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Original Article

Impaired driving simulation in patients with Periodic Limb Movement Disorder and patients with Obstructive Sleep Apnea Syndrome

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ABSTRACT

Background: Excessive daytime sleepiness (EDS) is considered to be responsible for increased collision rate and impaired driving simulator performance in Obstructive Sleep Apnea Syndrome (OSAS) patients. Periodic Limb Movement Disorder (PLMD) patients also frequently report EDS and may also have impaired driving capacities.
Methods: PLMD patients ($n = 16$), OSAS patients ($n = 18$), and controls ($n = 16$) performed a monotonous 25-min driving simulation task. Parameters for driving capacity were the slope of the standard deviation of the lane position, lapses of attention (LOA), and structural deviations. The severity of sleep disruption and the degree of subjective sleepiness were measured.
Results: Slope and LOA were significantly higher in patients than controls, pointing to a decreased driving performance. At start patients and controls had similar driving capacity. The PLMD and OSAS groups did not differ on any scale or simulation performance, although OSAS patients generally performed worse. Subjective sleepiness was higher in patients than controls, and correlated positively with driving simulator parameters. Severity of the disorder and performance were uncorrelated.
Conclusion: PLMD and OSAS patients showed impaired performance in a simulated monotonous driving task. At start, patients and controls performed similarly, but patient performance decreased clearly with time, suggesting that decreased vigilance as a result of disturbed sleep is an important component of deteriorated simulated and, possibly, real driving performance.

1. Introduction

Patients with a sleep disorder frequently report excessive daytime sleepiness (EDS) [1]. EDS is characterized by persistent sleepiness and sudden involuntary sleep onset during the daytime. This may result in unsafe driving and crashes [2–4]. Each year in the United States of America approximately 40000 injuries and 1500 deaths in motor vehicle crashes are the result of driver sleepiness [5].

A well-known sleep disorder is Obstructive Sleep Apnea Syndrome (OSAS). This disorder is characterized by repeated complete or partial obstructions of the upper airway during sleep (apneas and hypopneas, respectively), usually resulting in arousals and sleep fragmentation [6]. The severity of the disease is often indicated by the Apnea Hypopnea Index (AHI), the total number of apneas and hypopneas per hour of sleep. During the resulting EDS patients are commonly troubled with reduced vigilance. Vigilance is defined as the state of heightened readiness to perform efficiently [7]. OSAS patients as a group have increased automobile crash risks compared to control subjects [2,8]. Their EDS is considered responsible for this increased rate. Reversely, treatment of OSAS with continuous positive airway pressure is an effective intervention for the prevention of road traffic accidents [9].

A higher traffic crash rate has also been suggested in other sleep disorders, including Periodic Limb Movements in Sleep (PLMS) [2,3,10,11]. Periodic Limb Movements in Sleep are repetitive, stereotyped, and involuntary dorsiflexion movements of the lower limbs during sleep [12]. These movements can be monitored by electromyographic registration of leg muscles during a sleep study (polysomnography) and are present in more than 30% of adults over 60 years of age. Excessive movements are considered to disrupt normal sleep in the form of arousals and sleep fragmentation. Periodic Limb Movement Disorder (PLMD) is the combination of PLMS and insomnia or excessive daytime sleepiness (EDS) not

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better explained by another current sleep disorder, medical or neurological disorder, mental disorder, medication use, or substance use disorder. The exact prevalence of PLMD is not known [12]. Only one study reported four out of 26 PLMS or Restless Legs Syndrome (RLS) patients (with EDS) being involved in sleep related accidents [10]. Further information is lacking, so the role of PLMS in driving crashes due to drowsiness is yet unknown [2].

Performance on driving simulators of varying complexity and vigilance tests have also been reported to be impaired in OSAS patients as a group [13–15]. The use of driving simulator-data has several advantages over crash rates in assessing the effects of sleep disorders. For example, specific tasks can indicate the individual severity of the attention problems and the effects of treatments. A driving simulator can also be used in comparing the effects of different types and characteristics of sleep disorders. In the present study we used a driving simulator to compare the driving capabilities of PLMD patients and control subjects. Moreover, we included a group of OSAS patients to compare our PLMD group with this more extensively studied patient group with a documented higher car crash rate. As far as we know no studies have been performed using a driving simulator in PLMD.

The aim of this study was to determine if and to what extent PLMD patients have difficulties with a monotonous driving simulation task compared to controls and compared to patients with OSAS. As driving performance in a simulator is poorer in sleepy subjects regardless of the cause of sleepiness [16], poorer performance is expected in PLMD patients as well as in OSAS patients compared with control subjects.

