F*
PSQI Global Score	10.18 (2.77)	8.08 (2.62)	1.39	4.20
PSQI Sleep Latency	.87 (.94)	.83 (.63)	1.49	0.06
PSQI Sleep Duration	.67 (.87)	.54 (.88)	1.50	0.29
PSQI Sleep Efficiency	.78 (1)	.37 (.69)	1.48	1.99
PSQI Sleep Disturbance	2.06 (.42)	1.88 (.44)	1.42	1.71
PSQI Sleep Medication	1.13 (.45)	1 (0)	1.49	2.10
PSQI Daytime Dysfunction	1.79 (.16)	1.69 (.13)	1.48	0.23
PSQI subj. Sleep Quality	2.04 (.62)	1.81 (.68)	1.49	1.52

Note. PSQI = Pittsburg Sleep Quality Inventory.

spend at least one night in the hospital. Patients sleep medication intake $M = 1.13$ (SD = 0.45) and control group sleep medication intake $M = 1.00$ (SD = 0) did not differ significantly.

No patient or control was diagnosed by the SCID as having a psychological disorder. The groups did not differ in GSI ($t(50) = –0.52$, $p = 0.61$). None of the participants reached the GSI disorder threshold (GSI > 62). Means and standard deviations of traffic victims and controls in the PSQI in the past 2 weeks are listed in Table 1.

Spearman correlations were calculated for GSI and sleep parameters. The amount of perceived sleeping time in minutes in the first night negatively correlated with GSI ($r = –0.286$, $p = 0.04$). Furthermore, there were no significant correlations.

At the three month follow-up, patients scored higher than controls on the PDS ($t(55) = 2.10$, $p = 0.04$; M-Patients = 6.59, $SD = 8.80$, M-Controls = 2.11, $SD = 2.83$). They had slightly higher PSQI global scores (worse sleep) than controls, but group differences on other PSQI scores did not reach significance. For the two actigraphy nights and their corresponding sleep log measures, there were no main Group effects or interactions with Group in the calculated ANCOVA's with work status as covariate (Table 2). A method effect was observed in that SOL was shorter by actigraphy than by logs. There were no group differences.

DISCUSSION

We had expected to find significant sleep disturbance in victims of an accident three months after the accident, at which time they had higher scores than controls on the Posttraumatic Diagnostic Scale. The accident had been severe enough to require hospitalization. However, neither self-report nor actigraphic sleep measures on the two recording nights at the three-month follow-up were different between victims and controls. Only on a PSQI looking back over the previous 2 weeks, did victims report slightly poorer sleep.

The retrospective assessment of subjective sleep quality during the 2 weeks before data collection showed differences in line with previous studies [10] with traffic accident victims reporting subjectively poorer sleep quality. Our finding, that actigraphy scored less minutes SOL than did the logs is probably due to lying quietly awake trying to go to sleep is mistaken for sleep by actigraphy [24]. This is a major limitation of actigraphy and a challenge for the development of better algorithms [25]. Furthermore, there were no differences between subjective and objective (actigraphy) sleep measures in contrast to past studies [14–16]. These past studies [10] found a discrepancy of subjective sleep quality of PTSD patients compared to actigraphic measures. This suggested that PTSD patients suffer from a sleep misperception rather than actual sleep disruptions. The findings in our study question this assumption. Self-reports of past sleep can be affected by memory or expectancy biases, and actigraphy can be inaccurate for sleep onset latency and wake after sleep onset, but their concurrence in not showing group effects on the recording nights strengthens the probability that sleep was normal in those nights.

