JYX
JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

This is a self-archived version of an original article. This version may differ from the original in pagination and typographic details.

Author(s): Onninen, Jussi; Hakola, Tarja; Puttonen, Sampsa; Tolvanen, Asko; Virkkala, Jussi; Sallinen, Mikael

Title: Sleep and sleepiness in shift-working tram drivers

Year: 2020

Version: Accepted version (Final draft)

Copyright: © 2020 Elsevier

Rights: CC BY-NC-ND 4.0

Rights url: https://creativecommons.org/licenses/by-nc-nd/4.0/

Please cite the original version:

Onninen, J., Hakola, T., Puttonen, S., Tolvanen, A., Virkkala, J., & Sallinen, M. (2020). Sleep and sleepiness in shift-working tram drivers. Applied Ergonomics, 88, 103153. https://doi.org/10.1016/j.apergo.2020.103153

Sleep and sleepiness in shift-working tram drivers
Running head: Sleep and sleepiness in shift-working tram drivers

Authors

Jussi Onninen[12], Tarja Hakola[2], Sampsa Puttonen[2], Asko Tolvanen[1], Jussi Virkkala[23], & Mikael Sallinen[12]

Affiliations

1: Department of Psychology, University of Jyväskylä, Jyväskylä, Finland.
2: Finnish Institute of Occupational Health, Helsinki, Finland.
3: Department of Clinical Neurophysiology, University of Helsinki and Helsinki University Hospital, Helsinki, Finland.

Correspondence

Jussi Onninen, Department of Psychology, University of Jyväskylä, Jyväskylä, Finland.
Email: jussi.onninen@jyu.fi

Author contributions

Concept and design (MS, TH, SP), data collection (TH, JV, MS), analyses and interpretation of data (JO, AT, MS, SP, TH), field study set-up (JV, TH, MS), processing and design of manuscript (JO, TH, SP, AT, JV, MS), supervision (MS).

Abstract. Driver sleepiness contributes to traffic accidents. However, sleepiness in urban public transport remains an understudied subject. To fill this gap, we examined the sleepiness, sleep, and on-duty sleepiness countermeasures (SCMs) in 23 tram drivers working morning, day, and evening shifts for three weeks. Sleepiness was measured using Karolinska Sleepiness Scale (KSS). Nocturnal total sleep time (TST) was measured with wrist actigraphy. SCMs and naps were self-reported with a smartphone application. Caffeine and napping were considered effective SCMs. Severe sleepiness (KSS ≥ 7) was observed in 22% of shifts with no differences between shift types. Rest breaks were associated with slight reductions in sleepiness. TST between days off averaged 7 h but was 1 h 33 min and 38 min shorter prior to morning and day shifts, respectively. The use of effective SCMs showed little variance between shift types. These results highlight the need for fatigue management in non-night-working tram drivers.

Keywords: sleep loss, urban transportation, driver fatigue

Highlights

1. Tram drivers experience severe sleepiness in over one-fifth of non-night shifts
2. Sleep prior to morning and day shifts is shorter than generally recommended
3. Effective sleepiness countermeasures such as napping and caffeine not widely used
4. Fatigue management might benefit driver alertness, lowering accident risk

1. Introduction

Sleepiness or difficulty staying awake represents a safety hazard in many industries. There is ample research on sleepiness in motor vehicle drivers (Connor et al., 2002) and professions of transportation where shift work is prevalent, such as long-haul truck drivers (Häkkänen & Summala, 2000; Mitler et al., 1997; Pylkkönen et al., 2015), airline pilots (Caldwell, 1997; Sallinen et al., 2017), or train drivers (Härmä et al., 2002; Sallinen et al., 2003). Sleepiness in shift-working drivers is mostly conceptualized as a consequence of circadian and homeostatic factors (Horne & Reyner, 1999), that is, inopportune times of day and insufficient prior sleep. Recommendations to optimize shift scheduling can be made at the regulatory, organizational, and individual level (Kecklund et al., 2017). However, the field of professional transportation is heterogenous in terms of operational characteristics. Therefore, improving driver alertness and safety in various working environments requires field-specific research.

In urban public transport, compromised fitness to drive increases the accident risk of not only the driver but passengers and pedestrians as well. The nature of the job can be considered hectic due to tight timetables, dense traffic, frequent stops, and overseeing ticket purchases. However, relatively little is known about the drivers' sleep and sleepiness in this field. One study of urban bus drivers found that 19% of the drivers had to fight to stay awake during driving bouts at least 2-3 times a week (Anund et al., 2016). Another study of urban bus drivers found that a majority of the drivers experienced severe sleepiness while driving at least 2-4 times a month (Anund et al., 2018). These are in line with findings that falling asleep while driving and near-miss situations due to sleepiness are not uncommon among bus drivers (Vennelle et al., 2010). Research is lacking on specifically tram drivers' sleep, despite trams being a popular means of urban transport globally.

Public transport operators have little autonomy in timing their rest breaks. Finnish tram drivers' maximum driving time without a break is four hours according to the general collective agreement for municipal personnel (KVTES). During breaks, sleepiness can be efficiently alleviated with caffeine products (Wesensten et al., 2015) and naps (Horne & Reyner, 1996). Other popular sleepiness countermeasures (SCMs) include listening to music or socializing (Anund et al., 2008). To ensure that the drivers' work is as alertness-supporting as possible, it is important to know what the role of rest breaks is in sleepiness mitigation and to what extent are various SCMs utilized during them. This knowledge is still missing.

To address the gap in research, our key aims were to answer the following questions. Firstly, do tram drivers' sleepiness levels and on-duty SCMs differ between shift types? Are these measures accumulating across work shifts? Secondly, is the nocturnal sleep prior to work shifts different in various shift types? To our knowledge, this is the first study to investigate on-duty sleepiness, sleep, and the use of SCMs in this profession.

2. Methods

2.1. Participants

Prior to the three-week field study, a questionnaire (see Section 2.2.1) was sent to 436 tram drivers, all employed by Helsinki City Transport. 158 drivers completed the questionnaire. These drivers were informed about the aim, stages, and schedule of the study, and about the possibility to withdraw from it at any time. 53 drivers with different shift schedules volunteered. 28 drivers working non-night shifts constituted the only group large enough to be reliably analyzed. Of these, 25 drivers were able to participate in the field study within the preset time frame. 23 full-time tram drivers (11 females, 12 males) completed the field study. This study was approved by the Ethics Committee of Finnish Institute of Occupational Health (FIOH).

