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Original Article

# Prevalence of sleep apnea and daytime sleepiness in professional truck drivers

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ABSTRACT

*Introduction:* The prevalence of obstructive sleep apnea (OSA) among professional truck drivers has varied from 28 to 78% in previous studies. In this study we wanted to estimate the prevalence of OSA and OSA with both subjectively measured sleepiness and objectively measured ability to stay awake (ie obstructive sleep apnea syndrome, OSAS) among professional truck drivers in Finland.
*Subjects and methods:* Altogether 2066 professional truck drivers received a structured questionnaire. 175 drivers had a clinical examination and sleep laboratory studies, which included respiratory polygraphy (RP) and maintenance of wakefulness test (MWT). Three groups were formed: 75 subjects with suspected sleep apnea, 75 healthy controls and a random sample of 25 subjects.
*Results:* 1095 drivers answered the questionnaire. RP was performed on 172 drivers and 167 drivers participated in MWT. The mean age was 40.7 years and the mean BMI was 27.7 kgm$^{-2}$. The prevalence of sleep apnea in professional truck drivers using various criteria were: AHI ≥5: 40.1%, AHI≥ 15: 16.2% and, AHI≥ 30: 7.2%. The prevalence depended on clinical history. Prevalence of AHI≥5 varied between 20 and 56.9% and prevalence of AHI≥15 was 4.3–25%. Altogether 4.8% of subjects with AHI ≥15 had abnormally short sleep latency in MWT (<19.4 min).
*Conclusions:* Moderate sleep apnea is common among professional truck drivers but significant inability to stay awake, defined as MWT <19.4 min, is found in about one of twenty professional drivers.


## 1. Introduction

Obstructive sleep apnea (OSA) is a medical disorder that can cause daytime sleepiness and is associated with cardiovascular, neurocognitive and metabolic comorbidities [1,2]. In a Swiss study about 50% of men and 25% of women over 40 years had apnea-hypopnea index (AHI) ≥15, which was defined as moderate-to-severe OSA [3]. These figures are clearly higher than for example the figures of the Wisconsin sleep cohort in a working population age 30–60 years [4]. In that original Wisconsin sleep cohort the occurrence of AHI≥15 in 30-60-year-old men and women was 9.1% and 4%, respectively. In a more recent analysis of the same cohort in 30-70-year-old men and women the prevalence of AHI≥15 was 13% and 5.6%, respectively [5]. The increase in the prevalence of sleep-disordered breathing in Wisconsin was explained significantly by the obesity epidemics. The difference between the Swiss and Wisconsin studies can partly be explained by changes in the scoring rules of hypopnea.

Symptomatic obstructive sleep apnea syndrome (OSAS) is less common. In the original Wisconsin sleep cohort the estimated prevalence of OSAS (AHI≥5 and presence of excessive daytime sleepiness (EDS)) was around 4% in men and 2% in women aged 30–60 years [4,6,7]. In the more recent analysis of the same cohort the estimated prevalence of OSAS (AHI≥5 and EDS) was 14.3% in men and 5% in women aged 30–70 years [5]. The increase in prevalence was explained significantly by the increase of obesity in the US. In previous studies the estimated prevalence of OSA in professional truck drivers has varied between 28 and 78% and prevalence of OSAS has varied between 15.8 and 20% [8,9]. Driver fatigue and sleepiness is considered a significant risk for driving safety [10–12]. Obstructive sleep apnea syndrome is a treatable disease, for example by continuous positive airway pressure (CPAP)

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**List of abbreviations**

| | |
|---|---|
| AASM | American Academy of Sleep Medicine |
| AHI | Apnea-Hypopnea Index |
| BNSQ | Basic Nordic Sleep Questionnaire |
| CI | Confidence Interval |
| CPAP | Continuous Positive Airway Pressure |
| EDS | Excessive Daytime Sleepiness |
| EDT | Excessive Daytime Tiredness |
| ESS | Epworth Sleepiness Scale |
| HC | Healthy Controls |
| MWT | Maintenance of Wakefulness Test |
| OSA | Obstructive Sleep Apnea |
| OSAS | Obstructive Sleep Apnea Syndrome |
| RDI | Respiratory Disturbance Index |
| RP | Respiratory Polygraphy |
| RS | Random Sample |
| SD | Standard Deviation |
| SL | Sleep Latency |

[10,11]. There is also evidence that CPAP treatment reduces risk of motor vehicle accidents [12,13].

It is well known that professional drivers drive much more than non-professional drivers. In Finland a non-professional driver drives on an average 14 000 km/year [14].

According to the current European Union directives all drivers with suspected moderate to severe OSAS (ie AHI≥15 with excessive daytime sleepiness) "shall be referred for further authorized medical advice before a driving license is issued or renewed". Diagnosed and treated patients with moderate or severe sleep apnea must be reviewed at least once a year (group 2 license) or at least once every three years (group 1 license) (Commission directive 2014/85/EU). In this study we wanted to estimate the prevalence of a) OSA/S with AHI ≥5 and b) OSA/S with AHI ≥15 in professional truck drivers in Finland. Our primary objective was to estimate the prevalence of AHI≥5 and the secondary objective was to estimate prevalence of obstructive sleep apnea syndrome with subjective sleepiness and objective ability to stay awake in a maintenance of wakefulness test (MWT).

