Sleep research

Sleep duration and sleep efficiency in UK long-distance heavy goods vehicle drivers

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ABSTRACT

Objectives To profile sleep duration and sleep efficiency in UK long-distance heavy goods vehicle (HGV) drivers and explore demographic, occupational and lifestyle predictors of sleep.

Methods Cross-sectional analyses were carried out on 329 HGV drivers (98.5% men) recruited across an international logistics company within the midland’s region, UK. Sleep duration and efficiency were assessed via wrist-worn accelerometry (GENEActiv) over 8 days. Proportions of drivers with short sleep duration (<6 hour/24 hours and <7 hour/24 hours) and inadequate sleep efficiency (<85%) were calculated. Demographic, occupational and lifestyle data were collected via questionnaires and device-based measures. Logistic regression assessed predictors of short sleep duration and inadequate sleep efficiency.

Results 58% of drivers had a mean sleep duration of <6 hour/24 hours, 91% demonstrated <7-hour sleep/24 hours and 72% achieved <85% sleep efficiency. Sleeping <6 hour/24 hours was less likely in morning (OR 0.45, 95% CI 0.21 to 0.94) and afternoon (OR 0.24, CI 0.10 to 0.60) shift workers (vs night) and if never smoked (vs current smokers) (OR 0.45, CI 0.22 to 0.92). The likelihood of sleeping <7 hour/24 hours reduced with age (OR 0.92, CI 0.87 to 0.98). The likelihood of presenting inadequate sleep efficiency reduced with age (OR 0.96, CI 0.93 to 0.99) and overweight body mass index category (vs obese) (OR 0.47, CI 0.27 to 0.82).

Conclusions The high prevalence of short sleep duration and insufficient sleep quality (efficiency) rate suggest that many HGV drivers have increased risk of excessive daytime sleepiness, road traffic accidents and chronic disease. Future sleep research in UK HGV cohorts is warranted given the road safety and public health implications.

INTRODUCTION

Long-distance heavy goods vehicle (HGV) drivers, responsible for transporting goods within a vehicle in excess of 3.5 tonnes (gross vehicle weight), work within hazardous conditions that jeopardise their health and well-being. Hazardous occupational factors, such as shift working and demanding delivery schedules, and undesirable lifestyles, such as poor nutritional intake, low levels of physical activity and sleep deprivation, culminate in an increased risk of accidents, higher rates of chronic disease and reduced life expectancy compared with general populations. Healthy sleep (eg ≥7 hour/24 hours) is critical for long-distance HGV drivers and other road user safety. Insufficient sleep (ie, <7-hour sleep duration), which can lead to daytime sleepiness, fatigue and impaired vigilance, is responsible for a disproportionately high number of fatigue-related road accidents involving HGV drivers. Healthy sleep is also essential for well-being and to avoid comorbidities. For instance, very short sleep (<6 hours/24 hours) is associated with all-cause mortality, diabetes mellitus, cardiovascular disease, diabetes mellitus, cardiovascular disease,

Key messages

What is already known about this subject?

► Internationally, heavy goods vehicle (HGV) drivers are known to have insufficient sleep.

► Insufficient sleep carries risks of daytime sleepiness, road traffic accidents, reduced mental well-being and chronic disease in HGV drivers.

► Accelerometer-measured sleep data during free living conditions are needed in UK HGV drivers to build on the predominant self-reported evidence-base currently available.

What are the new findings?

► Within a UK HGV sample, almost all drivers had short sleep duration (<7 hour) and almost three quarters had inadequate sleep efficiency (<85%) compared with National Sleep Foundation recommendations.

► Short sleep duration and inadequate sleep efficiency were predicted by shift type, smoking status, age and body mass index category.

How might this impact on policy or clinical practice in the foreseeable future?

► Further sleep research should develop and evaluate interventions targeting sleep behaviours in HGV drivers.

► UK-based logistic companies should include more comprehensive assessments of sleep behaviour and incorporate sleep surveillance as part of routine training and medical evaluation procedures.

► Weight management and sleep behaviour awareness training should also be considered.

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obesity, lower self-esteem and optimism compared with regularly obtaining 7–8 hour/24 hours sleep.\textsuperscript{11,12} Given the public health and road safety implications, sleep should be a priority lifestyle behaviour for HGV drivers.

