Sleep Medicine 136 (2025) 106873

Contents lists available at ScienceDirect

Sleep Medicine

journal homepage: www.elsevier.com/locate/sleep

Objective vs perceived sleep in Belgian occupational drivers: A field study

An-Marie Schyvens [a,b,*], Nina Catharina Van Oost [c], Brent Peters [d], Frederik Veys [a,b], Jean-Marie Aerts [c], Federica Masci [c], An Neven [d], Hélène Dirix [d], Geert Wets [d], Veerle Ross [d,e], Johan Verbraecken [a,b]

[a] Laboratory of Experimental Medicine and Pediatrics, University of Antwerp, Wilrijk, Belgium
[b] Multidisciplinary Sleep Disorders Centre, Antwerp University Hospital, Edegem, Belgium
[c] Department of Biosystems, KU Leuven, Leuven, Belgium
[d] UHasselt – Hasselt University, Transportation Research Institute (IMOB), Martelarenlaan 42, Hasselt, 3500, Belgium
[e] Faresa, Evidence-Based Psychological Centre, Hasselt, Belgium

ARTICLE INFO

Keywords:
Sleep
Occupational drivers
Sleep quality
Wearable

ABSTRACT

Study objective: This prospective, descriptive observational study aimed to investigate objective and subjective sleep among Belgian occupational drivers, focusing on short haul (SHD), long haul (LHD), and local delivery drivers (LDD).
Methods: A total of 31 drivers wore a Fitbit Charge 5 for one month to capture total sleep time (TST), time in bed (TIB), sleep efficiency (SE), wakefulness and sleep stage distribution. Subjective sleep was assessed daily using a 5-point scale. Data were analyzed using descriptive statistics, one-way ANOVAs and Pearson correlations.
Results: Drivers averaged 6.2 ± 0.7 h of TST and 7.1 ± 0.7 h of TIB, with a mean SE of 87.3 ± 2.1 %. Sleep stages were distributed as follows: 60.1 ± 5.2 % light sleep (LS), 18.0 ± 3.3 % deep sleep (DS), 21.2 ± 4.2 % REM sleep and 12.8 ± 1.8 % of awake. 12.9 % of participants had low DS (<15 %) and 25.8 % had low REM (<20 %). 29.0 % of participants experienced elevated nocturnal wakefulness. One-way ANOVA revealed no significant group differences in most sleep parameters, except for DS ($F = 3.47$, $p = 0.05$), with LHD showing the lowest proportion. Subjectively, most drivers rated their sleep from good to neutral. However, one-third reported poor sleep. Modest correlations were found between better subjective sleep and higher DS, TST, and SE.
Conclusion: Although SE was adequate, chronic sleep restriction was common. Group differences were minimal, suggesting that individual and environmental factors may outweigh driver type in influencing sleep. Subjective assessments only partially aligned with objective measures, reflecting a discrepancy between perceived and objective sleep.

1. Introduction

Sleep is a critical determinant of health, safety and performance, particularly in occupations involving sustained attention and physical endurance [1]. Among these, road freight driving represents a high-risk profession where sleep quantity and quality directly impact not only the well-being of the drivers but also public safety. Occupational road freight drivers frequently deal with irregular schedules, long working hours and high work demands, which are factors that can disrupt circadian rhythms and compromise sleep [2–4].

Fatigue-related driving incidents, often due to impaired vigilance, reaction time, decision-making and lane-keeping ability, are a significant concern [5–8]. A study from 2017 by Vias Institute [6], a Belgian road safety institute, found that approximately 4.8 % of Belgian car drivers exhibited signs of sleepiness during individual trips. The problem is even more pronounced among professional drivers. A study of Belgian truck drivers in 2011 [9] found that 18 % experienced excessive daytime sleepiness and 27.2 % reported poor sleep quality. Internationally, sleepiness at the wheel is estimated to account for up to 30 % of all severe crashes, underscoring the global importance of this issue [6,9,10].

The economic implications of these road accidents are substantial. In 2020, the total cost of road crashes in Belgium was estimated at €13 billion, representing 2.9 % of the country's GDP. Fatigue-related crashes contribute to this burden through medical costs, lost productivity, vehicle damage, and broader societal consequences. This figure

* Corresponding author. Multidisciplinary Sleep Disorders Centre Antwerp University Hospital, Drie Eikenstraat 655, Edegem, 2650, Belgium.
E-mail address: an-marie.schyvens@uantwerpen.be (A.-M. Schyvens).

https://doi.org/10.1016/j.sleep.2025.106873
Received 17 July 2025; Received in revised form 17 October 2025; Accepted 17 October 2025
Available online 17 October 2025
1389-9457/

underscores the financial burden that fatigue-related incidents impose on the national economy [11].

Beyond quantity, the quality of sleep has emerged as an area of growing concern. Truck drivers are often exposed to physically and psychologically demanding work conditions, such as exposure to noise, irregular schedules, high work pressure and long sedentary driving, that may contribute to sleep disturbances [3,10,12–15].

Although numerous studies have assessed sleep patterns in this population, much of the existing literature relies heavily on self-reported, subjective sleep measures, which may not accurately reflect actual sleep behavior and can contribute to discrepancy between perceived and objective sleep. This is of concern, as drivers who subjectively rate their sleep as adequate, despite obtaining insufficient or poor-quality sleep, may not fully recognize their resulting fatigue and associated risks of impaired performance and accidents [16–18]. Prior work has also shown that chronic sleep restriction can generally lead individuals to underestimate their level of fatigue over time, further highlighting the limitations of self-reported sleep assessments. Conversely, objective assessments offer more precise insights but are less commonly utilized in field settings [19].

This study adopts a prospective, descriptive observational design to examine both objective and subjective sleep characteristics in a sample of occupational road freight drivers from the MILESTONE (MobILe and tEchnological SoluTions for OccupatioNal drivErs) project, encompassing specifically short haul (SHD), long haul (LHD) and local delivery drivers (LDD). This project aimed to develop and test wearable-based monitoring systems and technological interventions that target difficult working conditions, stress, sleep disturbances and their impact on driving behavior and health. By comparing the objective and subjective characteristics of sleep in this sample, we seek to better understand the extent of sleep in this population.

2. Materials & methods

All procedures contained herein were approved by the Ethics committee of Antwerp University Hospital on the April 3, 2023 (reference number 3126). Written consent was obtained from each participant prior to engagement.

2.1. Participants

Thirty-one occupational drivers participated in this study (28 male, 3 female; mean age $\pm$ SD $=$ 42.7 $\pm$ 10.8 years). These drivers were active in the transport sector, were working for a company or were self-employed. Each of these drivers belonged to one of three specific driving occupations: (1) LHD, driving over large distances and eventually being away from home for multiple days; (2) SHD, who can make multiple deliveries in a single trip; or (3) LDD, who carry out package delivery.

Aside from belonging to one of these driver categories, each participant had to adhere to other criteria in order to be included in the study: (1) possession of a smartphone, (2) Dutch-speaking, (3) no excessive alcohol use and no drug use, (4) not having an infectious disease and (5) not being pregnant. No additional restrictions were imposed to capture a naturalistic sample reflecting the diversity of professional drivers' working conditions.

These participants were recruited by approaching transport companies and individual drivers through email and social media campaigns. Eligible drivers who expressed interest were screened for the inclusion criteria and, upon providing informed consent, were enrolled in the study.

2.2. Procedure

Participants wore a Fitbit Charge 5 (firmware version 57.20001.188.58) continuously over a one-month period to objectively monitor their sleep patterns in a real-world setting. This wearable device was chosen for its feasibility in field-based research, offering non-intrusive, continuous sleep tracking [19]. The Fitbit Charge 5 records key sleep parameters, including total sleep time (TST), time in bed (TIB), sleep efficiency (SE) and sleep stage distribution (light, deep, and REM sleep). Its selection was supported by prior validation against polysomnography [19]. The sleep data were downloaded using the Fitbit application. Only nocturnal sleep episodes were included. No instances of naps or split sleep nights were observed in this sample, so this did not affect data handling. The nights where no data were recorded (due to e.g. device malfunction, non-wear or battery depletion) were excluded from the analysis.