## 2. Subjects and methods

The base population consisted of professional truck drivers living in Helsinki and its surroundings in Southern Finland. Altogether 2066 professional truck drivers were sent a questionnaire. The drivers were randomly selected from the registry of Finnish Truck Drivers (Rahtarit ry). A sample of these were asked to participate in sleep studies including respiratory polygraphy (RP) and tests of daytime sleepiness and ability to stay awake, including MWT. In addition to the demographic information (gender, age etc) we gathered information on weight and height to compute the body mass index {BMI = weight (kg)/[height (cm)]}$^2$, driving history, sleeping habits, feelings of tiredness and excessive sleepiness, snoring and sleep apnea as in the Basic Nordic Sleep Questionnaires (BNSQ) [15]. In addition the subjects answered to the Epworth Sleepiness Scale (ESS) [16].

### *2.1. Questionnaire study and screening for possible sleep apnea*

A questionnaire modified from the BNSQ was used [15]. Additional items included questions about driving history and other driving related items. The questionnaire was sent by post mail. A response envelope with return address and a stamp was included. A new letter and questionnaire were sent to drivers who did not answer to the first query. In addition, the non-answering drivers were contacted by phone.

We used questions on snoring as the basis for screening of sleep apnea. Snoring history as such is not a reliable question to screen for sleep apnea as more than 75% of people snore at least sometimes [17,18]. However, frequent or habitual snoring may be used in screening of sleep apnea [18]. In this study, according to the BNSQ snoring was asked as: Do you snore when you are sleeping (ask others if you do not know)? The five response alternatives for the question (scored 1–5) were: 1) "never or less than once per month", 2) "less than once per week", 3) "on 1–2 nights per week", 4) "on 3–5 nights per week" and 5) "every night or almost every night". Those responding 1) were considered "non-snorers". Those responding 5) were considered "habitual snorers". "Frequent or habitual snorer" was defined as snoring at least on three nights per week (response >3).

Quality of snoring was asked as: "How do you snore (ask other people about the quality of your snoring)?" Response alternatives were: 1) "I don't snore", 2) "my snoring sounds regular and it is of low voice", 3) "it sounds regular but rather loud", 4) "it sounds regular but it is very loud (other people hear my snoring in the next room)", 5) "I snore very loudly and intermittently there are silent breathing pauses when snoring is not heard and at times very loud snorts with gasping".

Witnessed apneas were asked as: "Have you had breathing pauses (sleep apnea) at sleep (have other people noticed that you have pauses in respiration when you sleep)?" Response alternatives were: 1) "never or less than once per month", 2) "less than once per week", 3) "on 1–2 nights per week", 4) "on 3–5 nights per week", and 5) "every night or almost every night".

Snoring history was asked as: "If you snore at least 1–2 times per week, how many years have you been snoring (ask other people if you don't know)?" The response was given as: "I have been snoring for about _____ years. I was about _____ years old when I started to snore."

Three randomly selected groups were formed: A) subjects with frequent or habitual snoring (FREQSNR; all snoring at least on three nights per week); B) Healthy controls (HC) who snored less often than on three nights per week. C) The third group consisted of a random sample (RS) of the remaining respondents. Seventyfive (n = 75) of the FREQSNR and 75 of the HC -groups and 25 drivers of the RS group were selected for sleep laboratory studies. The last group was selected to estimate prevalence of sleep apnea in the drivers. We expected that the prevalence in the FREQNSR group be close to the maximum prevalence and the prevalence in the HC-group would be close to the minimum prevalence in the whole population. A more conservative and traditional design would have been to select a random sample of all responders to the recordings. As our secondary objectives were to have more information about the occurrence of sleepiness in the subjects with sleep apnea, we wanted to assure that we have enough subjects with probable sleep apnea. Therefore, a screening method based mainly on snoring history was used.

**The screening criteria (Unikuorma-criteria) for suspected sleep apnea (FREQSNR-group)**

The following criteria were used to detect subjects with suspected sleep apnea:

a) snoring at least on three nights per week (snoring frequency responses 4 or 5)
b) snoring is loud and/or irregular (snoring quality responses 4 or 5)

c) witnessed apneas during sleep at least once a week (response 3, 4 or 5 in the BNSQ)
d) snoring for at least 20 years.

For inclusion in the group FREQSNRsubjects had to fulfill combination of criteria either (a and b and c) or (a and c and d).