Adults should try to achieve 7–8 hour/24 hours of sleep for good health.\textsuperscript{13} Sleep efficiency, a measure of the actual time asleep while in bed, is used as an indicator of sleep quality and considered ‘good’ if ≥85%.\textsuperscript{9} In USA and Australian HGV drivers, numerous studies have reported an average sleep duration of <7 hour/24 hours\textsuperscript{14,15} and others have observed high proportions (eg >40%) of drivers reporting short sleep.\textsuperscript{16–17} Sleep quality has been self-reported as ‘poor’ in around a fifth of US and European HGV drivers,\textsuperscript{7,18,19} with 78% sleep efficiency reported in Australian drivers from device-based data.\textsuperscript{20} These sleep outcomes compare unfavourably to general populations.\textsuperscript{20–21}

Sleep behaviour is influenced by multiple demographic, occupational and lifestyle factors. For instance, sleep duration and efficiency generally decrease with age,\textsuperscript{21} a potentially significant factor in the ageing workforce of UK HGV drivers.\textsuperscript{22} Shift workers show high rates of sleep disorders compared with conventional workers\textsuperscript{23} and less HGV driving experience has been associated with poor sleep quality.\textsuperscript{27} Poor lifestyles, widespread in HGV drivers,\textsuperscript{16} such as smoking, low levels of physical activity and obesity, are also associated with sleep disorders and sleep deprivation.\textsuperscript{24–26} Sleep research should explore the distribution of these factors in UK HGV drivers, to help effectively target sleep interventions.

Most research examining sleep in HGV drivers has relied on self-report measures, which can be prone to overestimation.\textsuperscript{21} Accelerometry is increasingly being used, as a convenient and inexpensive method, in large population studies, which assess longitudinal patterns in sleep behaviour and health outcomes (eg, UK Biobank, NHANES). Such sleep data can also provide supplementary estimates of sleep characteristics that self-report cannot, such as fragmented/accumulated sleep during time in bed.\textsuperscript{27} To date, no information on UK HGV driver’s sleep duration and efficiency collected via accelerometry have been reported.

Drawing on the needs identified in this at-risk population, our research aimed to (1) profile the sleep behaviour of a UK HGV driver cohort and (2) explore potential demographic, occupational and lifestyle-related predictors of short sleep duration and inadequate sleep efficiency.

**METHODS**

**Study design, setting and participants**

This cross-sectional study used baseline data collected from long-distance HGV drivers taking part in the ‘Structured Health Intervention For Truckers (SHIFT)’ study; a cluster-randomised controlled trial. The full protocol is available elsewhere.\textsuperscript{28} Briefly, data collection took place within an international logistics company. Participants were recruited from 25 sites located across the midland’s region of the UK (n=1502 employed HGV drivers in total across participating sites), operating within the transport, retail, hospitality, healthcare, pharmaceutical, construction, oil and gas and automotive industries. All drivers were eligible to take part unless diagnosed with cardiovascular diseases, haemophilia, blood-borne viruses or had mobility limitations that prevented them from increasing daily physical activity (physical activity was the primary outcome of the SHIFT trial). Ethical approval was obtained from the Loughborough University Ethics Approvals Sub-Committee (Reference: R17-P063) and all participants provided written informed consent.

**Measurements**

Data collection occurred between January 2018 and July 2019 at respective worksites during a 2-hour assessment (undertaken by trained researchers), at the beginning or end of participants working shift. Participants self-reported demographic, occupational and lifestyle information including sex, date of birth, ethnicity, education, shift pattern, years worked as an HGV driver, weekly working hours, smoking status, alcohol intake and chronotype (Morningness-Eveningness Questionnaire (MEQ short-version)).\textsuperscript{20} Height was measured without shoes using a portable stadiometer (Seca 206, Oxford, UK). Weight was determined via Tanita DC-360S scales (Tanita Corporation, Tokyo, Japan). Body mass index (BMI) was calculated as weight (kg)/height\textsuperscript{2} (m\textsuperscript{2}). Daily steps were determined via an activPAL3 micro accelerometer (PAL Technologies, Glasgow UK) worn continuously for 8 days (following the health assessment) on the midline anterior aspect of the upper thigh (waterproofed using a nitrite sleeve and Hypafix (BSN Medical) dressing). Median number of daily steps was the outcome of interest from the activPAL data.