Subjective sleep ratings were assessed daily, at the end of their (work)day, using the question "How would you rate your sleep from the previous night?" Participants responded using a five-point scale: Good, Rather good, Neutral, Rather bad, or Bad.

2.3. Data analysis

Descriptive statistics were used to summarize key sleep parameters from the Fitbit Charge 5, including TST, TIB, SE, light sleep (LS), deep sleep (DS), REM sleep, wake time (W), as well as subjective sleep ratings, to characterize sleep patterns among the occupational drivers. Next, to examine whether there were significant differences in sleep parameters between the three types of drivers (SHD, LHD, LDD) a one-way ANOVA was conducted on the objective sleep parameters [20,21]. Effect sizes are reported as eta squared (η^2). Finally, to investigate the relationship between objective and subjective sleep measures, Pearson correlations were performed. Correlation effect sizes are presented as *r* values, along with 95 % confidence intervals (CI) [22].

All statistical analyses were conducted using Python (version 3.13.3) and Microsoft Excel (2024). A p-value of $<$0.05 was considered statistically significant. This study was exploratory and no single primary outcome was pre-specified. To reduce the risk of false positives from multiple testing we report unadjusted p-values together with effect sizes and 95 % CI to facilitate interpretation beyond reliance on *p*-values alone.

3. Results

A total of 31 occupational drivers participated in the study. The majority was male (n $=$ 28), with only three female participants. The mean age of the sample was 42.7 $\pm$ 10.8 years old. Participants were categorized into the three transport types: SHD (n $=$ 14, mean age $=$ 43.5 years old), LHD (n $=$ 8, mean age $=$ 45.9 years old), and LDD (n $=$ 9, mean age $=$ 39.0 years old). This demographic overview highlights a male-dominated sample with a slightly younger group in the LDD category compared to LHD and SHD. In total, 762 nights of sleep data were recorded across the 31 participants. The median number of valid nights per participant was 26. A detailed overview of participant demographics, number of recorded nights and availability of subjective sleep data is provided in Appendix Table A1.

3.1. Objective sleep

As shown in Table 1, participants demonstrated on average a SE of 87.3 $\pm$ 2.1 %, indicating relatively consolidated sleep. The distribution of sleep stages across the full sample of occupational drivers showed that participants spent the majority of their sleep time in LS, averaging 60.1 $\pm$ 5.2 %. DS accounted for 18.0 $\pm$ 3.3 %, while REM sleep comprised 21.2 $\pm$ 4.2 % of total sleep time. On average, participants were awake for 12.8 $\pm$ 1.8 % of the time spent in bed.

This pattern aligns with typical adult sleep architecture, where LS generally makes up around 50 %, DS around 15–25 % and REM sleep around 20–25 % of TST [23]. However, the notable amount of W may reflect disrupted sleep. The TST across the sample averaged 6.2 $\pm$ 0.7 h,

Table 1
Mean objective sleep parameters including sleep efficiency (SE), amount of light sleep (LS), deep sleep (DS), REM sleep and wake (W), total sleep time (TST) and time in bed (TIB) for the overall sample size and per transport type.

	N	SE (%)	LS (%)	DS (%)	REM (%)	W (%)	TST (hrs)	TIB (hrs)
SHD	14	87.6 ± 2.9	58.8 ± 5.8	18.5 ± 3.4	22.5 ± 4.6	12.8 ± 2.3	6.2 ± 0.6	7.1 ± 0.6
LHD	8	87.1 ± 1.5	61.1 ± 4.6	16.2 ± 3.5	20.9 ± 3.5	13.0 ± 1.9	5.9 ± 0.9	6.8 ± 1.0
LDD	9	87.2 ± 0.8	61.3 ± 4.7	18.8 ± 2.5	19.5 ± 3.7	12.5 ± 0.6	6.4 ± 0.6	7.3 ± 0.7
Total	31	87.3 ± 2.1	60.1 ± 5.2	18.0 ± 3.3	21.2 ± 4.2	12.8 ± 1.8	6.2 ± 0.7	7.1 ± 0.7

SHD: Short Haul Drivers.
LHD: Long Haul Drivers.
LDD: Local Delivery Drivers.

while TIB averaged 7.1 ± 0.7 h. These results suggest that, while most drivers achieved relatively high SE and substantial DS proportions, the TST was generally below the recommended 7–8 h for adults, indicating potential chronic sleep restriction in this population [23].

3.1.1. *Total sleep time, time in bed and sleep efficiency*

TST ranged from 4.8 h to 7.5 h. Analysis of TST revealed that only 5 out of 31 drivers (16.1 %) achieved the recommended 7–8 h of sleep per night [23]. The remaining 83.9 % had suboptimal TST, with several individuals (n = 22, 80 %) sleeping less than 6.5 h.

While TST was frequently insufficient, TIB was generally more favorable ranging from 5.6 h to 8.6 h 16 drivers (51.6 %) spent at least 7 h in bed, suggesting that sleep opportunity was not necessarily lacking.

SE was relatively well preserved across the group ranging from 83.8 % to 94.3 %. 28 out of 31 drivers (90.3 %) had a SE of 85 % or higher (Table 1, Fig. 1).

3.1.2. *Wake time and sleep stages*

DS ranged from 9.8 % to 25.3 %. Twenty-six drivers (83.9 %) fell within the recommended range of 15–25 % [23]. DS is critical for physical restoration and immune functioning, and deviations from this range may reflect underlying sleep architecture disturbances. Four drivers (12.9 %) had values below 15 %, which could indicate poor restorative sleep quality [24,25].

REM sleep percentages were more variable ranging from 10.8 % to 30.5 %. Twenty drivers (64.5 %) were within the recommended 20–25 % REM sleep range. Eight individuals (25.8 %) had REM percentages below 20 %, potentially reflecting stress or disrupted circadian rhythms. On the other hand, three drivers (9.7 %) showed elevated REM percentages above 25 %, which may represent compensatory REM rebound or altered sleep architecture [23,25–27].

The percentage of time spent in LS among the 31 occupational drivers showed considerable variation, ranging from 52.4 % to 72.1 %. The average LS reference line in Fig. 2, indicated at around 50 %, shows that most participants exceeded this typical benchmark, suggesting a trend toward elevated proportions of LS.

The amount of W ranged from 8.9 % to 16.2 %. Twenty-two drivers (71.0 %) stayed below the threshold of 15 % W. The remaining nine drivers (29.0 %) experienced elevated nocturnal wakefulness, suggesting sleep fragmentation or disturbances (Table 1, Fig. 2).

3.2. *Objective sleep per transport type*

The distribution of sleep stages across transport types showed relatively small, non-significant differences. LHD appeared to have the lowest proportion of DS (16.2 ± 3.5 %). REM sleep was most prominent in SHD (22.5 ± 4.6 %), who showed a slightly higher proportion compared to the other groups. LDD exhibited the highest average TST and TIB, while LHD had the shortest TST (Table 1, Fig. 3).

The ANOVA results revealed no statistically significant differences between the groups for most of the examined sleep variables (p-values >0.05), except for DS ($F(2,28) = 3.47$, $p = 0.05$). These findings suggest that, based on the measured sleep parameters, there is no evidence that the type of driving work (SHD, LHD or LDD) results in systematic differences in SE, LS, REM, W, TST and TIB. The low F-values in combination with high p-values indicate that the observed differences between groups are likely due to chance or natural variation within the sample, rather than an underlying effect of driver type (Table 2).

DS approached the threshold for significance ($F(2,28) = 3.47$, $p = 0.05$, $\eta^2 = 0.20$ (95 % CI [0.00, 0.38])), suggesting a potential group-level difference in the proportion of deep sleep across driver types. Descriptively, long-haul drivers exhibited the lowest average proportion of deep sleep compared to SHD and LDD groups (Fig. 3, Table 2).

However, the difference in DS should be considered a nominal, hypothesis-generating observation rather than conclusive evidence of group differences. As these analyses are exploratory, they do not imply causal differences between driver groups, and the observed trends should be interpreted with caution.