In line with former findings [10] no difference in actigraphic measures of sleep quality between PTSD and non-PTSD participants, we also found no difference between traffic accident victims and controls. Former studies [6] found, that from 3 months after a traumatic event, sleep quality is starting to differ between subjects developing a PTSD and those who do not. In past studies it was found, that poor sleep may double the risk for and is a mediator of the development of a psychological disease [12, 26]. It was shown, that in severely injured accident victims who did not fulfill any diagnosis of a psychologi-

Table 2
Means, standard deviations and results of ANCOVA comparing sleep measures from actigraphy and sleep logs with work status as covariate

	Method (A)	Night (B)	Group (C)	Mean (SD) (SD)	Method (A)	AxC	Night (B)	AxB	AxBxC
TST	Actigraphy	1	Control	406.3 (58.0)	F(1, 47) 0.088	F (1, 47) 0.793	F(1, 47) 0.005	F(1, 47) 0.490	F(1, 47) 2.017
		2		405.6 (72.0)					
		1	Patient	425.9 (66.2)					
		2		439.0 (65.8)	*p = 0.768*	*p = 0.378*	*p = 0.942*	*p = 0.487*	*p = 0.162*
	Sleep-Log	1	Control	383.9 (60.8)					
		2		394.7 (76.6)					
		1	Patient	402.1 (66.9)					
		2		411.1 (72.5)					
WASO	Actigraphy	1	Control	14.6 (11.8)	F(1, 43) 0.106	F(1, 43) 1.427	F(1, 43) 1.128	F(1, 43) 0.122	F(1, 43) 0.469
		2		17.3 (18.3)					
		1	Patient	13.9 (14.2)					
		2		15.2 (11.6)	*p = 0.746*	*p = 0.239*	*p = 0.294*	*p = 0.728*	*p = 0.497*
	Sleep-Log	1	Control	12.4 (18.7)					
		2		5.6 (9.7)					
		1	Patient	21.7 (43.0)					
		2		15.8 (20.3)					
TIB	Actigraphy	1	Control	432.1 (65.3)	F(1, 50) 0.433	F(1, 50) 0.443	F(1, 50) 0.165	F(1, 50) 0.063	F(1, 50) 0.013
		2		422.5 (70.7)					
		1	Patient	448.2 (68.4)					
		2		461.4 (65.1)	*p = 0.514*	*p = 0.509*	*p = 0.686*	*p = 0.803*	*p = 0.911*
	Sleep-Log	1	Control	433.9 (68.9)					
		2		422.3 (88.0)					
		1	Patient	465.9 (64.3)					
		2		465.9 (69.5)					
SOL	Actigraphy	1	Control	3.78 (3.48)	F(1, 48) 5.001	F(1, 48) 2.059	F(1, 48) 1.090	F(1, 48) 1.067	F(1, 48) 0.044
		2		3.07 (2.18)					
		1	Patient	3.12 (1.72)	*p = 0.030*	*p = 0.158*	*p = 0.302*	*p = 0.307*	*p = 0.835*
		2		3.60 (2.26)					
	Sleep-Log	1	Control	17.70 (13.32)					
		2		13.19 (8.03)					
		1	Patient	23.12 (22.92)					
		2		21.08 (17.04)					

Note. TST: Total sleep time; WASO: Minutes awake after sleep onset; TIB: time in bed; SOL: Sleep onset latency.

cal disorder, the incidence of PTSD was low with 4.7% meeting the PTSD diagnosis 2 weeks after the accident and 1.9% one year after the accident [27]. If participants in our sample met the diagnostic criteria for a PTSD-diagnosis at a later time remains unclear. We found a correlation of perceived sleeping time and general PTSD-like symptoms. The perception of a reduced sleeping time was associated with more symptoms. This could be due to an influence of PTSD-like symptoms on the perceived sleeping time but it is only a correlative connection. If sleep disturbances are due to PTSD-like symptoms remains unclear and needs to be addressed in future studies. Yet there were no other correlations between PTSD-like symptoms and sleep quality.

A limitation of this study is, that pain levels were not assessed for traffic accident victims though one can suggest that this could also influence sleep quality. Also, work status did differ significantly between groups with 36% of traffic victims and 69% of controls had to go to work. However, work status was included as a covariate in our calculations.

Overall, our findings did not reveal a subjective overestimation of sleep disturbances by individuals involved in a traffic accident, which challenges the assumption that individuals with PTSD overreport sleep disturbances. Future studies should address the predictive role of sleep quality for PTSD. In general, more longitudinal studies are needed to assess if sleep quality is a predictor for the development of a PTSD after a traffic accident.

CONFLICT OF INTEREST

The authors have no conflict of interest to report.

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