### 2.2. Power-analysis

Power computations were done using the nQuery program (Statistical Solutions, USA). We assumed, based on previous findings among truck and bus drivers in Finland that the prevalence of sleep apnea would be 20%. The prevalence of sleep apnea in healthy adults was assumed to be around 3%. With power of 80% and Type I error of 0.05 the required sample size calculated was 72 subjects in both groups. When the prevalence of sleep apnea among controls was assumed as 4%, the number of subjects needed was 85 in both groups. If the prevalence of sleep apnea would be 22% among truck drivers and 4% among controls the number needed was 71 in each group.

### 2.3. Sleep recordings and evaluation of daytime sleepiness

#### 2.3.1. Polygraphic recordings

Full-night cardiorespiratory polygraphic sleep recordings were performed on 175 subjects. Nasal airflow, thoracic and abdominal respiratory movements were recorded. Also snoring sounds, sleep position, pulse and oxygen saturation were recorded. Originally hypopnea and apnea were scored using the American academy of sleep medicine AASM 1999 rules [19], and they were re-verified using the current AASM rules [20]. We used a limit of ≥4% from pre-event baseline for oxygen desaturations (AASM 1999 Type A definition/AASM 2.2 Criteria 1B for detection of hypopnea) [19,21]. As reported, the 1999 rules with the 4% desaturation criteria give essentially similar results as the new 2.2. AASM rules [21]. We categorized the apnea-hypopnea index (AHI) into four groups of severity: AHI <5/h (normal), 5≤ AHI <15 (mild), 15≤ AHI <30 (moderate) and AHI≥30 (severe).

#### 2.3.2. Maintenance of Wakefulness Test

Following overnight sleep study, a maintenance of wakefulness test (MWT) was performed. MWT consisted of four 40 min sessions every 2 h [22,23]. Subjects were seated in bed with the back and head supported by a bedrest in a darkened room with a small light source (5 lx) at the floor level. Thirty second epochs were used. Sleep latency (SL) of each MWT session was defined as the elapsed time from the start of the recording to the beginning of any sleep stage (N1, N2, N3 or REM). In the following text we abbreviate “MWT sleep latency” shortly as “MWT”. Recording was ended after three consecutive epochs of N1-sleep or after one epoch of any other stage of sleep. If the subject remained awake during the whole recording session, 40 min was used in the calculation of the mean sleep latency (MWT = 40). We used the limit suggested by Philip et al. as normal (MWT≥34 min) [24]. As a pathological limit we used 19.4 min as suggested by Doghramji [22], which is close to the limit of 19 as suggested by the French group [24,25].

#### 2.3.3. Subjective estimates of sleepiness

Questions from the BNSQ were used also here. To estimate the subjective excessive daytime tiredness (EDT), we asked “Do you feel tired during daytime?”. The five response alternatives for the question (scored 1–5) were: 1) “never or less than once per month”, 2) “less than once per week”, 3) “on 1–2 days per week”, 4) “on 3–5 days per week” and 5) “daily or almost daily”. Those responding 4 or 5 (tired on ≥ 3 days per week) were defined as drivers with EDT. To estimate the subjective excessive daytime sleepiness (EDS), we asked “Do you feel excessively sleepy during daytime?”. The same five-point scale was used. Those responding 4 or 5 (on ≥ 3 days per week) were defined as drivers with EDS. The questionnaire also contained the Epworth sleepiness scale (ESS). ESS measures subjective sleep tendency during the past three months in eight specific situations. Using the ESS, excessive daytime sleepiness was defined as ESS>10 [26,27]. We used also a cut-point of 13 (ESS>13).

### 2.4. Statistics

Statistical analyses were done using the STATA version 15.1 (StataCorp, USA). Medians, means, standard deviations (SD) and range were computed. Statistical differences between groups were tested using Student's t-test, Mann–Whitney's U-test or the Kruskal–Wallis test depending of the number of groups and nature of the distribution. The normality of the distribution was tested by the Shapiro–Wilk test [28]. Pearson's chi-square test was computed from the cross-tabulations. Also weighted analyses were done. Using sex as a frequency weight did not change the results as almost all subjects were men. Robust 95% confidence intervals were used for continuous variables. Exact Clopper-Pearson confidence intervals were used for single proportions.

### 2.5. Ethical considerations

The study was approved by the ethical committee of Helsinki University Hospital. A written informed consent was obtained. Only the investigators had access to the data and results. If sleep apnea was diagnosed or if some other findings were obtained the study subjects were contacted personally to make plans for furthers examinations and treatment. All information was strictly confidential. The employers of the truck drivers did not get any data.

## 3. Results

### 3.1. Respondents

Altogether 2066 professional truck drivers were sent a structured questionnaire by mail. Randomly selected (according to the Unikuorma-criteria represented in methods) 175 drivers had a clinical examination and sleep laboratory studies. The flow chart will better give a view to the population (see Fig. 1). 713 (34.5%) subjects filled in the questionnaire in the first round. After sending the questionnaire again to non-respondents we received 334 more responses giving a response rate of 50.7%. After this we succeeded to reach additional 48 subjects by phone. The total number of respondents to the questionnaire was 1095 subjects (response rate 53%). The total number of subjects with complete responses, RP studies and MWT was 167.