3.3. *Subjective sleep*

Subjective sleep ratings were collected using a daily subjective question in which participants rated their sleep from the previous night on a 5-point scale: 0 = *Good*, 1 = *Rather good*, 2 = *Neutral*, 3 = *Rather bad*, and 4 = *Bad*. Although 31 drivers participated in the study, only 20 consistently completed the daily sleep assessments. Responders versus non-responders did not differ significantly in age (responders: 42.4 ± 11.0 years; non-responders: 44.8 ± 10.7 years) or sex distribution (responders: 18 males, 2 females; non-responders: 10 males, 1 female). Similarly, no meaningful differences were observed in objective sleep parameters, including TST (responders: 6.3 ± 0.7 h; non-responders: 6.1 ± 0.8 h), TIB (7.1 ± 0.6 h vs. 7.0 ± 0.8 h), or SE (87.4 ± 2.0 % vs. 87.1 ± 2.4 %). These findings suggest that subjective non-response was primarily due to compliance issues and does not appear to reflect systematic differences in demographic or objective sleep characteristics.

The values presented reflect each participant's average sleep rating across the study period of one month. The results showed a relatively wide range in subjective sleep ratings among the occupational drivers, with average scores ranging from 0.5 to 2.8. The majority of participants (n = 12, 60 %) had average scores below or equal to 2.0, suggesting that most drivers in this sample perceived their sleep as generally *good* to *neutral*. 8 participants (40 %) reported on average a rating above 2.0 indicating more *neutral* to *rather bad* sleep (Fig. 4).

3.4. *Objective vs subjective sleep*

To assess the relationship between objective sleep parameters and subjective sleep evaluations, a Pearson correlation coefficient was computed for each participant across the set of objective sleep metrics (SE, DS, LS, REM, W, TST and TIB) and subjective sleep ratings. These correlations are visualized in Fig. 5. Negative correlations indicate that higher values on the objective variable are associated with lower subjective scores (i.e. better perceived sleep). Correlation effect sizes are presented as *r* values, along with 95 % CI.

The results demonstrated considerable inter-individual variability in the strength and direction of correlations. In general, a trend toward

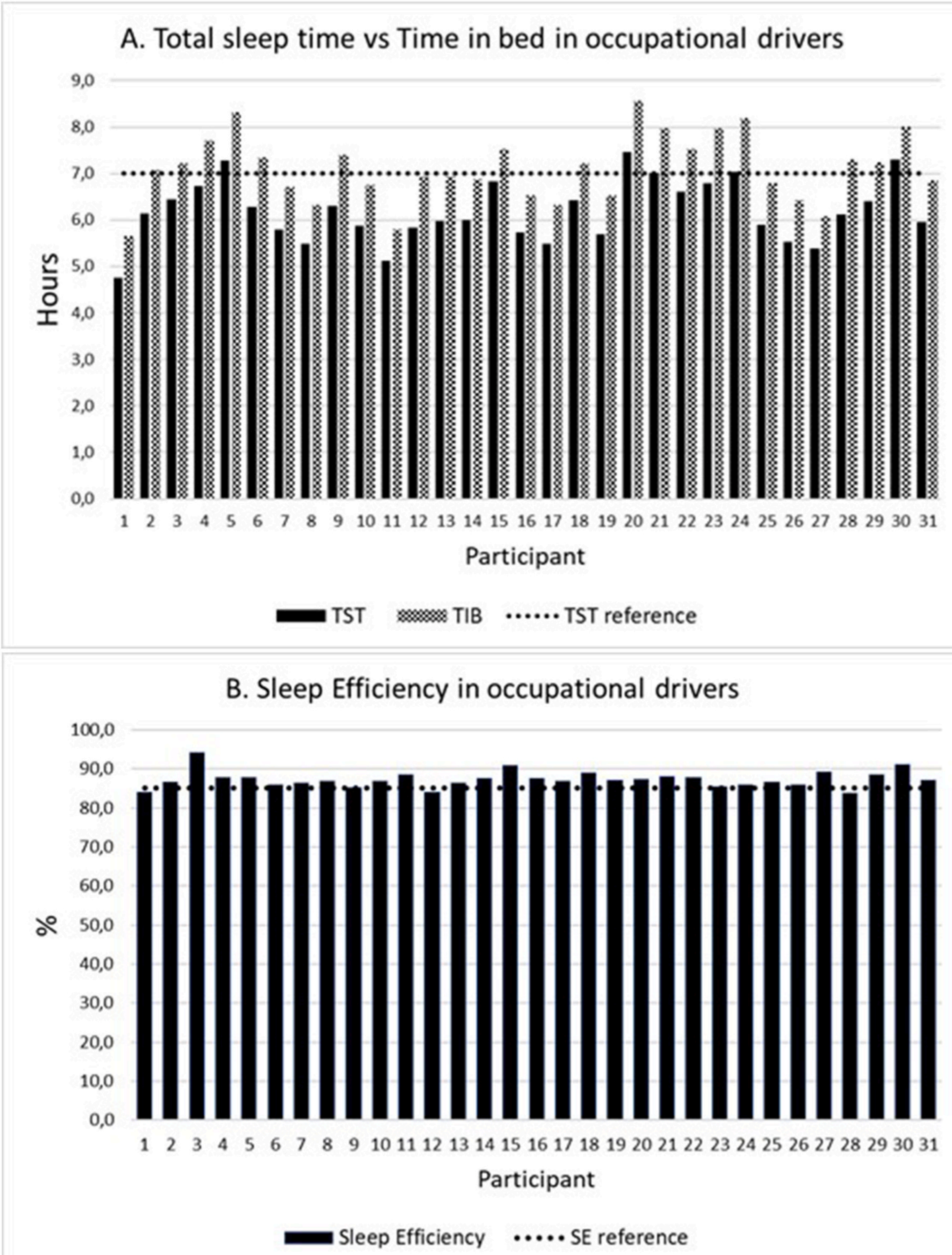

Fig. 1. Average objective total sleep time (TST), time in bed (TIB) and sleep efficiency (SE) in occupational drivers. (A) TST and TIB in hours are presented for each participant (n = 31). The dotted line represents the recommended average TST of 7 h [23]. (B) SE (%) for each participant is displayed. The dotted line indicates the general SE reference of 85 % [23].

negative correlations was observed for SE, TST and DS suggesting that higher values on these objective indicators were associated with better subjective sleep ratings. This pattern was particularly consistent for DS, where the majority of participants (80 %) exhibited significant negative correlations.

By contrast, correlations involving LS and W were more variable and tended to be closer to 0, with some participants showing weak positive correlations, indicating a possible link between fragmented or lighter sleep and poorer subjective evaluations. Notably, the magnitude of correlations across most variables remained within a low to moderate