**Sleep**

Participants wore a tri-axial accelerometer (GENEActiv, Activ-Insights, Kimbolton, UK) on the non-dominant wrist continuously for 8 days (during work and non-work periods), following the health assessment, to estimate sleep duration and efficiency. The device collected data at 100 Hz with a ±8 g dynamic range. Participants were provided with a daily log to record time into bed, sleep onset time (explained to the participant as ‘lights out’), wake-up time, out of bed time, working periods and any non-wear periods.

**Data processing**

GENEActiv devices were initialised and downloaded using manufacturer proprietary software (GENEActiv V3.1). Accelerometer files were processed in the R package GGIR V1.8–0\textsuperscript{20} to generate sleep outcome variables. Sleep windows were guided by the self-reported sleep onset time and out of bed time provided by the daily log. Where sleep log data were missing, automated sleep window detection was used.\textsuperscript{31} Sleep duration within this window was calculated using a validated sleep detection algorithm.\textsuperscript{27} Briefly, arm angle relative to the horizontal plane is detected to determine sleep periods; a low frequency of changes in arm angle can be identified as sleep if occurring within a specified sleep window period. The sleep window is determined by the daily log (sleep onset and out-of-bed times) or the algorithm if daily log data were not available (the longest block/series of sustained inactivity, with no more than a 60 min gap between blocks, within a 24-hour period (noon–noon)). This algorithm has demonstrated high sensitivity and specificity in detecting sleep periods.\textsuperscript{27} A wear time of ≥16 hours over a 24-hour period was required to determine a valid night of sleep data.\textsuperscript{27} Individual nights of data with a sleep window >13 hour or <2 hour or sleep duration >12 hour or <1 hour were identified as erroneous and removed. Participants were included in the analysis if providing ≥3 nights of valid data. Online supplemental file 1 includes two additional more stringent quality control criteria and sensitivity analyses within these robust subsamples of data. Variables of interest from GGIR analysis included sleep window onset (‘lights out’), sleep window end (‘out of bed’ time), sleep window duration (duration between ‘lights out’ and ‘out of
bed’ time), sleep duration (periods of sleep accumulated during the sleep window) and sleep efficiency (sleep duration/window duration×100). Short sleep duration was identified as <6 hour/24 hours and <7 hour/24 hours, and inadequate sleep efficiency as <85%. activPALS were initialised and downloaded using manufacturer proprietary software (activPAL Professional V7.2.38). Event files were generated and processed using the freely available Processing PAL software (https://github.com/UOL-COLS/ProcessingPAL, V1.3, University of Leicester, (Leicester UK)), which uses a validated algorithm to determine waking wear time. Participants providing ≥10 hours of valid waking wear time daily, on ≥3 days, were included in the analysis. The first day of data was removed from the analysis.

Statistical analysis
Descriptive data were reported as mean and SDs (or median and IQR) or numbers and percentages as appropriate. Continuous data were reported for age, years as an HGV driver, average weekly working hours and daily steps. Alcohol intake score, a discrete variable, was calculated by combining scores from two 5-point items; how often do you have a drink containing alcohol? (answers ranging from ‘never’ to ‘four or more times a week’) and How many units of alcohol do you have on a typical day when you are drinking? (answers ranging from ‘1 or 2’ to ‘10 or more’). Each item was scored 0–4 for a combined score out of 8 (units per week could not be calculated from these two question items). Participants were grouped for shift pattern (morning, afternoon, night or rotating), smoking status (never, previous smoker, current smoker), BMI (normal (20.0–24.9 kg/m²), overweight (25–29.9 kg/m²), obese (≥30.0 kg/m²)) and chronotype (based on MEQ scores: eveningness (<12), intermediate12–17 and morningness (>17)). Due to inconsistent work times between worksites for each shift pattern, it was not possible to provide clear definitions of shift types. Differences in demographic, occupational and lifestyle factors between those who did or did not provide valid GENEActiv data were compared using independent t-tests, Mann-Whitney U tests or Pearson χ² tests.