The mean age of respondents was 40.7 years, [standard deviation (SD) 11.0, median age 40.3 years, range 18–71]. There were 1057 (96.5%) men and 38 women (3.5%). This is quite similar than the proportion of women drivers among Finnish truck drivers. In 2010 the proportion of women among members of the Rahtarit Ry was 4.95% (www.rahtarit.fi/jasenyys.html). The mean weight was 88.2 kg (SD 17.0, median 86 kg, range 48–165 kg). Mean height was 178 cm (SD 7.0, median 178 cm, range 152–203 cm). Some of the demographic results can be found in Table 1. BMI was ≥30 in 27.0% and ≥35 in 7.8% if the drivers. The age, sex, and driving history distributions of the respondents and non-respondents did not differ statistically significantly.

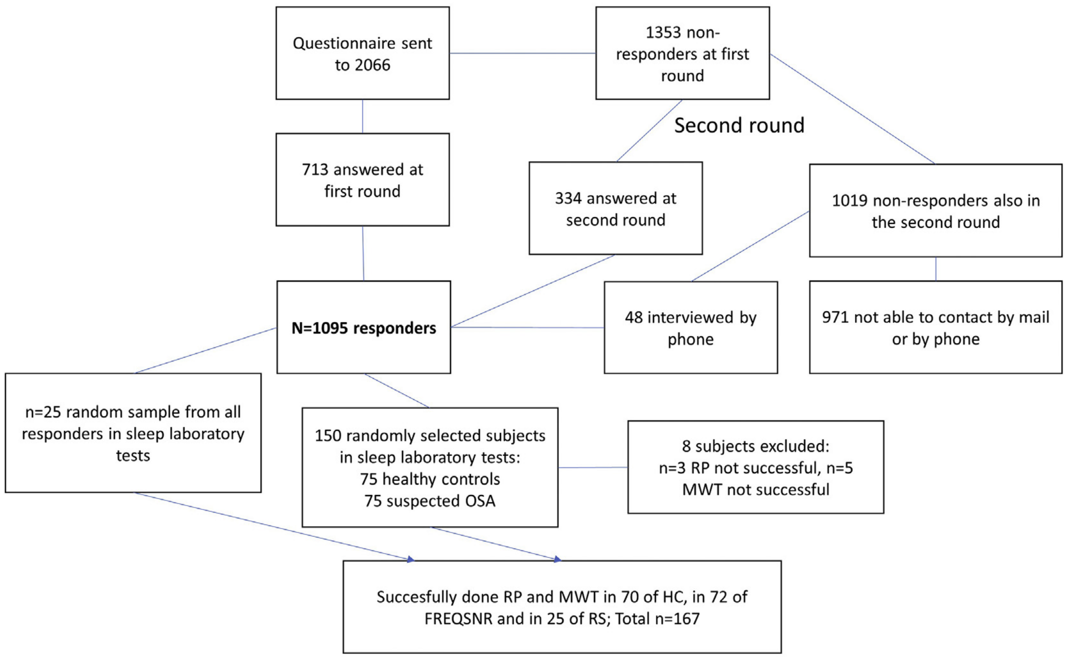


**Fig. 1.** Flow chart on the sample formation. RP = respiratory polygraphy, MWT = maintenance of wakefulness test, HC = healthy controls, FREQSNR = suspected to have obstructive sleep apnea (OSA), RS = random sample.

**Table 1**
Demographic results (N = 1095 professional truck drivers).

| | Mean | SD | Median | Range |
|---|---|---|---|---|
| Age (years) | 40.7 | 11.0 | 40.3 | 18–71 |
| BMI (kgm$^{-2}$) | 27.7 | 4.9 | 27.0 | 17.8–52.7 |
| Driven kms/year | 100 749 | 63 659 | 100 000 | 25-500 000 |

SD = standard deviation, BMI = body mass index.

### 3.2. Subjective daytime tiredness, sleepiness, habitual snoring and reported sleep apneas

Altogether 18.4% (n = 199; 95% CL 16.1 to 20.9) of all drivers in the Unikuorma-cohort complained of EDT (feeling tired on at least three days per week). 10.7% complained of daily or almost daily tiredness. Excessive daytime sleepiness (EDS) on at least three days per week was complained by 13.6% (n = 147; 11.6 to 15.8) of all responders. Daily or almost daily sleepiness was present in 7.0% (n = 75) of the drivers. The mean ESS was 7.6 (SD 4.0, median 7, range 0–24). ESS score was ≥11 points in 23.2% (95% CI: 20.8 to 25.9), and ≥16 in 4.0% (2.9–5.3). Of all respondents 80.1% snored at least once a month. 62.9% reported snoring at least once a week. 44.8% (491 subjects) reported snoring at least three nights a week. There were 377 habitual snorers who reported snoring every night or almost every night, that is 35.1% (95% CI: 32.3 to 38.1) of all the subjects. Among all 1095 responders 374 (34.2%) drivers (34.7% of men and 18.4% women) reported of having had sleep apneas at least once per month. 154 (14.1%) drivers (14.3% of men and 7.9% of women) reported having apneas at least on three nights per week.