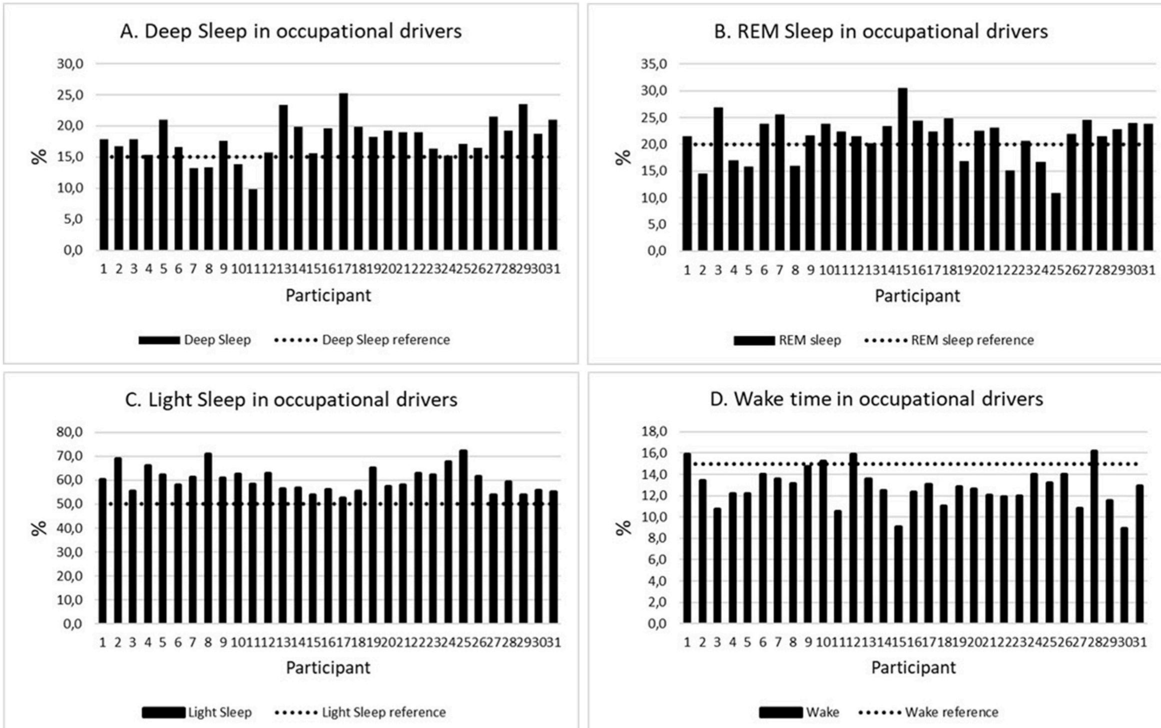

Fig. 2. Average distribution of deep sleep (DS), REM sleep, light sleep (LS) and wake time (W) in occupational drivers. (A) Average DS (%) across the sample (n = 31). The dotted line shows the average reference value for DS (15–25 %). (B) Average REM sleep (%) across the sample. The dotted line shows the average reference value for REM sleep (20–25 %). © Average LS (%) across the sample. The dotted line shows the average reference value of 50 % LS. (D)Average W (%). The dotted line shows the average reference value of maximum 15 % W.

range (|r|≈0.1–0.4, highlighting the nuanced and individualized nature of the relationship between objective and subjective sleep [22].

The Pearson correlation analyses between the overall objective sleep variables and subjective sleep are in line with the individual correlations values and revealed that some objective sleep measures were modestly associated with subjective sleep experiences. Most notably, a higher percentage of DS was associated with better perceived sleep ratings (r = −0.25, 95 % CI [−0.62, 0.22]), indicating that individuals who spent a greater proportion of the night in DS tended to rate their sleep more positively. Similarly, TST also correlated negatively with subjective sleep score (r = −0.19, 95 % CI [−0.58, 0.28]), suggesting that longer sleep durations are perceived more favorably. SE (r = −0.17, 95 % CI [−0.57, 0.29]) and TIB (r = −0.16, 95 % CI [−0.56, 0.30]) also showed small-to-moderate negative correlations, further supporting the link between consolidated sleep and improved sleep perception. Conversely, the percentage of time spent awake during the night was positively correlated with poorer subjective sleep (r = 0.14, 95 % CI [−0.32, 0.55]), indicating that fragmented or disturbed sleep is linked with worse sleep ratings. The proportions of LS (r = 0.06, 95 % CI [−0.39, 0.49]) and REM sleep (r = 0.04, 95 % CI [−0.41, 0.47]) showed very weak positive correlations with worse perceived sleep, though these associations were minimal (Fig. 5).

Taken together, these findings suggest that fewer awakenings, higher SE, more DS and longer sleep duration are most consistently associated with better subjective sleep ratings. Nevertheless, the very low to low correlation values emphasize that subjective sleep perception showed a discrepancy with objective sleep parameters, as it was only partially explained by them (Fig. 5).

4. Discussion

This study aimed to explore both objective and subjective sleep characteristics among occupational drivers, with particular attention to differences across SHD, LHD and LDD. In addition, by comparing the drivers' objective sleep data from the Fitbit Charge 5 with the subjective daily sleep ratings, we aimed to better understand how well their perceived sleep matches their objective sleep quality. The use of wearable technology not only enabled this comparison but also allowed for continuous, real-life monitoring of sleep parameters in a field setting. This dual approach offers valuable insight into individual differences in sleep perception and behavior and underscores the potential of wearables as practical tools for both research and real-time health monitoring. Overall, our findings provide a comprehensive picture of sleep behavior and perception in a high-risk occupational group.

A central finding was the widespread presence of chronic sleep restriction, with most drivers (83.9 %) failing to meet the recommended 7–8 h of TST per night [23]. Although our study cannot establish consequences, this pattern is consistent with earlier reports describing links between insufficient sleep, vigilance impairment and crash risk among professional drivers [5,7,8,28]. When compared to the general Belgian population, the extent of sleep restriction among drivers in this sample is particularly concerning. According to a recent survey by Helan, 58.1 % of Belgian adults report sleeping the recommended 7–8 h on weekdays, and only 28 % sleep less than 6 h [29]. In contrast, the current sample showed that fewer than one in five drivers achieved 7–8 h of sleep, and a much larger proportion fell below the 6.5-h mark. These descriptive differences point to a notable disparity between professional drivers and the broader working population, warranting closer attention in future research.

Interestingly, despite shortened TST, SE remained high, suggesting that once asleep, drivers tended to maintain consolidated sleep. This could reflect compensatory adaptations, allowing individuals to preserve sleep quality under restricted conditions [30,31]. However, the observed shift toward elevated LS and variability in REM sleep may indicate less restorative sleep, and potentially indicating stress, circadian misalignment or other regulatory disruptions [23–25,27]. This is