All drivers worked a maximum of 120 hours per three weeks and had the following shift schedule: 3 early shifts, 2 days off, 3 late shifts, 2 days off, 4 early, 1 day off, 4 late, 2 days off (Figure 1). Due to overlap in the early (starting between 5:05—9:10 and ending between 10:20—17:20) and late shifts (8:30—19:15 to 17:19—2:25), working hours were categorized into new shift types as follows: morning, day, and evening (Figure 2). The day shifts consisted of early shifts starting unusually late and late shifts ending unusually early. By criteria, morning shifts started no later than 7:00, day shifts started at 7:00 or later and ended before 21:00, and evening shifts ended no earlier than 21:00. Shift durations were 8:43 ± 0:34, 9:00 ± 0:41, and 8:54 ± 0:35 h for morning, day, and evening shifts, respectively. There were no night shifts. All shifts included at least one rest break and 64% at least two. Three rest breaks were observed in 33% of morning, 47% of day, and 23% of evening shifts, but due to scarcity of data, only the first two breaks were analyzed.

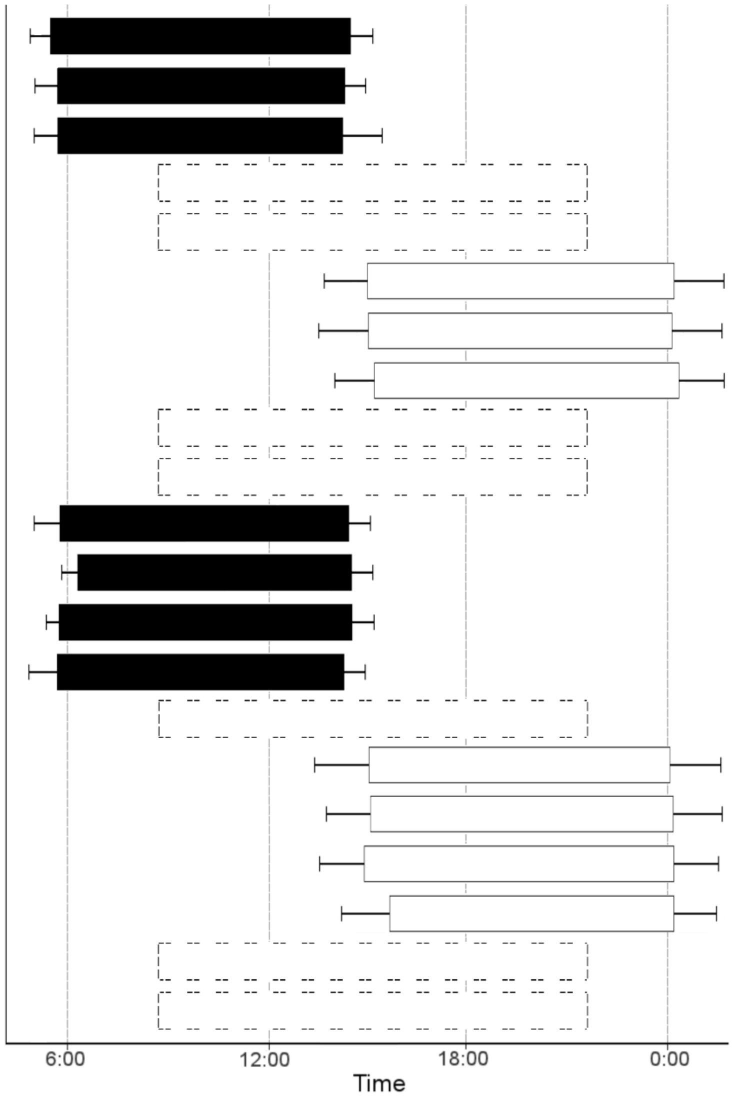

Figure 1. The shift rotation of the drivers. Black rectangles denote early shifts, white rectangles late shifts, and dashed rectangles days off. Error bars denote standard deviations in starting or ending times.

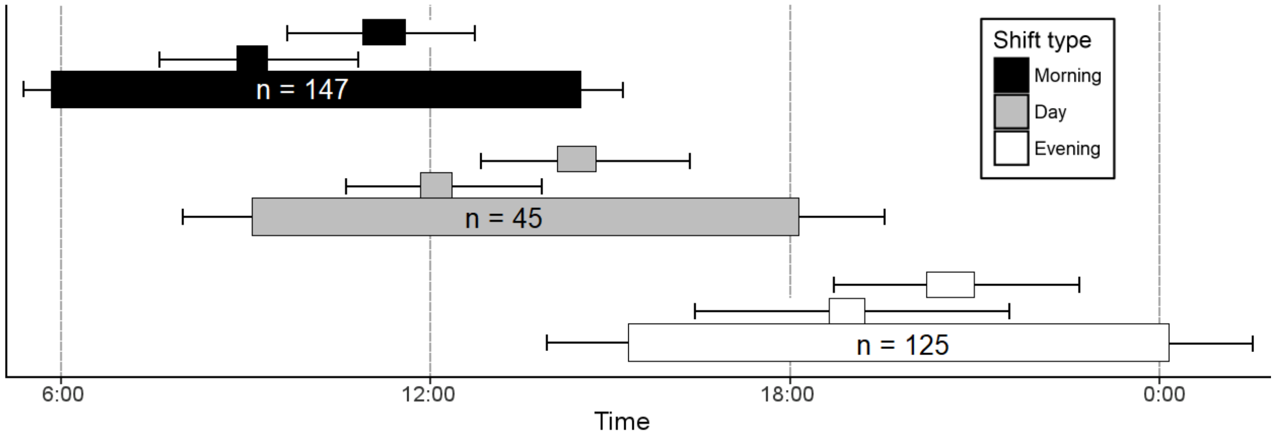

Figure 2. The timing of morning, day, and evening shifts and of their first and second statutory rest breaks. Top rectangles represent rest breaks during respective shifts. Error bars denote standard deviations in starting or ending times.

2.2. Procedures

2.2.1. Pre-measurement questionnaire

The questionnaire contained items about demographic factors, work experience, habitual sleep need and duration (Partinen & Gislason, 1995), and diurnal type (Torsvall & Åkerstedt, 1980). Habitual sleep and sleep need were queried with “During the last three months, how many hours per day, naps included, do you usually sleep?”, and “How much sleep do you need to feel alert and fit for work duties the following day?”, respectively.

2.2.2. Field measurements

The field measurements occurred between November 2016 and May 2017. Each driver was studied for three weeks during which their sleep, working hours, sleepiness at work, SCMs during and outside statutory rest breaks, and sleep aid and alcohol use were recorded or queried daily. The measurement period encompassed one complete shift rotation. The smartphones with a pre-installed application (described in Section 2.3) were provided by FIOH for the duration of the field measurements. Data were then retrieved from the participants' smartphones. The nursing staff of FIOH assisted with the field measurements.

2.3. Outcome measures

Driver sleepiness was measured using the Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990) via the smartphone application. Verbal anchors were assigned to each point (1: Extremely alert, 2: Very alert, 3: Alert, 4: Rather alert, 5: Not sleepy nor alert, 6: A little sleepy, 7: Sleepy, but no difficulties staying awake, 8: Sleepy, some effort required to stay awake, 9: Very sleepy, a lot of effort required to stay awake). Drivers rated their sleepiness in the beginning and at the end of the shifts and rest breaks. KSS ratings were treated as continuous and KSS ≥ 7 was defined as severe sleepiness, as such levels best correspond to physiological sleepiness (Åkerstedt & Gillberg, 1990) and impaired performance (Åkerstedt et al., 2014).