### 3.3. Results based on sleep recordings

Both sleep recordings and MWT were successfully done on 167 subjects of the initial selection of 175 randomly selected drivers. Seventy-two were in the FREQSNR-group (96% of the 75 invited subjects), 70 (93% of the invited) were healthy controls (HC). In addition, twenty-five drivers were selected randomly (RS) from all respondents.

Results of the sleep laboratory tests are shown in Table 2. Among all recorded 167 drivers the apnea-hypopnea index (AHI) was ≥5 in 40.1%. In the FREQSNR-, HC-, and RS-groups AHI was ≥5 in 56.9% (44.7–68.6), 20% (11.3–31.2) and 48% (27.8–68.7), respectively. Even that no one in the HC group reported frequent or habitual snoring (snoring at least on three nights per week), 14 (20%) of them had AHI≥5. In the randomly selected sample (RS) 12 (48%) had AHI≥5.75% of them (n = 9) were frequent or habitual snorers. Of the frequently or habitually snoring (n = 13) drivers in the RS-group 69.2% had AHI≥5. As selected, all drivers in the FREQSNR were frequent or habitual snorers and 56.9% of them had AHI≥5, as already written. 88% of those with AHI≥5 snore at least sometimes and 75% snore at least on three nights a week. 36% of those with AHI<5 snore at least on three nights a week.

### 3.4. MWT results

Altogether 167 drivers participated in the MWT recordings. The results are shown in Table 3. The mean SL of all participants was 29.6 min (SD 10.5 min, median 33 min, range 1.5–40 min, 95% CI 27.9–31.1 min). More than 40% of drivers had MWT sleep latency ≥34 min, which is considered normal according to Philip et al. [29] In six drivers (3.6% of all recorded subjects) the MWT SL was <8 min, which may be considered definitely abnormal limit [23]. The AHI of these six drivers were 2, 6, 10, 11, 23 and 61. The subject with AHI = 2 was a healthy control.

Of the drivers with mild sleep apnea (AHI≥5) 23.9% had no lapses in any MWT sessions, and 88.6% of them had MWT ≥ 19.4 min. 70.4% of the drivers with AHI≥ 15 had SL ≥ 19.4 and 55.6% of the drivers with AHI≥15 had normal MWT results (SL in MWT was ≥34 min).

### 3.5. Prevalence of obstructive sleep apnea syndrome among professional truck drivers

Different estimates of the prevalence of OSA and OSAS may be derived from Table 2. Sleep apneas are common in professional

**Table 2**
Occurrence of sleepiness, snoring, sleep apnea and sleep apnea syndrome.

| | FREQSNR n = 72<br>%<br>95% CI | Healthy Controls n = 70<br>%<br>95% CI | Random sample n = 25<br>%<br>95% CI | All together n = 167<br>%<br>95% CI |
|---|---|---|---|---|
| Habitual snorers | 86.1<br>75.9 to 93.1 | 0<br>0 to 5.1[a] | 32.0<br>14.9 to 53.5 | 41.9<br>34.3 to 49.8 |
| EDT (feeling tired on ≥ 3 d/wk) | 31.9<br>21.4 to 44.0 | 15.7<br>8.1 to 26.4 | 12.0<br>2.5 to 31.2 | 22.2<br>16.1 to 29.2 |
| EDS (feeling sleepy on ≥ 3 days per week) | 29.6<br>19.3 to 41.6 | 11.4<br>5.1 to 21.3 | 12.0<br>2.5 to 31.2 | 19.2<br>13.5 to 26.0 |
| ESS>10 | 41.7<br>30.2 to 53.9 | 22.9<br>13.7 to 34.4 | 8.0<br>1.0 to 26.0 | 28.9<br>22.2 to 36.4 |
| AHI≥5 | 56.9<br>44.7 to 68.6 | 20.0<br>11.3 to 31.2 | 48.0<br>27.8 to 68.7 | 40.1<br>32.6 to 48.0 |
| AHI≥15 | 25.0<br>15.5 to 36.6 | 4.3<br>0.1 to 12.0 | 24.0<br>9.3 to 45.1 | 16.2<br>10.9 to 22.6 |
| AHI≥30 | 12.5<br>5.9 to 22.4 | 1.4<br>0 to 8.0 | 8.0<br>0 to 26.0 | 7.2<br>3.8 to 12.2 |
| OSAS: AHI≥5 and EDS | 15.3<br>7.9 to 25.7 | 0<br>0 to 5.1[a] | 8.0<br>1.0 to 26.0 | 7.8<br>4.2 to 12.9 |
| OSAS: AHI≥5 and ESS>10 | 26.4<br>16.7 to 38.1 | 1.4<br>0.04 to 7.8 | 4.0<br>0.1 to 20.4 | 12.6<br>8.0 to 18.7 |
| Moderate OSAS:<br>AHI≥15 and EDS | 4.2<br>0.8 to 11.7 | 0<br>0 to 5.1[a] | 4.0<br>0.1 to 20.3 | 2.4<br>0.6 to 6.0 |
| Moderate OSAS:<br>AHI≥15 and ESS>10 | 9.7<br>4.0 to 19.0 | 0<br>0 to 5.1[a] | 4.0<br>0.1 to 20.4 | 4.8<br>2.1 to 9.3 |
| AHI≥5 and MWT<19.4min | 23.6<br>14.4 to 35.1 | 1.4<br>0.04 to 7.7 | 4.0<br>0.1 to 20.4 | 11.4<br>7.0 to 17.2 |
| AHI≥15 and MWT<19.4min | 11.1<br>4.9 to 20.7 | 0<br>0 to 5.1[a] | 0<br>0 to 13.7[a] | 4.8<br>2.1 to 9.3 |
| AHI≥15 and MWT<8 min | 2.8<br>0.3 to 9.7 | 0<br>0 to 5.1[a] | 0<br>0 to 13.7[a] | 1.2<br>0.1 to 4.3 |