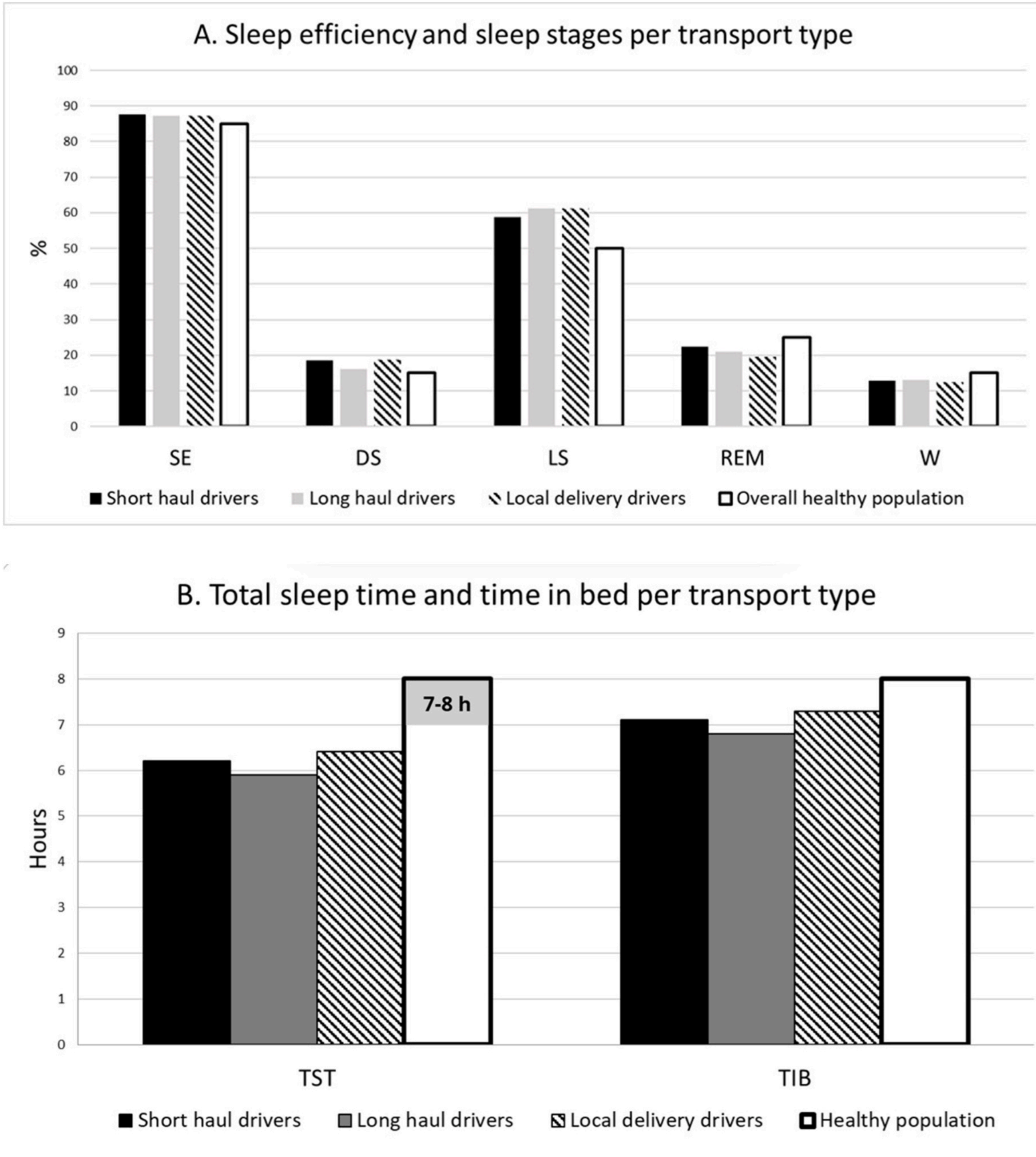

Fig. 3. Group comparisons of objective sleep variables by transport type. (A) Mean values (in %) of sleep efficiency (SE), deep sleep (DS), light sleep (LS), REM sleep, and wake time (W) are shown across three transport groups (short-haul drivers (SHD), long-haul drivers (LHD), and local delivery drivers (LDD)) compared to the overall healthy global population [25]. (B) Total sleep time (TST) and time in bed (TIB), measured in hours, are shown for each transport type and the overall healthy population. The recommended range for TST is 7–8 h.

Table 2
One-way ANOVA results for the sleep parameters by transport type.

Sleep parameter	F-value	p-value	η^2
SE (%)	0.17	0.85	0.01
DS (%)	3.47	**0.05**	0.20
LS (%)	0.32	0.73	0.02
REM (%)	0.10	0.90	0.01
W (%)	0.20	0.82	0.01
TST (hrs)	1.13	0.34	0.08
TIB (hrs)	0.09	0.91	0.01

consistent with reports in populations exposed to irregular schedules or environmental disturbances [2,3,36]. Such alterations could compromise recovery and alertness, posing potential risks for driver safety [32–35]. In addition, roughly one third (29.0 %) of drivers experienced elevated nocturnal wakefulness, suggesting significant sleep fragmentation or disturbances. This could undermine the restorative function of sleep and may contribute to fatigue during waking hours, a critical concern for occupational safety in this population [28,35,37].

Although previous studies [1,38–40] suggested that driver type might influence sleep, particularly as LHD often face more night driving and irregular schedules, we found no significant group differences in objective sleep measures, except for deep sleep (DS). Descriptively, LHD

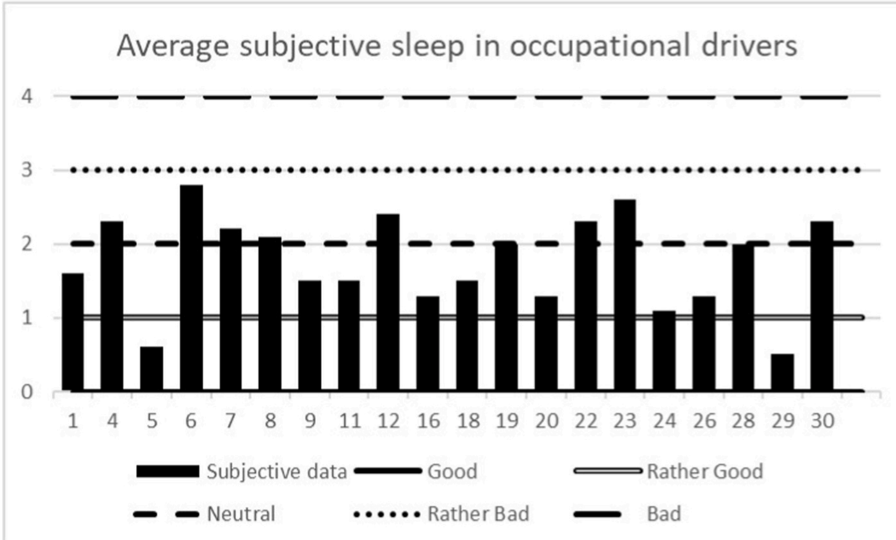

Fig. 4. Average subjective sleep ratings in occupational drivers. The average subjective sleep ratings for each participant (n = 20) based on daily self-reported responses to the question, "*How would you rate your sleep from the previous night*?" Responses were given on a 5-point scale, where 0 = *Good*, 1 = *Rather good*, 2 = *Neutral*, 3 = *Rather bad*, and 4 = *Bad*. The horizontal reference lines indicate the qualitative boundaries for each response category (Good to Bad).

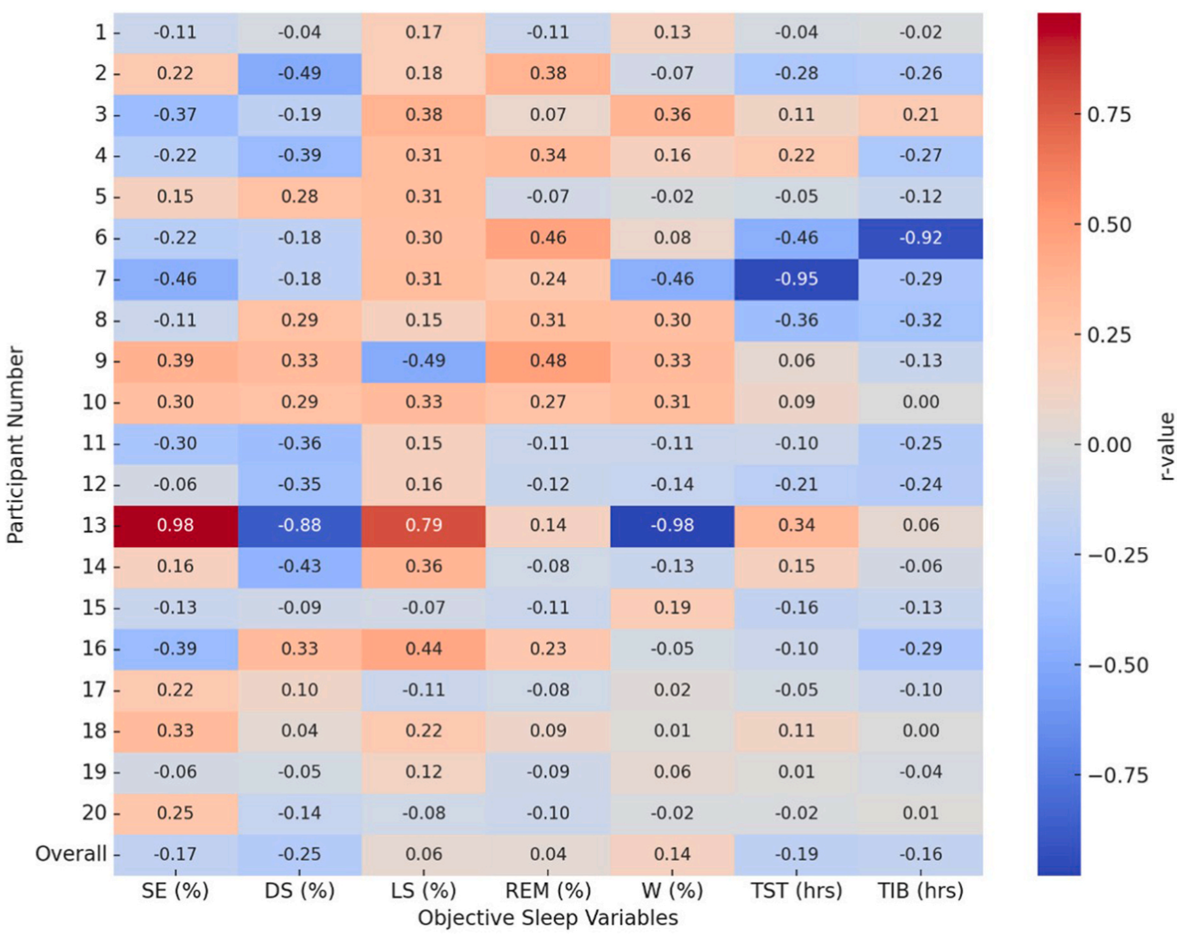

Fig. 5. Pearson correlation coefficients between objective sleep parameters and subjective sleep ratings per participant.

exhibited the lowest average proportion of DS compared to SHD and LDD groups. LHD often experience extended driving hours, irregular schedules and overnight trips, leading to disrupted circadian rhythms and limited access to consistent sleep environments [1]. In contrast, SHD and LDD typically have more predictable routes and may return home daily, potentially allowing for more regular sleep routines [2,4]. Although LHD showed descriptively lower DS, the absence of significant group effects should also be interpreted in light of limited study power.