Logistic regression assessed demographic, occupational and lifestyle predictors of three outcomes: <6 hour/24 hours and <7 hour/24 hours sleep duration and <85% sleep efficiency. Age, shift pattern, years as an HGV driver, average weekly working hours, chronotype, smoking status, alcohol intake, BMI category and valid nights of sleep data were independent variables entered into each of the three models via forced entry. Statistical analyses were conducted using SPSS V23 (SPSS, Chicago, Illinois). Statistical significance was set at p<0.05.

RESULTS
Three hundred and eighty-six HGV drivers were recruited into the trial (25.7% recruitment rate across participating work sites) and underwent baseline measures. Of these, 329 provided valid GENEActiv data (85.2%) and are included in this analysis. Comparisons between those providing valid GENEActiv data (n=329) and those who did not (n=57) revealed significantly more daily steps in those not providing valid data (+1237 steps, p<0.05) and differences (p<0.05) within smoking status and chronotype categories. There was a smaller proportion of current smokers (−16.7%, p<0.05) in the group without valid data, more intermediate chronotypes (+18.2%, p<0.05) and fewer morning chronotypes (−15.0%, p<0.05).

Table 1 provides details of the full sample (n=329). Most participants were men, White British ethnicity, married and educated to General Certificate of Secondary Education level.

Table 1 Sample characteristics

| Variable                              | n (%)/mean±SD* |
|---------------------------------------|----------------|
| Full sample, n (%)                    | 329 (100)      |
| Sex                                   |                |
| Male, n (%)                           | 324 (98.5)     |
| Age                                   |                |
| Overall, mean±SD (years)              | 47.8±4.9       |
| Ethnicity                             |                |
| White British, n (%)                  | 261 (79.3)     |
| Other White, n (%)                    | 45 (13.7)      |
| Other ethnicities, n (%)              | 23 (7.0)       |
| Marital status                        |                |
| Married, n (%)                        | 173 (52.6)     |
| Co-habiting, n (%)                    | 58 (17.6)      |
| Single, n (%)                         | 41 (12.5)      |
| Other, n (%)                          | 57 (17.3)      |
| Education                             |                |
| GCSE or equivalent, n (%)             | 214 (65.0)     |
| A-level or equivalent, n (%)          | 33 (10.0)      |
| University degree or higher, n (%)    | 82 (24.9)      |
| Shift pattern                         |                |
| Morning, n (%)                        | 211 (64.1)     |
| Afternoon, n (%)                      | 35 (10.6)      |
| Night, n (%)                          | 63 (19.1)      |
| Rotating, n (%)                       | 19 (5.8)       |
| Years worked as HGV driver            |                |
| Overall, median±IQR                   | 15.0±8.6–25.0  |
| Hours worked per week                 |                |
| Overall, median±IQR                   | 48.0±45.0–50.0 |
| Steps per day (activPAL) (n=298)†*    |                |
| Number of valid days, median±IQR      | 8.0±7.0–8.0    |
| Valid waking wear time, median±IQR, hours/day | 16.5±15.9–17.2 |
| Overall, median±IQR, steps/day        | 8544±6902–10 625 |
| Smoking status                        |                |
| Never smoked, n (%)                   | 133 (40.4)     |
| Previous smoker, n (%)                | 140 (42.6)     |
| Current smoker, n (%)                 | 56 (17.0)      |
| Alcohol intake score                  |                |
| Overall, mean±SD                      | 3.7±2.1        |
| BMI                                   |                |
| Overall, median±IQR, BMI (kg/m²)      | 29.8±27.0–33.2 |
| Normal weight (19.5–24.9 kg/m²), n (%) | 37 (11.2)      |
| Overweight (25–29.9 kg/m²), n (%)     | 134 (40.7)     |
| Obese (≥30 kg/m²), n (%)              | 158 (48.0)     |
| Chronotype                            |                |
| Evening, n (%)                        | 28 (8.5)       |
| Intermediate, n (%)                   | 111 (33.7)     |
| Morning, n (%)                        | 190 (57.8)     |

Data presented as number (percentage) or mean±SD unless otherwise stated.
†Number (percentage)/mean SD.
*Other Ethnicities group includes nine ethnic categories; Indian (n=6), Black Caribbean (n=4), Black African (n=3), White Irish (n=3), White and Black Caribbean (n=2), Other Asian (n=2), White and Black African (n=1), Other Black (n=1), Chinese (n=1).
‡N=33 participants did not provide valid activPAL data, n=296 included in the analysis. All other variables include a full sample of data (n=329).
BMI, body mass index; GCSE, General Certificate of Secondary Education; HGV, heavy goods vehicle.