Sleep was measured using wrist-worn actigraphs (GENEActiv, Activinsights Ltd, UK). Bedtime, get up time, time in bed (TIB), total sleep time (TST), and sleep efficiency were derived. Naps were self-reported with the smartphone application. On-duty napping was possible in a dedicated break room and at final stops.

The drivers used the smartphone application to report the start and ending times of their work shifts. The start and ending times of the rest breaks were obtained from the application data using the times at which KSS ratings were given. Where the short time span between the KSS input times suggested that the driver forgot to rate his/her sleepiness appropriately, only the end time of the rest break was reported. Rest break KSS input times falling outside the span of the shift were also excluded.

The SCMs during statutory rest breaks were queried with the smartphone application with a closed-ended questionnaire item (“What did you do during statutory rest breaks?”). The answers included: napping, consuming caffeinated drinks (coffee/cola/energy drinks), having a light meal/snack, having a heavy (as opposed to light) meal/snack, smoking, walking outside, talking with others, doing vehicle maintenance, and something else. The SCMs outside statutory rest breaks were queried with the application (“If you felt sleepy, what did you do?”). The drivers were not asked to specify whether they were already feeling sleepy or trying to prevent sleepiness, that is, whether the SCMs were restorative or prophylactic in nature. Following Anund et al. (2008), SCMs were categorized as described in Table 1. In SCMs during and outside statutory rest breaks, the use of caffeine or napping was classified as an effective SCM.

Table 1. The categorization of the on-duty sleepiness countermeasures outside statutory rest breaks.

Sleepiness countermeasure	Category
Drinking coffee Drinking caffeinated drinks Consuming caffeine tablets	Caffeine
Stopping to have a break inside the vehicle (with no sleep) Stopping and walking outside Stopping and exercising outside	Supplementary rest break
Stopping and having a nap	Nap
Moving around in the vehicle Opening the window Adjusting the fan and/or temperature Listening to the radio Increasing radio volume Singing, talking, or whistling Driving faster Driving slower Driving more active	Self-activation
Continued driving	Nothing

2.4. Predictor variables

In the analyses of sleep and sleepiness outcome measures, the predictor variables were the shift type and shift position. Two different procedures for defining shift position were used to draw inference about adaptation to work shifts following days off and about the accumulation of sleepiness during shift periods. The predictor variables and reference terms are elaborated in Table 2. Shift periods (3-4 consecutive work shifts) including more than one deviant shift type and including both day and evening shifts were excluded from the analyses (n = 10). Shift periods longer than usual (n = 2) or those interrupted by sick leave (n = 2) were also excluded. Three shift periods of four days instead of three were exceptionally included.

2.5. Statistical analyses

The statistical analyses are outlined in Table 2. For severe sleepiness between shift types, day shifts were used as reference (Philip et al., 2002), since sleepiness is usually less common during them (Åkerstedt et al., 2014). For TST, the reference was the nocturnal sleep between two successive days off.

Table 2. Outline of the statistical analyses performed.

Outcome measure	Predictor variables	Reference terms
Total sleep time Sleep efficiency	Shift type (morning, day, evening) Shift position[1] (first/successive shift)	Second successive days off Successive shifts Evening shifts[2]
Severe sleepiness (Karolinska Sleepiness Scale ≥ 7) Sleepiness countermeasures	Shift type (morning, day, evening) Shift position[1] (first/last shift)	Day shifts Last shifts Evening shifts[2]
Sleepiness during rest breaks (KSS, continuous)	Shift type (morning, day, evening) Break (beginning, end) × Order of the break (first, second)[3]	Break beginnings Second breaks

Note: [1] Day shifts not included in the analyses. [2] Used as reference in interaction terms. [3] The interaction effect analyzed separately in each shift type.

Analyses were carried out using generalized estimating equations (GEE; Liang & Zeger, 1986). Binomial probability distribution was used for binary and Gaussian for continuous outcomes. Correlation structures were selected based on the quasi-likelihood under the independence model criterion (QIC; Pan, 2001). Alpha was set at 0.05 for all analyses. Missing rates were <5% in all analyses and were considered insignificant. In the GEE models, results are presented as regression coefficients (odds ratios for binary outcomes) with 95% confidence intervals with p values from F tests of term significance (Fay & Graubard, 2001). Analyses were carried out in R. To account for small sample size, estimates were corrected for bias with R packages *BCgee* (Lunardon & Scharfstein, 2017) and *saws* (Fay & Graubard, 2001).

3. Results

3.1. Drivers' characteristics

Table 3. Driver demographics and sleep characteristics.

	Mean ± SD or %
Age, yr	40.59 ± 11.39
Females	48
Body mass index, kg/m^2	26.49 ± 6.13
Work experience, yr	10.64 ± 9.22
Has children aged <7 yr	30
Diurnal type[1]	
Morning	35
Intermediate	17
Evening	50
Habitual sleep duration, h:min[2]	7:07 ± 0:56
Habitual sleep need, h:min[2]	7:35 ± 0:44

Note: [1] Torsvall & Åkerstedt (1980). [2] Partinen & Gislason (1995).

3.2. Sleepiness during different shift types

67% of the drivers reported severe sleepiness at least once. Severe sleepiness was observed in 22% of all shifts and in 24% of morning, 16% of day, and 19% of evening shifts. Compared to day shifts, the odds ratio (OR) of severe sleepiness was not significantly higher during the morning ($p = .064$) or evening shifts ($p = .241$) (Table 4). The OR of severe sleepiness during first shifts, compared to last, was not statistically significant ($p = .055$). The interaction effect between shift type (morning vs. evening) and position (first vs. last) was not significant ($p = .362$). The maximum KSS ratings reported during different shift types averaged 5.13 ± 1.68 (standard deviation) for morning, 5.17 ± 1.40 for day, and 5.00 ± 1.67 for evening shifts. KSS ratings for shift starts for morning, day, and evening shifts were 3.85 ± 1.68, 2.90 ± 1.10, and 2.84 ± 1.28 on average. The respective KSS ratings for shift ends were 4.11 ± 1.68, 4.31 ± 1.63, and 4.47 ± 1.93.

Table 4. GEE results using odds ratios (OR) for severe sleepiness (Karolinska Sleepiness Scale ≥ 7 at least once during the shift) in different shift types and positions (first vs. last shifts).

		95% CI		
Term	OR	Low	High	*p*
(Day)	1			
Morning	2.40	0.94	6.13	0.064
Evening	2.04	0.58	7.13	0.241
(Last)	1			
First	1.74	0.99	3.08	0.055
(Intercept)	1			
Morning	0.98	0.45	2.12	0.950
First	1.37	0.66	2.84	0.374
Morning*first	1.59	0.57	4.45	0.362

Note: Terms in parentheses represent model intercepts. Morning = morning shifts. Day = day shifts. Evening = evening shifts. First = first (vs. last) shift. 95% CI = 95% confidence intervals for odds ratios (OR).