With a sample of 31 drivers, the study had only moderate sensitivity to detect small-to-moderate between-group differences ($\eta^2 < 0.10$). Therefore, subtle effects may have gone undetected, and future studies with larger samples are needed to confirm or refute these patterns. The current findings nonetheless suggest that individual-level and contextual factors (e.g. sleep environment, coping strategies and personal habits) may play a more decisive role than occupational classification alone [41,42]. This emphasizes that these exploratory analyses should be interpreted cautiously and do not imply causal differences between driver types. Future research should therefore examine these factors more systematically to identify modifiable determinants of poor sleep among professional drivers.

Subjective sleep ratings varied across participants, with some reporting consistently positive sleep and others rating their sleep more negatively. Correlation analyses between subjective ratings and objective sleep parameters revealed a general but modest alignment. Specifically, higher DS, SE and TST were associated with better subjective sleep ratings, whereas more W and LS correlated weakly with worse perceived sleep. However, as this study was conducted in a relatively small sample and relied on wearable-derived sleep staging, the findings should be regarded as preliminary. Nevertheless, these findings are consistent with previous literature suggesting that individuals tend to rely on indicators such as duration and depth of sleep when evaluating their own sleep [43,44]. However, the overall strength of correlations remained low to moderate, underscoring the partial and individualized nature of this relationship. Discrepancy between perceived and objective sleep may be influenced by mood, stress, cognitive biases or inaccurate memory of the night's sleep underscoring the subjective nature of sleep perception [45,46]. These findings highlight the importance of incorporating both subjective and objective measures when assessing sleep quality.

Taken together, this study provides an observational snapshot of sleep patterns and perceptions among professional drivers. These findings suggest that while most drivers generally achieve consolidated sleep, they remain chronically sleep-restricted, with potential consequences for health and occupational safety. Future research should include larger samples, explore contextual factors affecting sleep and develop strategies to improve drivers' sleep, with particular emphasis on integrating both subjective and objective measures.

5. Limitations

Several limitations should be acknowledged in interpreting the results of this study. First, the sample size was relatively small (n = 31) with only three females, and not all participants completed subjective ratings (n = 20). This may limit the generalizability and statistical power of the findings, especially regarding subgroup comparisons. Additionally, while the use of Fitbit Charge 5 allowed for convenient and continuous objective sleep tracking in a field setting, wearable devices may have limited precision in differentiating between sleep stages compared to the gold-standard method, namely polysomnography [19]. In addition, as individuals age, there is a decline in REM sleep. Although pronounced reductions in REM sleep are most commonly seen in older adults, in the context of this sample with a mean age of 42.7 ± 10.8 years, one might begin to observe early signs of this REM sleep decline, especially in the individuals at the upper end of this age distribution [47–49].

Another important consideration is that psychiatric or neurological comorbidities and the use of medications that may affect sleep were not systematically assessed. These factors could act as potential confounders influencing both objective and subjective sleep outcomes, and their absence from the dataset limits the ability to fully interpret variability in sleep patterns.

Furthermore, subjective sleep was assessed using a single daily item. This approach minimized participant burden and supported higher compliance across the study. However, detailed sleep diaries or questionnaires offer more complexity of sleep perception and contextual factors, but could lead to lower adherence [50–53]. The timing of these subjective assessments (completed in the evening) may also have increased recall bias. Lastly, other influential variables such as caffeine intake or environmental sleep conditions were not systematically assessed and could have influenced both subjective and objective sleep outcomes.

Future studies should consider larger samples to explore the subgroups in occupational drivers with greater statistical power and examine factors such as chronotype, psychiatric/neurological comorbidities, medication use, stress and sleep environment in greater depth.

6. Conclusion

This study provides insights into the sleep patterns and perceptions of Belgian occupational road freight drivers by comparing objective sleep data with self-reported sleep ratings across different types of drivers. While the majority of participants experienced reasonably efficient sleep, TST was often below recommended levels, raising concerns about chronic sleep restriction in this population. Differences in objective sleep parameters between driver categories (SHD, LHD, LDD) were not statistically significant, except for DS. Descriptively, LHD exhibited the lowest average proportion of DS compared to SHD and LDD. However, the high p-values for most of the sleep parameters suggests that factors beyond driver type, such as individual behavior, environment and personal habits, may be more influential.

Additionally, subjective sleep evaluations showed only weak-to-moderate alignment with objective data, underscoring the complexity of sleep perception and the potential for discrepancy between perceived and objective sleep.

These findings suggest that while most drivers generally achieve consolidated sleep, they remain chronically sleep-restricted, with potential consequences for health and occupational safety.

This underlines the need for transport companies to implement education and effective fatigue management such as ensuring sufficient rest opportunities and designing schedules that reduce the risks of chronic sleep restriction. At a policy level, the findings support the development of regulations and guidelines that encourage appropriate work schedules and the integration of wearable monitoring tools to detect and manage fatigue in real time.

CRediT authorship contribution statement

An-Marie Schyvens: Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nina Catharina Van Oost:** Writing – review & editing, Investigation, Data curation. **Brent Peters:** Writing – review & editing, Investigation, Data curation. **Frederik Veys:** Writing – review & editing. **Jean-Marie Aerts:** Writing – review & editing, Conceptualization. **Federica Masci:** Writing – review & editing. **An Neven:** Writing – review & editing, Resources, Funding acquisition. **Hélène Dirix:** Writing – review & editing. **Geert Wets:** Writing – review & editing, Resources. **Veerle Ross:** Writing – review & editing. **Johan Verbraecken:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Statement of significance

Sleep is a critical factor in ensuring health and safety, particularly for occupational drivers who face irregular schedules, long hours and high work demands. Fatigue contributes to up to 30 % of severe traffic accidents globally. In Belgium, many professional drivers report poor sleep and excessive daytime sleepiness. Although numerous studies have assessed sleep patterns in this population, much of the existing literature relies heavily on self-reported, subjective sleep measures, which may not accurately reflect actual sleep behavior and can lead to discrepancies between perceived and objective sleep. This study combines objective and subjective sleep assessments in Belgian short haul, long haul and local delivery drivers. It offers critical insights into sleep patterns within this high-risk group and emphasizing the need for combining objective and subjective sleep evaluations to improve sleep health and safety.

Funding

This work was supported by Flanders Innovation & Entrepreneurship—VLAIO (Vlaams Agentschap Innoveren & Ondernemen; HBC.2021.0387).

The collaborative effort of the consortium resulted in a comprehensive and well-balanced research paper. Each author has approved the final version of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Table A1
Participants' demographics including sex, age, transport type, number of recorded nights and availability of subjective data.