Ninety per cent reported working some form of shift pattern (ie, deviation from conventional 8 am–6 pm working hours). Most were morning shift workers, obese and morning chronotypes.

Table 2 reports sleep data for the whole sample and by different occupational and lifestyle factors. The sample demonstrated a mean sleep duration of 5.8±1.0 hour, with most
drivers (58.0%) having a mean sleep duration <6 hour/24 hours and almost all (91.0%) demonstrating <7-hour sleep/24 hours. Almost three-quarters (72.0%) demonstrated inadequate sleep efficiency (<85%).

Table 3 shows logistic regression models that include demographic, occupational and lifestyle-related predictors of short sleep duration (<6 hour and <7 hour) and inadequate sleep efficiency (<85%). Drivers were less likely to sleep <6 hour/24 hours if morning or afternoon shift workers compared with night shift workers and if never smoked compared with current smokers. The likelihood of sleeping <7 hour/24 hours reduced with age. The likelihood of having inadequate (<85%) sleep efficiency reduced with age and in the overweight BMI category compared with obese. For clarity on continuous and discreet variables, using the <6-hour model (short sleep) as an example, the likelihood of having less than 6 hour sleep per 24 hours reduced by 2% with every year increase in age, reduced by 3% for every unit increase of alcohol score (this discreet variable has a total score of 8) and reduced by 17% for every valid night of sleep data (although the 95% CIs for each of these variables spanned 1.0). Total years as an HGV driver, average weekly working hours and daily steps, did not increase or decrease the likelihood of sleeping less than 6 hour per 24 hours.

DISCUSSION
This is the first study in the UK to profile the sleep behaviour of long-distance HGV drivers using an accelerometer assessment of sleep. We found that more than half of drivers in this study (58%) had a mean sleep duration of <6 hour, and almost all (91%) demonstrated <7-hour sleep/24 hours. Short sleep duration (<6 or <7 hour) is associated with increased risk of premature mortality, morbidity, reduced mental well-being and road traffic accidents. Previous studies in US HGV drivers have reported a mean self-reported sleep duration of <7 hours, an ~60 min longer sleep duration compared with the present study (6.9 hour and 6.7 hour vs 5.8 hour). These differences may be partly due to self-reported measures overestimating sleep duration, compared with accelerometer measures. For example, Baulk and Fletcher, using wrist-worn accelerometry in 37 Australian HGV drivers, observed an average of 6.3-hour sleep duration, compared with 7.7 hours when self-reported. Although not a HGV driver study, Zhu et al reported a mean self-reported sleep duration of <7 hours, an average ~80 min (17%) additional sleep for reduced morbidity risk and enhanced road safety. More studies using wrist-worn accelerometry are needed to confirm this, including longitudinal studies that account for temporal and seasonal sleep variation.

Almost three-quarters (72%) of drivers had a mean sleep efficiency of <85% in this study. Insufficient sleep quality (efficiency) is associated with reduced psychological well-being and an increased risk of road traffic accidents in HGV drivers. Our findings are consistent with previous international evidence suggesting that insufficient sleep quality is highly prevalent within this workforce. A small sample of Australian HGV drivers have exhibited a mean sleep efficiency of 78% from wrist-worn accelerometry data. Approximately one-fifth of Italian (17.3% n=526) and Belgian (17.3% n=476) HGV drivers have self-reported poor sleep quality previously. Zhu et al reported a mean sleep efficiency of 81% in middle-to-older-aged UK men (n=82 995) compared with a median 80% efficiency in the present study. This suggests that sleep efficiency is similar in UK HGV drivers compared with other similar-aged UK men.