CI = 95% confidence interval; Habitual snorers = Snoring every night or almost every night; EDS = Feeling sleepy on at least three days per week from the Basic Nordic Sleep Questionnaire (BNSQ); ESS = Epworth sleepiness score; AHI = Apnea-hypopnea index; OSAS=Obstructive Sleep Apnea Syndrome; MWT = Maintenance of Wakefulness Test, sleep latency in the multiple wakefulness test consisting of four sessions of 40 min.
[a] = one-sided 97.5% confidence interval.

**Table 3**
Results of the maintenance of wakefulness test (MWT) in different groups of drivers.

| MWT Sleep Latency | FREQSNR n = 72 | Healthy Controls<br>N = 70 | Random sample<br>N = 25 | All together<br>N = 167 | P-value |
|---|---|---|---|---|---|
| Median (minutes) mean ± SD range | 30.2<br>26.9 ± 11.6[§#] 1.5 to 40 | 34.6 31.2 ± 9.4[§€]; 7.6 to 40 | 35.9<br>32.7 ± 7.7[#€] 15.8 to 40 | 33.0 29.6 ± 10.4<br>1.5 to 40 | §: 0.020<br>#: 0.030<br>€: 0.605 |
| Mean SL < 8 min | 6.9%[§#] (n = 5) | 1.4%[§€] (n = 1) | 0%[#€] (n = 0) | 3.6% (n = 6) | §: 0.209<br>#: 0.323<br>€: 1.000 |
| Mean SL < 19.4 min | 30.6%[§#] (n = 22) | 14.3%[§€] (n = 10) | 8%[#€] (n = 2) | 20.4% (n = 34) | §: 0.027<br>#: 0.030<br>€: 0.508 |
| Mean SL ≥ 34 min | 40.3%[§#] (n = 29) | 51.4%[§€] (n = 36) | 56%[#€] (n = 14) | 47.3% (n = 79) | §: 0.238<br>#: 0.243<br>€: 0.816 |
| Mean SL = 40 min | 16.7%[§#] (n = 12) | 34.3%[§€] (n = 24) | 32%[#€] (n = 8) | 26% (n = 44) | §: 0.020<br>#: 0.149<br>€: 1.000 |

For statistical comparisons: § = FREQSNR vs HC; # = FREQSNR vs RS; € = HC vs RS. Kruskall-Wallis or Fisher's exact tests were used.

drivers, but on the other hand OSAS (sleep apnea combined with daytime sleepiness) is not very common (see Table 2). Also, ESS was computed. The prevalence of OSAS varies depending on how we define excessive daytime sleepiness (EDS). The commonly used criterium is ESS>10, but we present also other combinations in Table 2.

From Table 2 we may estimate that the prevalence of OSAS (AHI≥5 and daytime sleepiness with ESS>10) is probably at least around 4% (random sample) and it may be up to 38.1% depending on the symptoms and results. In drivers with frequent snoring and other symptoms of possible sleep apnea, the estimated prevalence of OSAS is around 26.4% (16.7–38.1%). Altogether 8 (29.6%) of the drivers with AHI≥15 had MWT< 19.4 min. Altogether, the occurrence of subjects with AHI≥15 and MWT< 19.4 min was 4.8% (95% CI 2.1–9.3%) (objectively sleepy OSA-patients). These latter figures are of importance because the current EU directive instructs to estimate the sleepiness of all drivers with AHI≥15. Most professional drivers with sleep apnea had normal MWT results. Philip et al. defined the cut-point of 34 min as normal [25]. In our study, 9% of the successfully recorded ones had AHI≥15 and MWT≥34 min. 15 of the 27 drivers (55.6%) with AHI≥15 in the recordings had MWT≥34 min (Table 2). This percentage is even higher than the percentage (64/140; 45.7%) among subjects with AHI<15.