Besides elucidating the possible relationship between the severity of the sleep disorders and driving simulator performance, we also investigated if there was a correlation between sleepiness and driving performance. Subjective sleepiness, the actual feeling of the patient, is assumed to be negatively correlated with driving performance: the sleepier, the worse the performance. In this study, however, a measure for objective sleepiness is also introduced by recording the time slept during the day. One would expect subjects who require sleep throughout the day to be sleepier and consequently perform worse on the simulator. Until now contradictory results have been reported on the relationship between subjective sleepiness and the risk for car crashes in OSAS [8].

2. Methods

2.1. Subjects

Three different groups participated in this study: one patient group with PLMD, one patient group with OSAS, and one control group. All subjects had to be in possession of a drivers licence and otherwise fit to drive. Exclusion criteria were the presence of narcolepsy, (other) neurological or psychiatric disorders, and age older than 70 years.

All patients underwent a 24-h, ambulatory polysomnography (PSG). Recordings consisted of electroencephalography (EEG), electro-oculography (EOG), electrocardiography (ECG), and bilateral tibialis anterior electromyography (EMG). Airflow in the nose and mouth were recorded using thermistors. Ribcage and abdominal movements were monitored by inductance plethysmography and oxygen saturation (SaO2) was recorded by oximetry. Posture and potential snoring were also measured. Because patients were recorded all day, an objective measure of daytime sleepiness could be formulated, namely day time sleep.

Among patients who consulted the hospital for sleep related difficulties in the last four years, patients diagnosed with PLMD were selected retrospectively based on the inclusion and exclusion criteria. All PLMD patients had to have a PLMS index (PLMI) greater than five; this index is the number of periodic leg movements per hour of sleep. They had to have complaints of insomnia or EDS and a final diagnosis of PLMD. They could not have daytime complaints of RLS. Since one aim of the study was to explore the influence of disorder severity, patients over a wide range of PLMI's were recruited. PLMD patients with concomitant OSAS (Apnea Hypopnea Index [AHI] > 5) were excluded. If more than six months passed between diagnostic PSG and the driving experiment, a new PSG was performed. Severity of the sleep disorders was identified by AHI and PLMI. The OSAS patients also participated in a study on the effects of oral appliances on OSAS [15]. For OSAS patients a mild PLMS was allowed (PLMI < 25).

Healthy controls were recruited matched on age and sex with the PLMD patient group. Control subjects had no complaints of sleeping and clinical analyses by questionnaires also raised no evidence that they had a sleeping problem.

The trial was approved by the Groningen University Medical Center's ethics committee. Written informed consent was obtained from each patient before enrolment after full explanation of the procedure. In addition, all control subjects consented to participation in the study after full explanation of the procedure.

2.2. Questionnaires

Each subject completed three questionnaires with general questions concerning demographic data like age and gender, driving history, health information (smoking, caffeine consumption), and a depression scale (the Hospital Anxiety and Depression Scale = HADS) [17]. In addition, the Epworth Sleepiness Scale (ESS) [18] was used to evaluate subjective daytime sleepiness. Besides the total score on the ESS, one traffic-related question ("How likely are you to doze off in a car while stopped for a few minutes in traffic?") was evaluated separately. Before and after the driving task, the current level of subjective sleepiness was assessed using the Stanford Sleepiness Scale (SSS) [19].

2.3. Driving simulator

We used a PC version of the driving simulator developed by Brouwer and co-workers [20,21], but only used the steering subtask to keep the driving task as monotonous as possible. All subjects performed a 25-min driving simulator test after a 2-min practice and a 3-min level determination task. The level determination task was added to be able to discover possible differences in visual-motor coordination skill between the groups. The 25-min task was at the same easy level for all subjects, irrespective of the obtained maximum.

The subject was seated on a comfortable office chair behind a 21-inch computer screen on which a road scene of a straight road was projected. The subject was seated 75 cm from the screen with the eye level slightly above the center of the screen. The screen width (horizontal) was 40 cm so that the horizontal field of view was approximately 30°. The lower 2/5 of the screen (approx. 8°) was used for displaying the road (grey road with continuous white side lines, a discontinuous white middle line, and short black poles close to the side lines every 20 m) and the field to the side of the road (light green). The part of the screen above the horizon was light blue. The designed width of the road was 8 m, with 4 m for each lane. The designed width of the car was 2 m. Using a computer game steering wheel, the lateral position on this road could be controlled by the subject. In all conditions the speed of driving was fixed at 50 km/h and the only objective for the subject was to drive as straight as possible in the middle of the right lane, compensating the effect of an unpredictable "side wind" signal consisting of a complex, low frequency signal composed of three superimposed sine waves (1/15, 1/7.5 and 1/3.75 Hz). Because of this unpredictable "side wind," the subject constantly had to be alert to accomplish the task without errors.