ID	Sex	Age	Transport Type	Recorded nights	Subjective data
1	M	59	LHD	24	No
2	M	48	LDD	12	Yes
3	M	57	SHD	19	Yes
4	M	54	LDD	30	No
5	M	47	LDD	30	No
6	M	47	SHD	25	Yes
7	M	54	SHD	29	Yes
8	F	52	LHD	27	No
9	M	42	SHD	12	Yes
10	M	51	LHD	45	Yes
11	M	57	LHD	47	Yes
12	M	45	SHD	26	No
13	M	29	LDD	6	No
14	M	28	LDD	33	Yes
15	M	49	SHD	29	Yes
16	M	52	LDD	28	Yes
17	M	35	SHD	13	Yes
18	M	43	LHD	33	No
19	M	32	LDD	31	Yes
20	M	32	LHD	25	Yes
21	F	30	LDD	26	Yes
22	M	25	LHD	28	Yes
23	M	30	LDD	21	No
24	M	52	SHD	32	No
25	M	38	SHD	30	Yes
26	M	52	LHD	18	Yes
27	M	37	SHD	10	No
28	M	50	SHD	25	Yes
29	M	46	SHD	15	Yes
30	F	23	SHD	28	Yes
31	M	29	SHD	5	No

SHD: Short Haul Drivers.
LHD: Long Haul Drivers.
LDD: Local Delivery Drivers.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

References

[1] Mitler MM, Miller JC, Lipsitz JJ, Walsh JK, Wylie CD. The sleep of long-haul truck drivers. N Engl J Med 1997 Sep 11;337(11):755–61. https://doi.org/10.1056/nejm199709113371106. PMID: 9287232.

[2] Chen GX, Fang Y, Guo F, Hanowski RJ. The influence of daily sleep patterns of commercial truck drivers on driving performance. Accid Anal Prev 2016 Jun;91: 55–63. https://doi.org/10.1016/j.aap.2016.02.027. PMID: 26954762.

[3] Rocha FP, Marqueze EC, Kecklund G, Moreno CRC. Evaluation of truck driver rest locations and sleep quality. Sleep Sci 2022 Jan–Mar;15(1):55–61. https://doi.org/10.5935/1984-0063.20210028. PMID: 35662964.

[4] Lemke MK, Apostolopoulos Y, Hege A, Sönmez S, Wideman L. Understanding the role of sleep quality and sleep duration in commercial driving safety. Accid Anal Prev 2016 Dec;97:79–86. https://doi.org/10.1016/j.aap.2016.08.024. PMID: 27591416.

[5] Gottlieb DJ, Ellenbogen JM, Bianchi MT, Czeisler CA. Sleep deficiency and motor vehicle crash risk in the general population: a prospective cohort study. BMC Med 2018 Mar 20;16(1):44. https://doi.org/10.1186/s12916-018-1025-7. PMID: 29554902.

[6] Pelssers B, Diependaele K. Analysis of the extent and characteristics of sleepiness among Belgian car drivers in 2017. Vias Institute Report, https://www.vias.be/publications/Slaperig%20achter%20het%20stuur%202017/Sleepy_at_the_wheel.pdf. [Accessed 2 June 2025].

[7] Pizza F, Contardi S, Antognini AB, Zagoraiou M, Borrotti M, Mostacci B, et al. Sleep quality and motor vehicle crashes in adolescents. J Clin Sleep Med 2010 Feb 15;6 (1):41–5. PMID: 20191936.

[8] Tefft BC. Acute sleep deprivation and culpable motor vehicle crash involvement. Sleep 2018;41(10). https://doi.org/10.1093/sleep/zsy144.

[9] Braeckman L, Verpraet R, Van Risseghem M, Pevernagie D, De Bacquer D. Prevalence and correlates of poor sleep quality and daytime sleepiness in Belgian truck drivers. Chronobiol Int 2011 Mar;28(2):126–34. https://doi.org/10.3109/07420528.2010.540363. PMID: 21231874.