A very conservative estimate of the prevalence of sleepy obstructive sleep apnea drivers would count only those with MWT SL below 8 min and AHI≥15. That would decrease the prevalence to around 1.2% (0.1–4.2%), which is 7.4% of all recorded drivers with AHI≥15.

### 3.6. Association between ESS, AHI and MWT

There was no significant correlation between ESS and AHI (r = 0.11). In a regression analysis, ESS did not associate with AHI (AHI = 0.373*ESS + 5.0; P = 0.156; $R^2$ = 0.012). The results remained the same after standardization for gender. 16.3% of those with ESS >10 had an AHI≥15. The respective percentage among those with ESS≤10 was 18.0% (P = 0.791). The ESS scores of the six subjects with MWT latency below 8 min were 7, 9, 12, 13, 15 and 19 (correlation coefficient between ESS and MWT SL was −0.30, NS) (see Tables 2 and 3).

## 4. Discussion

In our study, the prevalence of obstructive sleep apnea syndrome associated with decreased ability to stay awake (AHI≥5 AND sleep latency in MWT < 19.4 min) in professional truck drivers is probably between 4.0 and 11.4% and probably below 17.2% (see Table 2). Only one (3.9%) of the 26 drivers without snoring or apnea history had AHI≥5 combined with MWT<19.4 min. This means that other possible reasons for decreased ability to stay awake at daytime must be taken into consideration among professional drivers who do not report snoring on at least three nights per week.

Previous data on professional drivers are variable, and partly controversial. Pack et al. studied 1329 commercial driver's license holders by questionnaire and performed sleep recordings for 406 drivers [9]. In that study the prevalence of AHI between 5 and 15 was 17.7% and using AHI>30 as the criterion the prevalence was 4.7%. Howard et al. studied 2342 commercial vehicle drivers with a questionnaire and performed polysomnography for 161 drivers [30]. In that study the prevalence of RDI (respiratory disturbance index) ≥5 was 59.6% and the prevalence of RDI ≥ 30 was 10.6%. For OSAS they used the criteria RDI ≥5 and ESS ≥11, and the prevalence of OSAS was 15.8% (see Table 4).

In the present study 26.9% of the drivers without any previous history of snoring or apneas had AHI ≥5. Only one of them had AHI ≥15 and none of them had AHI≥30. These results show that absence of snoring history does not mean that a professional driver could not have sleep apnea, but probability of clinically significant sleep apnea is very low.

Overall, based on our study, the total prevalence of AHI ≥5 (with 4% desaturation criteria for AHI) among professional truck drivers is somewhere between 27.8 and 68.7% and very likely between 40.1 and 48.0%. This is on an average roughly twice higher than the average prevalence of 22%, as reported by Franklin and Lindberg [6], but less than the average prevalence observed in a Swiss study by Heinzer [3]. Around 24% (9.3–45.1) of professional truck drivers may have moderate obstructive sleep apnea (AHI≥15) (see Table 2), which is again less than the prevalence in a random population in Switzerland [3]. This latter figure reflects occurrence of those professional drivers that should have further medical examination according to the current EU directives.

In previous studies it has been estimated that drivers with sleep apnea and impaired daytime vigilance have 2–6 times increased risk of having a sleep related accident [32,33]. In some studies the severity of sleep apnea has been noted to affect the driving capability and traffic accidents [11,32–34]. High apnea-hypopnea indices do not explain all impaired vigilance results and it is suggested that the ability to remain awake should be tested objectively, eg by MWT [24]. Drivers that had an abnormal result (<8min) in MWT in our study, had very different apnea-hypopnea indices. These results show that objectively measured pathological impairment in staying awake at daytime may be explained by sleep apnea but also by many other factors that are unrelated to sleep apnea.

It is also important to note that most subjects with sleep apnea are not sleepy, and do not have any difficulties in a monotonous task such as MWT. In the present study altogether 55.6% of the drivers with AHI≥15 had MWT sleep latency over 34 min, which is considered normal [24].

Strengths of our study include the large number of the subjects answering the questionnaire (1097 subjects). The response rate was also satisfactory, 53.2%. Most professional truck drivers are private employers and it was very difficult to arrange their participation in this study. In a study by Häkkänen and Summala response rate was only 34% [35]. In a study by Pack et al. a response rate was only 31% [9].

Apneas and hypopneas were registered with the respiratory polygraphy and the inability to stay awake was registered with the MWT, which is also a strength and increases the reliability of our results. Most other studies, including the excellent study of Howard [30], did not include any objective measurements of ability to stay awake and they relied only in subjective evaluations by Epworth Sleepiness Scale.