3.3. Sleepiness during statutory rest breaks

Figure 3 shows the average sleepiness ratings at different times of shifts. Sleepiness was significantly lower at the end of rest breaks compared to the beginnings during morning ($p < .001$) and evening shifts ($p = .045$), but not day shifts ($p = .091$) (Table 5). The observed reductions were small (0.29—0.75 KSS units). There were no significant interaction effects in morning or day shifts (all $p > .05$). In evening shifts, there was a significant interaction effect of break (end vs. beginning) and its order (first vs. second) on driver sleepiness ($p = .004$). That is, the reduced sleepiness following a rest break was less pronounced during the first breaks of the evening shifts.

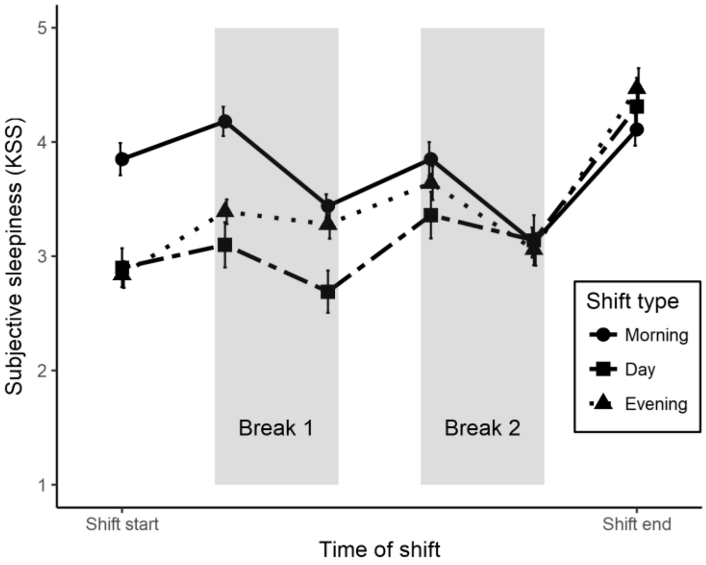

Figure 3. Subjective sleepiness (Karolinska Sleepiness Scale) during shift starts, rest breaks (grey blocks), and ends. Error bars denote standard errors. Graph proportions do not reflect actual durations of shifts or rest breaks.

Table 5. GEE results for subjective sleepiness (Karolinska Sleepiness Scale) during first and second rest breaks (starts and ends) in different shift types.

			95% CI		
Shift type	Term	*β*	Low	High	*p*
Morning	(Start)	4.14	3.71	4.58	0.000
	End	-0.75	-0.95	-0.55	0.000
	(Intercept)	4.03	3.58	4.49	0.000
	End	-0.77	-1.07	-0.46	0.000
	First break	0.17	-0.16	0.51	0.290
	End*first break	0.03	-0.30	0.36	0.854
Day	(Start)	3.22	2.76	3.67	0.000
	End	-0.34	-0.76	0.07	0.091
	(Intercept)	3.29	2.85	3.74	0.000
	End	-0.22	-0.90	0.45	0.455
	First break	-0.22	-0.67	0.23	0.292
	End*first break	-0.18	-0.92	0.56	0.577
Evening	(Start)	3.48	3.11	3.86	0.000
	End	-0.29	-0.57	-0.01	0.045
	(Intercept)	3.83	3.39	4.28	0.000
	End	-0.58	-0.93	-0.23	0.004
	First break	-0.50	-0.79	-0.21	0.003
	End*first break	0.46	0.18	0.75	0.004

Note: Terms in parentheses represent model intercepts. End = End (vs. start) of rest break. 95% CI = 95% confidence intervals for model coefficients (*β*).

3.4. Sleep on work days with different shift types and days off

Naps appeared approximately four to five times more common and longer in duration in association with morning shifts compared to day or evening shifts (Table 6). On days with morning shifts, the naps occurred only after the shifts. Sleep efficiency was roughly 83-85% prior to work shifts and did not significantly differ in any of the analyses (all $p > .05$).

Table 6. Sleep-related descriptive statistics for different shift types and successive days off.

	Shift type			Successive days off
	Morning	Day	Evening	
Bedtime (h:min)	21:55 ± 1:26	22:59 ± 1:35	01:14 ± 2:04	00:14 ± 2:17
Get up time (h:min)	4:30 ± 0:50	6:41 ± 1:18	9:16 ± 1:47	8:29 ± 1:55
Time in bed (TIB)	6:35 ± 1:50	7:42 ± 1:12	8:01 ± 1:29	8:15 ± 1:22
Total sleep time (TST)	5:33 ± 1:11	6:24 ± 1:11	6:47 ± 1:22	6:58 ± 1:19
TIB < 6 h, %	32.0	6.7	5.6	7.0
Nap(s), %	25.2	4.4	6.4	10.5
Daily nap sleep, h:min	0:59 ± 0:35	0:12 ± 0:11	0:43 ± 0:21	0:55 ± 0:32
Daily sleep total, h:min	6:49 ± 1:22	7:43 ± 1:11	8:04 ± 1:26	8:20 ± 1:22
Daily total sleep vs. habitual sleep need, h:min	-0:59 ± 1:16	0:15 ± 1:37	0:21 ± 1:35	0:41 ± 1:49
Sleep loss[1], %	61	40	32	29.8
Sleep efficiency, %	84.30 ± 7.82	82.55 ± 6.2	84.59 ± 6.63	84.42 ± 6.34
Sleep latency, h:min	0:12 ± 0:18	0:08 ± 0:11	0:12 ± 0:15	0:09 ± 0:12
Self-reported sleep latency, h:min	0:23 ± 0:31	0:16 ± 0:09	0:12 ± 0:14	0:17 ± 0:17
Time since awakening at the end of shift, h:min	11:03 ± 0:56	12:45 ± 1:59	16:03 ± 1:54	-
Alcohol prior to main sleep, %	0.7	2.2	8.0	21.1
Sleep aids prior to main sleep, %[2]	12.9	4.4	0.8	0.0

Note: [1] Daily total sleep (TIB and naps combined) less than 80% of habitual sleep need. [2] Only melatonin reported.

TST prior to different shift types are shown in Figure 4. Compared to days off, TST was significantly shorter prior to morning shifts (β = -1:33 [95% confidence interval {CI} -2:06–-1:00] h, $p < .001$) and day shifts (β = -0:38 [95% CI -1:13–-0:04] h, $p = .030$) but not evening shifts ($p = .392$) (Table 7). The effect of shift position (first vs. successive) was not significant ($p = .138$). However, the interaction effect between shift type (morning vs. evening) and position (first vs. successive) on TST was significant (Figure 5). That is, TST was pronouncedly short prior to first morning shifts ($p < .001$).