[10] Verpraet R. Epidemiological study on sleeping and driving habits of Flemish truck drivers. De Tijd. Interuniversitaire Gespecialiseerde Studie in de Arbeidsgeneeskunde; 2007.
[11] Forum IT. Belgium: Road safety country profile 2023. Paris: OECD Publishing; 2024.
[12] Baulk SD, Fletcher A, Kandelaars KJ, Dawson D, Roach GD. A field study of sleep and fatigue in a regular rotating 12-h shift system. Appl Ergon 2009 Jul;40(4): 694–8. https://doi.org/10.1016/j.apergo.2008.06.003. PMID: 18675388.
[13] Baulk SD, Fletcher A. At home and away: measuring the sleep of Australian truck drivers. Accid Anal Prev 2012 Mar;45:36–40. https://doi.org/10.1016/j.aap.2011.09.023.
[14] Jeong I, Park JB, Lee KJ, Won JU, Roh J, Yoon JH. Irregular work schedule and sleep disturbance in occupational drivers—A nationwide cross-sectional study. PLoS One 2018;13(11):e0207154. https://doi.org/10.1371/journal.pone.0207154. PMID: 30439972.
[15] Popp RF, Maier S, Rothe S, Zulley J, Crönlein T, Wetter TC, et al. Impact of overnight traffic noise on sleep quality, sleepiness, and vigilant attention in long-haul truck drivers: results of a pilot study. Noise Health 2015 Nov–Dec;17(79): 387–93. https://doi.org/10.4103/1463-1741.169698. PMID: 26572698.
[16] Faria BM, Lopes T, Oliveira A, Pimenta R, Gonçalves J, Carvalho V, et al. Sleep quality of heavy vehicles' professional drivers: an analysis based on self-perceived feedback. Sleep Vigil 2024 Dec;8(2):193–200. https://doi.org/10.1007/s41782-024-00270-x.
[17] Mao Y, Raju G, Zabidi MA. Association between occupational stress and sleep quality: a systematic review. Nat Sci Sleep 2023;15:931–47. https://doi.org/10.2147/nss.S431442. PMID: 38021213.
[18] Paviani L, Girotto E, Rumiato AC, Rodrigues R, González AD. Association between self-reported food intake and subjective sleep quality among truck drivers in a city in Southern Brazil. Dialogues Health 2023 Dec;2:100098. https://doi.org/10.1016/j.dialog.2023.100098. PMID: 38515466.
[19] Schyvens AM, Peters B, Van Oost NC, Aerts JM, Masci F, Neven A, et al. A performance validation of six commercial wrist-worn wearable sleep-tracking devices for sleep stage scoring compared to polysomnography. Sleep Adv 2025 Apr;6(2):zpaf021. https://doi.org/10.1093/sleepadvances/zpaf021. PMID: 40303381.
[20] Kim TK. Understanding one-way ANOVA using conceptual figures. Korean J Anesthesiol 2017 Feb;70(1):22–6. https://doi.org/10.4097/kjae.2017.70.1.22. PMID: 28184262.
[21] Troncoso Skidmore S, Thompson B. Bias and precision of some classical ANOVA effect sizes when assumptions are violated. Behav Res Methods 2013 Jun;45(2): 536–46. https://doi.org/10.3758/s13428-012-0257-2. PMID: 23055163.
[22] Schober P, Boer C, Schwarte LA. Correlation coefficients: appropriate use and interpretation. Anesth Analg 2018 May;126(5):1763–8. https://doi.org/10.1213/ane.0000000000002864. PMID: 29481436.
[23] Panel CC. Recommended amount of sleep for a healthy adult: a joint consensus statement of the American academy of sleep medicine and sleep research society. Sleep 2015;38(6):843–4. https://doi.org/10.5665/sleep.4716.
[24] Desai D, Momin A, Hirpara P, Jha H, Thaker R, Patel J. Exploring the role of circadian rhythms in sleep and recovery: a review article. Cureus 2024 Jun;16(6): e61568. https://doi.org/10.7759/cureus.61568. PMID: 38962617.
[25] Walker MP. The role of sleep in cognition and emotion. Ann N Y Acad Sci 2009 Mar;1156:168–97. https://doi.org/10.1111/j.1749-6632.2009.04416.x. PMID: 19338508.
[26] Feriante J, Singh S. REM rebound effect. 2024 sep 12. In: StatPearls [Internet]. Treasure Island (FL). StatPearls Publishing; 2025 Jan. PMID: 32809548.
[27] Nakazawa Y, Kotorii M, Kotorii T, Tachibana H, Nakano T. Individual differences in compensatory rebound of REM sleep, with particular reference to their relationship to personality and behavioral characteristics. J Nerv Ment Dis 1975 Jul;161(1):18–25. https://doi.org/10.1097/00005053-197507000-00002. PMID: 168312.
[28] Philip P, Sagaspe P, Moore N, Taillard J, Charles A, Guilleminault C, et al. Fatigue, sleep restriction and driving performance. Accid Anal Prev 2005 May;37(3):473–8. https://doi.org/10.1016/j.aap.2004.07.007. PMID: 15784201.
[29] Saerens R. Bijna 1 op de 3 Vlamingen haalt niet eens 6 uur slaap. Helan 2025. Available at: https://www.helan.be/nl/magazine/mijn-gezondheid/bijna-1-op-de-3-vlamingen-haalt-niet-eens-6-uur-slaap/. [Accessed 2 June 2025].
[30] Bonnet MH, Arand DL. Clinical effects of sleep fragmentation versus sleep deprivation. Sleep Med Rev 2003 Aug;7(4):297–310. https://doi.org/10.1053/smrv.2001.0245. PMID: 14505597.
[31] Djonlagic I, Saboisky J, Carusona A, Stickgold R, Malhotra A. Increased sleep fragmentation leads to impaired off-line consolidation of motor memories in humans. PLoS One 2012;7(3):e34106. https://doi.org/10.1371/journal.pone.0034106. PMID: 22470524.
[32] Berhanu R, Schnippel K, Mohr E, Hirasen K, Evans D, Rosen S, et al. Early outcomes of decentralized care for rifampicin-resistant tuberculosis in Johannesburg, South Africa: an observational cohort study. PLoS One 2016;11(11):e0164974. https://doi.org/10.1371/journal.pone.0164974. PMID: 27812140.
[33] Jackson ML, Croft RJ, Kennedy GA, Owens K, Howard ME. Cognitive components of simulated driving performance: sleep loss effects and predictors. Accid Anal Prev 2013 Jan;50:438–44. https://doi.org/10.1016/j.aap.2012.05.020. PMID: 22721550.
[34] Knott M, Classen S, Krasniuk S, Tippett M, Alvarez L. Insufficient sleep and fitness to drive in shift workers: a systematic literature review protocol. Inj Prev 2019 Dec; 25(6):589–94. https://doi.org/10.1136/injuryprev-2018-042972. PMID: 30554167.
[35] Garbarino S, Durando P, Guglielmi O, Dini G, Bersi F, Fornarino S, et al. Sleep apnea, sleep debt and daytime sleepiness are independently associated with road accidents: a cross-sectional study on truck drivers. PLoS One 2016;11(11): e0166262. https://doi.org/10.1371/journal.pone.0166262. PMID: 27902703.
[36] Zitting KM, Münch MY, Cain SW, Wang W, Wong A, Ronda JM, et al. Young adults are more vulnerable to chronic sleep deficiency and recurrent circadian disruption than older adults. Sci Rep 2018 Jul 23;8(1):11052. https://doi.org/10.1038/s41598-018-29358-x. PMID: 30038272.
[37] Heaton K, McManus BJ, Mumbower R, Vance DE. A pilot study of sleep, work practices, visual processing speed, and 5-year motor vehicle crash risk among truck drivers. Workplace Health Saf 2017 Dec;65(12):572–9. https://doi.org/10.1177/2165079917704448. PMID: 28621204.
[38] Diez JJ, Plano SA, Caldart C, Bellone G, Simonelli G, Brangold M, et al. Sleep misalignment and circadian rhythm impairment in long-haul bus drivers under a two-up operations system. Sleep Health 2020 Jun;6(3):374–86. https://doi.org/10.1016/j.sleh.2019.12.011. PMID: 32081596.
[39] Lemke MK, Apostolopoulos Y, Hege A, Sönmez S, Wideman L. Understanding the role of sleep quality and sleep duration in commercial driving safety. Accid Anal Prev 2016 Dec;97:79–86. https://doi.org/10.1016/j.aap.2016.08.024. PMID: 27591416.
[40] Pylkkönen M, Sihvola M, Hyvärinen HK, Puttonen S, Hublin C, Sallinen M. Sleepiness, sleep, and use of sleepiness countermeasures in shift-working long-haul truck drivers. Accid Anal Prev 2015 Jul;80:201–10. https://doi.org/10.1016/j.aap.2015.03.031. PMID: 25957933.
[41] Perrier J, Jongen S, Vuurman E, Bocca ML, Ramaekers JG, Vermeeren A. Driving performance and EEG fluctuations during on-the-road driving following sleep deprivation. Biol Psychol 2016 Dec;121:1–11. https://doi.org/10.1016/j.biopsycho.2016.09.010.
[42] Gander P, Hartley L, Powell D, Cabon P, Hitchcock E, Mills A, et al. Fatigue risk management: organizational factors at the regulatory and industry/company level. Accid Anal Prev 2011 Mar;43(2):573–90. https://doi.org/10.1016/j.aap.2009.11.007. PMID: 21130218.
[43] Åkerstedt T, Anund A, Axelsson J, Kecklund G. Subjective sleepiness is a sensitive indicator of insufficient sleep and impaired waking function. J Sleep Res 2014 Jun; 23(3):240–52. https://doi.org/10.1111/jsr.12158. PMID: 24750198.
[44] Kaplan KA, Hirshman J, Hernandez B, Stefanick ML, Hoffman AR, Redline S, et al. When a gold standard isn't so golden: lack of prediction of subjective sleep quality from sleep polysomnography. Biol Psychol 2017 Feb;123:37–46. https://doi.org/10.1016/j.biopsycho.2016.11.010.
[45] Feige B, Al-Shajlawi A, Nissen C, Voderholzer U, Hornyak M, Spiegelhalder K, et al. Does REM sleep contribute to subjective wake time in primary insomnia? A comparison of polysomnographic and subjective sleep in 100 patients. J Sleep Res 2008 Jun;17(2):180–90. https://doi.org/10.1111/j.1365-2869.2008.00651.x. PMID: 18482106.
[46] Harvey AG, Tang NK. Mis)perception of sleep in insomnia: a puzzle and a resolution. Psychol Bull 2012 Jan;138(1):77–101. https://doi.org/10.1037/a0025730. PMID: 21967449.
[47] Floyd JA, Janisse JJ, Jenuwine ES, Ager JW. Changes in REM-sleep percentage over the adult lifespan. Sleep 2007;30(7):829–36. https://doi.org/10.1093/sleep/30.7.829.
[48] Pace-Schott EF, Spencer RM. Age-related changes in the cognitive function of sleep. Prog Brain Res 2011;191:75–89. https://doi.org/10.1016/b978-0-444-53752-2.00012-6. PMID: 21741545.
[49] Scullin MK, Gao C, Fillmore P, Roberts RL, Pruett N, Bliwise DL. Rapid eye movement sleep mediates age-related decline in prospective memory consolidation. Sleep 2019 Jun 11;42(6):30860593. https://doi.org/10.1093/sleep/zsz055. PMID.
[50] Arora T, Broglia E, Pushpakumar D, Lodhi T, Taheri S. An investigation into the strength of the association and agreement levels between subjective and objective sleep duration in adolescents. PLoS One 2013;8(8):e72406. https://doi.org/10.1371/journal.pone.0072406. PMID: 23951321.
[51] Dietch JR, Sethi K, Slavish DC, Taylor DJ. Validity of two retrospective questionnaire versions of the consensus sleep diary: the whole week and split week self-assessment of sleep surveys. Sleep Med 2019 Nov;63:127–36. https://doi.org/10.1016/j.sleep.2019.05.015. PMID: 31622954.
[52] Fabbri M, Beracci A, Martoni M, Meneo D, Tonetti L, Natale V. Measuring subjective sleep quality: a review. Int J Environ Res Publ Health 2021 Jan 26;18(3). https://doi.org/10.3390/ijerph18031082. PMID: 33530453.
[53] Libman E, Fichten CS, Bailes S, Amsel R. Sleep questionnaire versus sleep diary: which measure is better? Int J Rehabil Health 2000 Jul;5(3):205–9. https://doi.org/10.1023/A:1012955423123.