**Table 4**
Prevalence of obstructive sleep apnea in professional truck drivers in different studies that have included sleep recordings.

| Study | Method | Number of subjects | Prevalence |
|---|---|---|---|
| Stoohs 1995 [8] | Portable screening device (MESAM-4) | 159 | 91% men, mean age 35.1 years, mean BMI 28.4 $kgm^{-2}$<br>ODI> 5: 78%, ODI>30:10%, Symptomatic: 20% |
| Sanchez Armengol et al., 1997 [31] | Questionnaire and sleep recordings | 100; sleep recordings for 35 | Mean age 41.5years, mean BMI 28.2 $kgm^{-2}$<br>59% had suspected OSAS, ODI>10: 28.6% of them - > estimation 16.9% of all |
| Howard et al., 2004 [30] | Questionnaire and sleep recordings | 2342; sleep recordings for 161 | 99% men, mean age 47.8 years, mean BMI 29.7 $kgm^{-2}$<br>RDI>5: 59.6%, RDI 5–15: 34.8%, RDI >30: 10.6%,<br>OSAS (RDI>5 ja ESS>10): 15.8% |
| Pack et al., 2006 [9] | Questionnaire and sleep recordings | 551; sleep recordings for 406 | 93% men, mean age 45.4 years, 88.7% had BMI≥25.<br>AHI>5: 28.1%, AHI>30: 4.7% |
| Huhta et al., 2021 (present study) | Questionnaire, sleep recordings, MWT etc. | 1095; sleep recordings and MWT for 167 | 96.5% men, mean age 40.7 years, mean BMI 27.7 $kgm^{-2}$<br>AHI≥5: 40.1% (20–56.9%), AHI≥15: 16.2% (4.3–25%), AHI≥30: 7.2% (1.4–12.5%);<br>AHI≥15 and MWT<19.4 min: 4.8% (0–11.1%) |

ODI: Oxygen Desaturation Index; OSAS: Obstructive Sleep Apnea Syndrome; RDI: Respiratory Disturbance Index; ESS: Epworth Sleepiness Scale; AHI: Apnea-Hypopnea-Index; MWT: Maintenance of Wakefulness Test, sleep latency in the multiple wakefulness test consisting of four sessions of 40 min.

There are also limitations in this study. All the truck drivers included in this study lived in Southern Finland, in Helsinki and surrounding areas. It is unclear whether the results can be used to describe the prevalence of sleep apnea in truck drivers in whole Finland. The proportion of men and women corresponded well with the initial study population of truck drivers in Southern Finland. However, as we had only few women, we cannot be sure that our figures represent well the prevalence of OSA and OSAS in female truck drivers. We also took this into account in our analysis by analyzing the results separately for the different sampling group (frequent snorers with high prior probability of sleep apnea, healthy controls and a random sample of professional drivers).

One limitation is the screening based on snoring. We used questions on frequent snoring (snoring at least on three nights per week) as the basis for forming different groups. History of snoring is not perfect for screening as people may not be aware of their snoring especially if sleeping without a bedpartner. However, asking about frequent snoring is important in routine clinical practice. Snoring sometimes is very common (80.1% in this study) and it is not useful as a screening question. On the contrary, snoring at least on three nights per week (44.8% in this study) is already better as reported by Telakivi et al. [18] This must be taken into account in the estimations. This is a limitation if we think about prevalence of sleep apnea among all truck drivers. In that case we should have done sleep studies only for a random sample of all truck drivers without any prior screening.

Our prevalence figures among the frequent snorers may be generalized to other frequent snorers, but not to a random sample of all truck drivers. The prevalence of sleep apnea combined with daytime sleepiness in truck drivers without any history of snoring is rare (see Table 2.). In sum we think that our figures give useful information for routine clinical practice.

A polysomnography would have permitted more specific information also about quality and length of sleep. Unfortunately, we were obliged to use respiratory polygraphy instead of polysomnography because of financial reasons. On the other hand, respiratory polygraphy is accepted for the diagnosis of sleep apnea also according to the AASM [19]. Finally, our results cannot be generalized to general public. However, the external validity related to male professional truck drivers is good.

## 5. Conclusions

Even that sleep apnea is common in professional truck drivers, OSAS, as defined by AHI$\geq$15 and decreased ability to stay awake, is less common than in general population. Most professional drivers with sleep apnea seem to have normal results in MWT. Thus, even that sleep apnea (AHI $\geq$5) is common, the prevalence of medically significant sleep apnea syndrome may not be as common as previously reported. On the other hand, there are other reasons than sleep apnea for daytime sleepiness and decreased ability to stay awake (eg sleep deprivation), which need to be recognized. Knowing that OSAS increases the risk of traffic accidents [12,32,36] all these factors should be taken into consideration in occupational health care and especially when evaluating the driving ability according to the current European Union directives. Since OSAS is a treatable disease, it should be diagnosed and treated as early as possible.

## Credit author statement

**Designing of the study:** Partinen Markku, Hirvonen Kari. **Data Collection:** Partinen Markku, Hirvonen Kari. **Data Analysing:** Partinen Markku, Hirvonen Kari, Huhta Riikka. **Manuscript writing:** Huhta Riikka, Partinen Markku, Hirvonen Kari. **Manuscript editing:** Huhta Riikka, Partinen Markku. I confirm, that all of the writers have been participating in the writing process.

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Dr. Hirvonen reports other from Neurotest Tampere Oy, outside the submitted work.

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## Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2021.02.023.

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