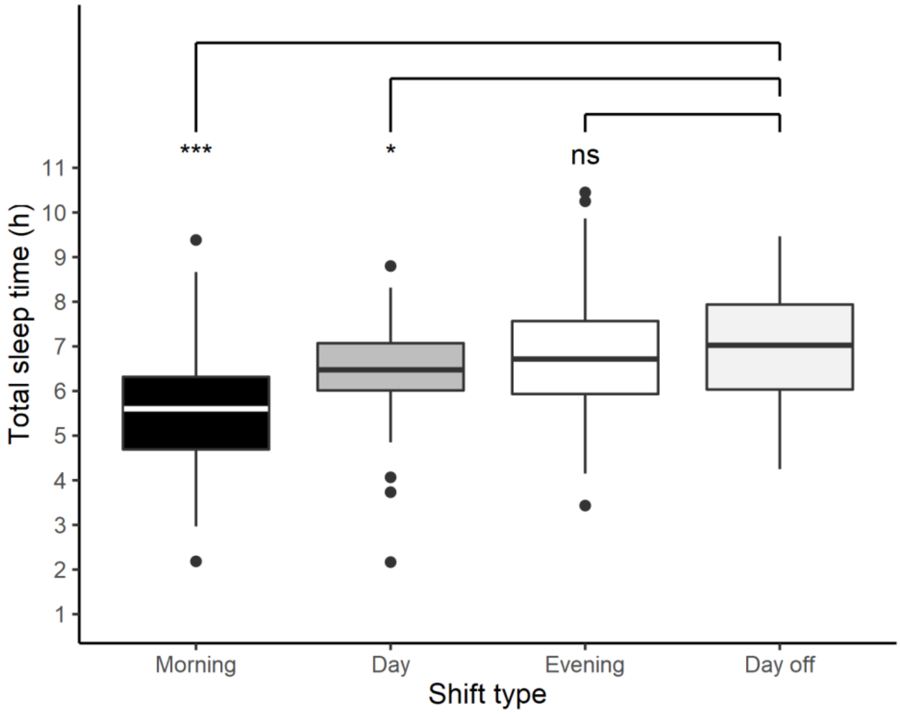

*Figure 4. Total sleep time in hours prior to morning, day, or evening shifts compared to second successive days off. * = p < .05, *** = p < .001, ns = p > .05.*

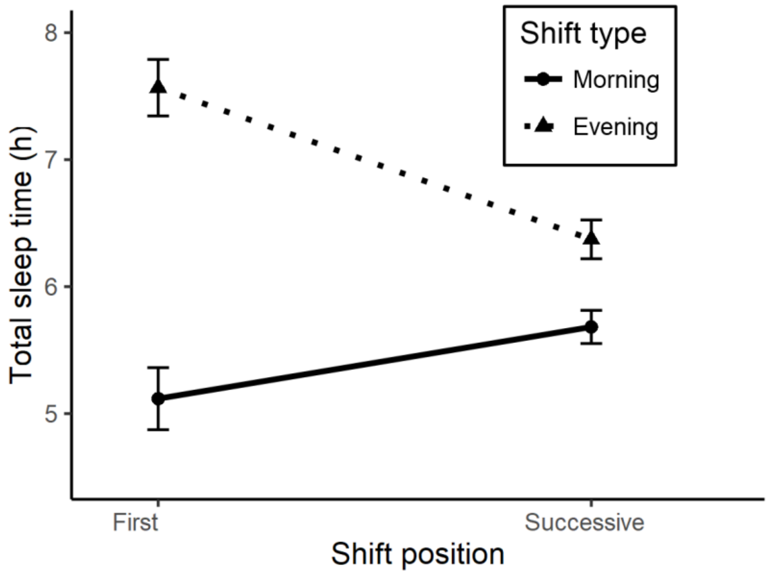

Figure 5. Total sleep time in hours prior to first and successive morning/evening shifts. Error bars denote standard errors.

Table 7. GEE results for total sleep time in hours.

Term	*β*	95% CI Low	95% CI High	*p*
(Days off)	7.02	6.56	7.47	0.000
Morning	-1.56	-2.10	-1.01	0.000
Day	-0.65	-1.22	-0.07	0.030
Evening	-0.19	-0.65	0.27	0.392
(Successive)	5.97	5.64	6.29	0.000
First	0.30	-0.11	0.70	0.138
(Intercept)	6.28	5.78	6.79	0.000
Morning	-0.57	-1.28	0.15	0.116
First	1.18	0.60	1.76	0.001
Morning*first	-1.75	-2.27	-1.23	0.000

Note: Terms in parentheses represent model intercepts. Morning = morning shifts. Day = day shifts. Evening = evening shifts. First = first (vs. successive) shifts. 95% CI = 95% confidence intervals for model coefficients (*β*).

3.5. Use of sleepiness countermeasures

3.5.1. Sleepiness countermeasures during statutory rest breaks

Having light meals and talking with others were the most common SCMs during statutory rest breaks (Figure 6). The drivers reported using less effective SCMs during evening shifts compared to day shifts (OR = 0.25 [95% CI 0.10-0.62], *p* = .005) but not during morning shifts *(p* = .186) (Table 8). No other significant effects were found (all *p* > 0.05)

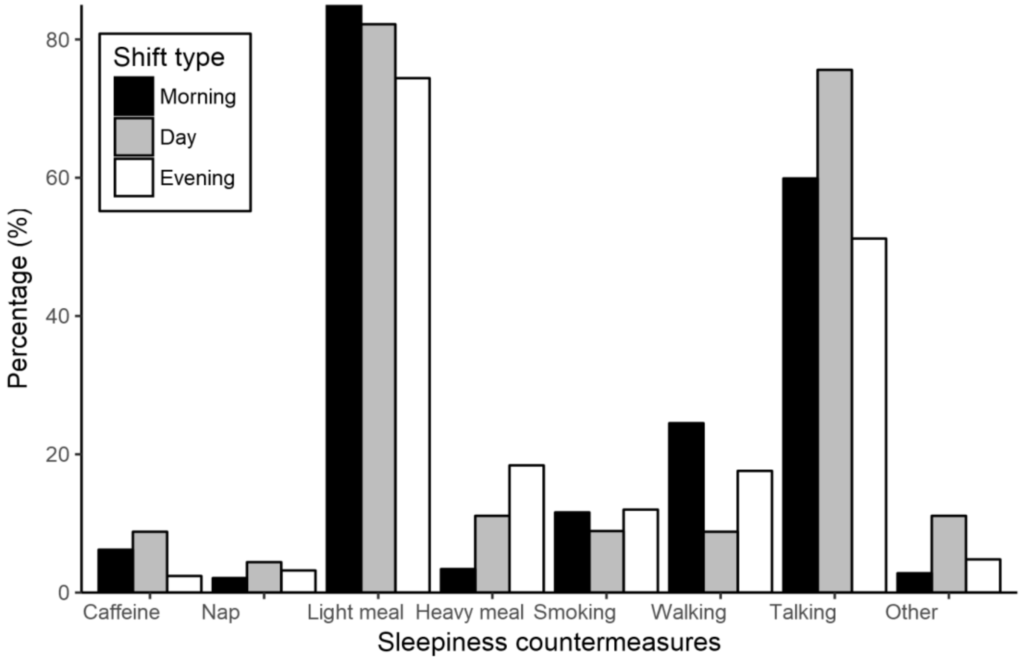

Figure 6. Proportions of shifts during which drivers reported using various sleepiness countermeasures at least once during statutory rest breaks.