The low sleep efficiency in combination with the short sleep duration is important when considering the sleep window (time spent in bed). A mean sleep window duration of 7.3 hour suggests that, although marginally, drivers on average provided themselves with sufficient time in bed to achieve ≥7 hour of sleep but most were unsuccessful. Some drivers may present with sleep disorders such as obstructive sleep apnoea or insomnia, but this was not captured in this study. Future studies should account for these factors, although sleep disorders are often undiagnosed within this occupational group. Sleep hygiene behaviours (ie, practices that optimise sleep) in UK cohorts, and the occupational barriers to healthy sleep habits,
also need to be explored using mixed-methods approaches to inform sleep interventions. Logistic regression analyses revealed different predictors of short sleep duration between the <6-hour and <7-hour models. This may be partly explained by only 9.1% of drivers sleeping for ≥7 hour/24 hours, whereas 41.6% of drivers achieved ≥6 hour/24 hours, suggesting that the <6-hour model is a better fit of the data. Within the <6-hour model, morning and afternoon shift workers were 55% and 76% less likely to have short sleep duration compared with night shift workers, respectively. Although approximately 90% of the samples were shift workers, who are more likely to have sleep disorders compared with those working conventional hours (ie, 8 am–6 pm), our analysis demonstrated that the greatest risk of short sleep was evident in night shift workers. Night shift workers are particularly vulnerable to circadian rhythm misalignment, resulting in reduced sleep duration and quality and increased risk of fatal occupational accidents. These workers may benefit the most from countermeasures known to enhance circadian adaption and benefit sleep outcomes such as maximising work time rest periods and napping opportunities or improving lifestyle behaviours (eg, increased physical activity). Also, within the <6-hour model, the likelihood of short sleep duration reduced by 55% in those who never smoked compared with current smokers. This is unsurprising given smoking is associated with a host of sleep disorders. Contrary to previous evidence, increasing age reduced the likelihood of short sleep duration and inadequate sleep efficiency within the <7-hour and <85% models, respectively. It could be that older drivers implemented better sleep hygiene practices through experience, and perhaps earned more favourable shift patterns over time (eg, morning shifts) compared with younger age groups. Online supplemental file 2, which reports sleep outcomes and shift types by age groups, broadly supports this argument. However, it should be noted that age was not a strong predictor in either the <7-hour or <85% models (OR 0.92 and 0.96, respectively). Nevertheless, if these trends are repeated in future studies, further qualitative research with older HGV drivers (eg, >50 years of age) may illustrate effective sleep hygiene behaviours that younger less experienced drivers could benefit from.

Drivers who were overweight were 53.0% less likely to have inadequate sleep efficiency compared with drivers who were obese. UK HGV drivers have higher than nationally representative rates of obesity, which was reflected in our sample as almost half of drivers were obese (48.0%). Sleep deprivation and obesity are bi-directional and given the host of environmental and occupational triggers for weight gain (eg, shift work, prolonged sedentary driving, unhealthy food options at service stations) the two may exacerbate one another over time within this workforce. Our analysis suggests that being overweight may include better sleep efficiency compared with being obese, which would be an important outcome from preventing weight gain in HGV drivers if reaching a normal BMI category through weight loss cannot be achieved.

Our findings suggest that UK HGV drivers are potentially sleep deprived, which carries important implications for UK road safety and public health. Further sleep research within UK cohorts is critical to effectively inform UK workplace policy for HGV drivers. However, as part of routine training and medical evaluation procedures, UK-based logistic companies should include more comprehensive assessments of sleep behaviour (eg, Epworth Sleepiness Scale) and incorporate sleep surveillance (eg, sleep logs, accelerometry). These approaches will provide a better understanding of sleep deprivation and potentially detect undiagnosed sleep disorders, common within this workforce. Furthermore, given the high prevalence of obesity within UK
HGV drivers, which is central to many chronic diseases and has a bi-directional relationship with sleep, weight management and sleep behaviour awareness training could be prudent workplace policies that warrant consideration.

A strength of this study is the use of a validated sleep detection process to profile sleep outcomes. This study has good generalisability to other UK HGV drivers due to the breadth of recruitment (25 worksites across the UK midlands region, operating within subcontracts across eight different industries). Another strength is the study sample, a priority, yet hard to reach, occupational group for health interventions, given the array of health risk factors observed. Limitations include the cross-sectional nature of the present analyses, all worksites being located within a single-parent logistic organisation and a potential recruitment bias for a health intervention study. However, the sample age (mean 47.8 years), sex distribution (98.5% males) and high rates of overweight and obesity compared with 45–54-year-old UK men (88.7% vs 79.0%) indicate that the present sample is representative of UK HGV drivers.