Table 8. GEE results using odds ratios (OR) for the use of efficient sleepiness countermeasures (caffeine products/naps) during statutory rest breaks in different shift types and positions (first vs. last shifts).

Term	OR	95% CI		*p*
		Low	High	
(Day)	1			
Morning	0.67	0.37	1.25	0.186
Evening	0.25	0.10	0.62	0.005
(Last)	1			
First	1.34	0.86	2.10	0.188
(Intercept)	1			
Morning	1.91	0.36	10.28	0.429
First	1.50	0.69	3.28	0.290
Morning*first	0.85	0.34	2.12	0.708

Note: Terms in parentheses represent model intercepts. Morning = morning shifts. Day = day shifts. Evening = evening shifts. First = first (vs. last) shifts. 95% CI = 95% confidence intervals for odds ratios (OR).

3.5.2. Sleepiness countermeasures outside statutory rest breaks

Napping outside statutory rest breaks occurred in one morning shift only. Supplementary rest breaks were also relatively scarce. Caffeinated products and self-activation were the most frequent SCMs outside statutory rest breaks (Figure 7). None of the analyses showed statistically significant differences between shift types or interaction effects (Table 9).

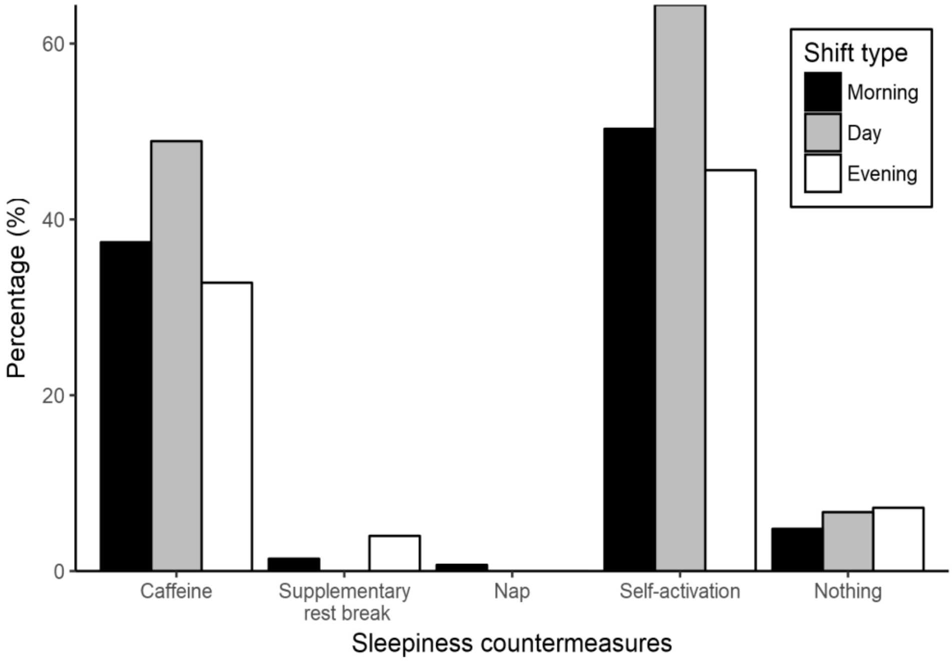

Figure 7. Proportions of shifts during which drivers reported using various sleepiness countermeasures at least once outside statutory rest breaks.

Table 9. GEE results using odds ratios (OR) for the use of efficient sleepiness countermeasures (caffeine products and/or naps) outside of statutory rest breaks in different shift types and positions (first vs. last shifts).

		95% CI		
Term	OR	Low	High	*p*
(Day)	1			
Morning	1.08	0.41	2.84	0.871
Evening	1.11	0.40	3.12	0.831
(Last)	1			
First	1.26	0.71	2.23	0.430
(Intercept)	1			
Morning	1.82	0.79	4.21	0.151
First	1.49	0.58	3.83	0.380
Morning*first	0.70	0.28	1.74	0.419

Note: Terms in parentheses represent model intercepts. Morning = morning shifts. Day = day shifts. Evening = evening shifts. 95% CI = 95% confidence intervals for odds ratios (OR).

4. Discussion

Here, we examined the sleep, on-duty sleepiness, and SCMs among tram drivers. Severe sleepiness was observed in 22% of all shifts. Statutory rest breaks were associated with reductions in sleepiness. TST before morning and day shifts was shorter than between days off. Effective SCMs showed minor differences between shift types.

Severe sleepiness was reported in over one-fifth of the shifts and in 67% of the drivers at least once. Shift types did not differ in the occurrence of severe sleepiness. The maximum sleepiness ratings were close to those reported from urban bus drivers (Anund et al., 2014). The average sleepiness levels during morning shifts closely followed those reported from a large pool of shift workers (Åkerstedt et al., 2014). The proportion of somnolent shifts was nearly double the proportion (11.7%) reported from truck drivers working non-night shifts (Pylkkönen et al., 2015), although it is worth noting that the truck drivers showed unusually low levels of sleepiness (Sallinen et al., in press).

Our findings suggest that accumulation of sleep loss during work periods was not severely affecting the drivers. Non-night shift workers have seldom been examined with regards to cumulative sleepiness across work shifts. Studies in day shift workers have shown that across 14-day deployments, sleepiness slightly increases especially after the work shift (Riethmeister et al., 2018; Riethmeister et al., 2019). In these studies, the work shifts lasted longer, almost three hours on average, than in our study. Furthermore, some studies on work related-accident risk across several work shifts have found an increase in accidents over successive work days (Folkard & Tucker, 2003). Arguably, the hectic nature of urban public transport may mask sleepiness that might surface in more monotonous situations.

Statutory rest breaks were mostly associated with reductions in sleepiness regardless of shift type. The reductions in sleepiness were most notable during morning shifts. Altogether, the reductions were small. These findings are consistent with studies suggesting that rest breaks are the most effective when occurring at the most soporific times of the day (Feyer & Williamson, 1995; Tucker, 2003). Rest breaks are likely important in keeping the drivers' alertness at acceptable levels.

Compared to days off, the drivers slept significantly less prior to morning and day shifts, roughly 1 h 33 min and 39 min less, respectively. TST prior to second successive days off averaged 7 h. The finding that shorter TST prior to work is pronounced in morning shifts is consistent with previous studies (Sallinen & Hublin, 2015). Off-duty napping appeared to be the most common on days with morning shifts. These naps occurred after the work shifts. This finding is consistent with previous studies (Sallinen et al., 2003; Åkerstedt et al., 1991).