Diagnosed sleep disorders were not captured, which would have enhanced the interpretation of sleep outcomes. We also acknowledge the limitations of a movement-based detection process to capture sleep, which is a complex physiological process. Naps were not measured in this study, which anecdotally occurred within some shift workers and may have impacted sleep outcomes. Specifically, sleep duration per 24 hours will have likely been underestimated in some early morning and night shift workers. Furthermore, sleep behaviours, such as insomnia or sleep latency, may have been misclassified as sleep if little arm/body movement occurred.

In conclusion, most drivers had short sleep duration and insufficient sleep quality; therefore, it is plausible that these drivers are at increased risk of excessive daytime sleepiness, road traffic accidents and chronic disease. Given the implications for road safety and public health, future research is warranted. Studies should explore sleep behaviour between work periods and non-work periods to understand if and how drivers may compensate for sleep deprivation between shifts. A greater understanding of sleep behaviours in this occupational group should inform interventions designed to improve sleep and improve driver health and road safety over the longer-term.

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REFERENCES

1. The Freight Transport Association. Logistics report 2019. London, 2019. https://www.santandercb.co.uk/files/tr-logistics-report-2019.pdf
2. Apostolopoulos Y, Sünnes S, Shattell MM, et al. Health survey of U.S. long-haul truck drivers: work environment, physical health, and healthcare access. Work 2013;46:113–23.
3. Crizelle AM, Bigelow P, Adams D, et al. Health and wellness of long-haul truck and bus drivers: a systematic literature review and directions for future research. J Transp Health 2017;7:90–109.
4. Caddick N, Varela-Mato V, Nimmo MA, et al. Understanding the health of lorry drivers in context: a critical discourse analysis. Health 2017;21:38–56.
5. Sieber WK, Robinson CF, Birdsey J, et al. Obesity and other risk factors: the National survey of U.S. long-haul truck driver health and injury. Am J Ind Med 2014;57:615–26.
6. Varela-Mato V, O’Shea O, King JA, et al. Cross-Sectional surveillance study to phenotype lorry drivers’ sedentary behaviours, physical activity and cardio-metabolic health. BMJ Open 2017;7:e013162.
7. Lemke MK, Apostolopoulos Y, Hege A, et al. Understanding the role of sleep quality and sleep duration in commercial driving safety. Accid Anal Prev 2016;97:79–86.
8. Jackson P, Hilditch C, Holmes A. Fatigue and road safety: a critical analysis of recent evidence. department for transport, road safety web publication 2011;21.
9. Ohayon M, Wickwire EM, Hirshkowitz M, et al. National sleep Foundation’s sleep quality recommendations: first report. Sleep Health 2017;3:6–19.
10. Stern HS, Blower D, Cohen ML, et al. Data and methods for studying commercial motor vehicle driver fatigue, highway safety and long-term driver health. Accid Anal Prev 2019;126:37–47.
11. Lernø S, Rikkönen K, Gomez V, et al. Optimism and self-esteem are related to sleep results from a large community-based sample. Int J Behav Med 2013;20:567–71.
12. Itani O, Jike M, Watanabe N, et al. Short sleep duration and health outcomes: a systematic review, meta-analysis, and meta-regression. Sleep Med 2017;32:246–56.
13. Chaput J-P, Mohiel J, Despres J-P, et al. Seven to eight hours of sleep a night is associated with a lower prevalence of the metabolic syndrome and reduced overall cardiometabolic risk in adults. PLoS One 2013;8:e72832.
14. Baulk SD, Fletcher A. At home and away: measuring the sleep of Australian truck drivers. Accid Anal Prev 2012;45 Suppl 36–40.
15. Olson R, Thompson SV, Witchell E, et al. Sleep, dietary, and exercise behavioral clusters among truck drivers with obesity: implications for interventions. J Occup Environ Med 2016;58:314.
16. Hege A, Perko M, Johnson A, et al. Surveying the impact of work hours and schedules on commercial motor vehicle driver sleep. Saf Health Work 2015;6:104–13.
17. Lemke MK, Hege A, Perko M, et al. Work patterns, sleeping hours and excess weight in commercial drivers. Occup Med 2015;65:725–31.
18. Guglielmi O, Magnavita N, Garbarino S. Sleep quality, obstructive sleep apnea, and psychological distress in truck drivers: a cross-sectional study. Soc Psychiatry Psychiatr Epidemiol 2018;53:521–6.
19. Brandman L, Vanpraet R, Van Rissegem M, et al. Prevalence and correlates of poor sleep quality and daytime sleepiness in Belgian truck drivers. Chronobiol Int 2011;28:126–34.
20. Cassidy S, Chau JY, Catt M, et al. Cross-Sectional study of diet, physical activity, television viewing and sleep duration in 233,110 adults from the UK Biobank; the behavioural phenotype of cardiovascular disease and type 2 diabetes. BMJ Open 2016;6:010038–11.
21. Zhu G, Catt M, Cassidy S, et al. Objective sleep assessment in >8,000 UK mid-life adults: Associations with sociodemographic characteristics, physical activity and caffeine. PLoS One 2019;14:e0226220–14.
22. Health and Social Care Information Centre. Health Survey for England 2019: Adult and child overweight and obesity [Internet]. 2019. Available: https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/
23. Paech GM, Jay SM, Lamond N, et al. The effects of different roster schedules on sleep in miners. Appl Ergon 2010;41:600–6.
24. Jaehne A, Loessl B, Bäkåk Z, et al. Effects of nicotine on sleep during consumption, withdrawal and replacement therapy. Sleep Med Rev 2009;13:363–77.
25 Simpson L, McAr dulie N, Eastwood PR, et al. Physical inactivity is associated with moderate-severe obstructive sleep apnea. *J Clin Sleep Med* 2015;11:1091–9.