TST prior to first morning shifts averaged just over 5 h. This could be related to the working time arrangement. Here, first morning shifts were preceded by seven late-starting shifts and/or days off characterized by longer and later sleep periods. Due to circadian adaptation, it might then be difficult to initiate sleep early enough (Burgess & Eastman, 2006). Furthermore, increased homeostatic sleep drive following short TST the night before would enable earlier bedtimes the night after. Few studies have examined sleep prior to non-night shifts with regards to shift position. Riethmeister et al. (2019) found that the amount of sleep day workers obtained remained quite stable across a two-week period. This discrepancy is likely related to the distinctively shorter bouts of days off in the drivers studied here (a maximum of 2 vs 14 successive days off).

Intrinsic to the investigation of rest breaks are the driver activities during them. Here, the use of effective SCMs (napping/caffeine) during statutory rest breaks was altogether uncommon. Conversely, caffeine has been reported as the most used SCMs in truck drivers (Pylkkönen et al., 2015). Effective SCMs were less frequently used during evening shifts than day shifts. The drivers presumably tend to avoid substances or activities that might hamper sleep afterwards. During statutory rest breaks, having light meals and socializing were the most common activities. Conversations during breaks may represent an aspect of social support that reduces sleepiness

(Eriksen et al., 2005) and the risk of sleep disturbance (Åkerstedt et al., 2002). Walking outside was also relatively common during morning shifts. It is unclear whether light exercise such as walking would reduce sleepiness alone (Eriksen et al., 2005; Reyner & Horne, 1997; Åkerstedt et al., 2008).

Outside of statutory rest breaks, no differences between shift types were seen in the use of effective SCMs. The most common SCMs were caffeinated products and self-activation. Napping and supplementary breaks were rarely used. This was expected since they are hardly feasible in tightly scheduled public transport operations. The wording in the smartphone application regarding the use of SCMs outside of statutory rest breaks was such that these activities would have been related to the driver feeling tired. Still, their usage was not more frequent during morning shifts despite the short prior TST. Overall, it is worth noting that the availability of suitable rest areas and individual factors (Watling et al., 2015) also affect the use of SCMs. Future research might elaborate on the use of prophylactic and restorative SCMs.

We acknowledge several limitations in the present study. The drivers were queried about their sleepiness relatively infrequently. Therefore, the proportions of shifts with severe sleepiness may have been underestimated. Sleepiness data from all rest breaks could not be reliably analyzed. The exact timing of caffeine consumption at work was not available. As such, changes in sleepiness during rest breaks could not be reliably analyzed vis-à-vis the effective SCMs. Since there are individual differences in tolerance to shift work (Saksvik et al., 2011), self-selection bias may have affected these results. The small sample size may limit the statistical power to detect effects of interest.

In conclusion, the present study shows that tram drivers working non-night shifts experience severe sleepiness in over one-fifth of work shifts. Sleep prior to morning and day shifts is shorter than generally recommended. There was no evidence of cumulative sleepiness across work periods, suggesting that the drivers can adapt to these working time arrangements. Statutory rest breaks were associated with reduced driver sleepiness. Effective sleepiness countermeasures during duty hours showed little variance between shift types. Further studies with larger sample sizes are needed to confirm our findings.

Acknowledgements

We thank the nursing staff of FIOH, the staff of Helsinki City Transport, and the participants for their contributions to the study. We are grateful to Dr Nicola Lunardon for helpful comments on the statistical analyses. The study was funded by the Finnish Work Environment Fund (grant no.

116132), Nordic Programme on Health and Welfare (grant no. 74809), and the Finnish Institute of Occupational Health.

REFERENCES

Anund, A., Kecklund, G., Peters, B., & Åkerstedt, T. (2008). Driver sleepiness and individual differences in preferences for countermeasures. J. Sleep Res. 17, 16–22. https://doi.org/10.1111/j.1365-2869.2008.00633.x

Anund, A., Kecklund, G., Fors, C., Ihlström, J., Ingre, M., Radun, I., & Söderström, B. (2014). Bus drivers' working hours and the relationship to fatigue. Swedish National Road and Transport Research Institute (VTI). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-6928

Anund, A., Ihlström, J., Fors, C., Kecklund, G., & Filtness, A. (2016). Factors associated with self-reported driver sleepiness and incidents in city bus drivers. Ind. Health 54, 337–346. https://doi.org/10.2486/indhealth.2015-0217

Anund, A., Fors, C., Ihlström, J., & Kecklund, G. (2018). An on-road study of sleepiness in split shifts among city bus drivers. Accid. Anal. Prev. 114, 71–76. https://doi.org/10.1016/j.aap.2017.05.005

Burgess, H. J., & Eastman, C. I. (2006). A late wake time phase delays the human dim light melatonin rhythm. Neurosci. Lett. 395(3), 191–195. https://doi.org/10.1016/j.neulet.2005.10.082

Caldwell, J. A. (1997). Fatigue in the aviation environment: An overview of the causes and effects as well as recommended countermeasures. Aviat. Space Environ. Med. 68, 932–938.

Connor, J. L., Norton, R., Ameratunga, S., Robinson, E., Civil, I., Dunn, R., … Jackson, R. (2002). Driver sleepiness and risk of serious injury to car occupants: population based case control study. BMJ 324, 1125–1125. https://doi.org/10.1136/bmj.324.7346.1125

Eriksen, C. A., Åkerstedt, T., Kecklund, G., & Åkerstedt, A. (2005). Comment on Short-Term Variation in Subjective Sleepiness. Percept. Mot. Skills 101, 943–948. doi:10.2466/pms.101.3.943-948

Fay, M. P., & Graubard, B. I. (2001). Small-sample adjustments for Wald-type tests using sandwich estimators. Biometrics 57, 1198–1206. https://doi.org/10.1111/j.0006-341X.2001.01198.x

Feyer, A. M., & Williamson, A. M. (1995). Work and rest in the long-distance road transport industry in australia. Work Stress, 9, 198–205. https://doi.org/10.1080/02678379508256554

Folkard, S., & Tucker, P. (2003). Shift work, safety and productivity. Occup. Med. 532, 95–101. https://doi.org/10.1093/occmed/kqg047

Horne, J. A., & Reyner, L. A. (1996). Counteracting driver sleepiness: Effects of napping, caffeine, and placebo. Psychophysiol. 33, 306–309. https://doi.org/10.1111/j.1469-8986.1996.tb00428.x

Horne, J., & Reyner, L. (1999). Vehicle accidents related to sleep: A review. Occup. Environ. Med. 56, 289–294. https://doi.org/10.1136/oem.56.5.289

Häkkänen H., & Summala, H. (2000). Sleepiness at Work Among Commercial Truck Drivers. Sleep 23, 1–9. https://doi.org/10.1093/sleep/23.1.1b

Härmä, M., Sallinen, M., Ranta, R., Mutanen, P., & Müller, K. (2002). The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers. J. Sleep Res. 11, 141–151. https://doi.org/10.1046/j.1365-2869.2002.00294.x

Kecklund, G., Sallinen, M., & Axelsson, J. (2017). Optimizing Shift Scheduling. In M. H. Kryger, T. Roth, & W. C. Dement (Eds.), Principles and Practice of Sleep Medicine. (6th ed.), 742–749. Philadelphia, PA: Elsevier.