26 Cooper CB, Neufeld EV, Dolezal BA, et al. Sleep deprivation and obesity in adults: a brief narrative review. *BMJ Open Sport Exerc Med* 2018;4:e000392–5.

27 van Hees VT, Sabia S, Anderson KN, et al. A novel, open access method to assess sleep duration using a wrist-worn accelerometer. *PloS One* 2015;10. doi:10.1371/journal.pone.0142533. [Epub ahead of print: 16 11 2015].

28 Clemes SA, Mato V V, Munir F. Cluster randomised controlled trial to investigate the effectiveness and cost-effectiveness of a structured health intervention for Truckers (the shift study): a study protocol. *BMJ Open* 2019;9:1–13.

29 Adan A, Almirall H. Morningness-Eveningness questionnaire: a reduced scale. *Pers Individ Differ* 1991;12:241–53.

30 Migueles JH, Rowlands AV, Huber F, et al. GGIR: a research Community–Driven open source R package for generating physical activity and sleep outcomes from Multi-Day RAW Accelerometer data. *J Meas Phys Behav* 2019;2:188–96. doi:10.1123/jmpb.2018-0063

31 van Hees VT, Sabia S, Jones SE, et al. Estimating sleep parameters using an accelerometer without sleep diary. *Sci Rep* 2018;8:1–11. doi:10.1038/s41598-018-31266-z

32 Winkler EAH, Bodicoat DH, Healy GN, et al. Identifying adults’ valid waking wear time by automated estimation in activPAL data collected with a 24 H wear protocol. *Physiol Meas* 2016;37:1653–68. doi:10.1088/0967-3334/37/10/1653

33 Metropolitan Transport Research Unit. Involvement in fatalities HGVs over 3. Stonnes compared to all traffic. 26.11.17. London, 2017. Available: https://bettertransport.org.uk/sites/default/files/pdfs/26.11.17 Fatal HGV collision rates ten year tables.pdf

34 American Academy of Sleep Medicine. International classification of sleep disorders. In: Darien IL, ed. 3rd, 2014.

35 Lemke MK, Apostolopoulos Y, Hege A, et al. Can subjective sleep problems detect latent sleep disorders among commercial drivers? *Accid Anal Prev* 2018;115:62–72.

36 Boixin DB, Boudreau P. Impacts of shift work on sleep and circadian rhythms. *Pathol Biol* 2014;62:292–301.

37 Åkerstedt T, Knutsson A, Westerholm P, et al. Work organisation and unintentional sleep: results from the wolf study. *Occup Environ Med* 2002;59:595–600.