Liang, K.-Y., & Zeger, S. L. (1986). Longitudinal data analysis using generalized linear models. Biometrika 73, 13–22. https://doi.org/10.1093/biomet/73.1.13

Lunardon, N., & Scharfstein, D. (2017). Comment on ‘Small sample GEE estimation of regression parameters for longitudinal data.’ Stat. Med. 36, 3596–3600. https://doi.org/10.1002/sim.7366

Mitler, M. M., Miller, J. C., Lipsitz, J. J., Walsh, J. K., & Wylie, C. D. (1997). The sleep of long-haul truck drivers. N. Engl. J. Med. 337, 755–761. https://doi.org/10.1056/NEJM199709113371106

Pan, W. (2001). Akaike’s information criterion in generalized estimating equations. Biometrics 57, 120–125. https://doi.org/10.1111/j.0006-341X.2001.00120.x

Partinen, M., & Gislason, T. (1995). Basic Nordic Sleep Questionnaire (BNSQ): a quantitated measure of subjective sleep complaints. J. Sleep Res. 4, 150–155. https://doi.org/10.1111/j.1365-2869.1995.tb00205.x

Philip, P., Taillard, J., Léger, D., Diefenbach, K., Akerstedt, T., Bioulac, B., & Guilleminault, C. (2002). Work and rest sleep schedules of 227 European truck drivers. Sleep Med. 3, 507–511. https://doi.org/10.1016/S1389-9457(02)00138-7

Pylkkönen, M., Sihvola, M., Hyvärinen, H. K., Puttonen, S., Hublin, C., & Sallinen, M. (2015). Sleepiness, sleep, and use of sleepiness countermeasures in shift-working long-haul truck drivers. Accid. Anal. Prev. 80, 201–210. https://doi.org/10.1016/j.aap.2015.03.031

Riethmeister, V., Bültmann, U., Gordijn, M., Brouwer, S., & de Boer, M. (2018). Investigating daily fatigue scores during two-week offshore day shifts. Appl. Ergon. 71, 87–94. https://doi.org/10.1016/j.apergo.2018.04.008

Riethmeister, V., Matthews, R. W., Dawson, D., de Boer, M. R., Brouwer, S., & Bültmann, U. (2019). Time-of-day and days-on-shift predict increased fatigue over two-week offshore day-shifts. Appl. Ergon. 78, 157–163. 10.1016/j.apergo.2019.02.010

Reyner, L. A., & Horne, J. A. (1997). Suppression of sleepiness in drivers: Combination of caffeine with a short nap. Psychophysiol. 34, 721–725. https://doi.org/10.1111/j.1469-8986.1997.tb02148.x

Saksvik, I. B., Bjorvatn, B., Hetland, H., Sandal, G. M., & Pallesen, S. (2011, August). Individual differences in tolerance to shift work - A systematic review. Sleep Med. Rev. 15, 221–235. https://doi.org/10.1016/j.smrv.2010.07.002

Sallinen, M., Härmä, M., Mutanen, P., Ranta, R., Virkkala, J., & Müller, K. (2003). Sleep-wake rhythm in an irregular shift system. J. Sleep Res. 12, 103–112. https://doi.org/10.1046/j.1365-2869.2003.00346.x

Sallinen, M., & Hublin, C. (2015). Fatigue-Inducing Factors in Transportation Operators. Rev. Hum. Factors Ergon. 10, 138–173. https://doi.org/10.1177/1557234X15574828

Sallinen, M., Sihvola, M., Puttonen, S., Ketola, K., Tuori, A., Härmä, M., … Åkerstedt, T. (2017). Sleep, alertness and alertness management among commercial airline pilots on short-haul and long-haul flights. Accid. Anal. Prev. 98, 320–329. https://doi.org/10.1016/j.aap.2016.10.029

Sallinen, M., Pylkkönen, M., Puttonen, S., Sihvola, M., & Åkerstedt, T. (in press) Are long-haul truck drivers unusually alert? A comparison with long-haul airline pilots. Accid. Anal. Prev.

Torsvall, L., & Åkerstedt, T. (1980). A diurnal type scale. Construction consistency and validation in shift work. Scand. J. Work Environ. Health 6, 283–290. https://doi.org/10.5271/sjweh.2608

Tucker, P. (2003). The impact of rest breaks upon accident risk, fatigue and performance: A review. Work Stress 17, 123–137. https://doi.org/10.1080/0267837031000155949

Vennelle, M., Engleman, H. M., & Douglas, N. J. (2010). Sleepiness and sleep-related accidents in commercial bus drivers. Sleep Breath. 14, 39–42. https://doi.org/10.1007/s11325-009-0277-z

Watling, C. N., Armstrong, K. A., & Radun, I. (2015). Examining signs of driver sleepiness, usage of sleepiness countermeasures and the associations with sleepy driving behaviours and individual factors. Accid. Anal. Prev. 85, 22–29. https://doi.org/10.1016/j.aap.2015.08.022

Wesensten, N. J., Balkin, T. J., & Belenky, G. (2015). Countermeasures for Mitigating Fatigue in Motor Vehicle Operators. Rev. Hum. Factors Ergon. 10, 115–137. https://doi.org/10.1177/1557234X15574827

Åkerstedt, T., & Gillberg, M. (1990). Subjective and objective sleepiness in the active individual. Int. J. Neurosci. 52, 29–37. https://doi.org/10.3109/00207459008994241

Åkerstedt, T., Kecklund, G., & Knutsson, A. (1991). Spectral analysis of sleep electroencephalography in rotating three-shift work. Scand. J. Work Environ. Health 17, 330–336. https://doi.org/10.5271/sjweh.1694

Åkerstedt, T., Knutsson, A., Westerholm, P., Theorell, T., Alfredsson, L., & Kecklund, G. (2002). Sleep disturbances, work stress and work hours: A cross-sectional study. J. Psychosom. Res. 53, 741–748. https://doi.org/10.1016/S0022-3999(02)00333-1

Åkerstedt, T. (2003). Shift work and disturbed sleep/wakefulness. Occup. Med. 53, 89–94. https://doi.org/10.1093/occmed/kqg046

Åkerstedt, T., Kecklund, G., & Axelsson, J. (2008). Effects of context on sleepiness self-ratings during repeated partial sleep deprivation. Chronobiol. Int. 25, 271–278. https://doi.org/10.1080/07420520802110589

Åkerstedt, T., Anund, A., Axelsson, J., & Kecklund, G. (2014). Subjective sleepiness is a sensitive indicator of insufficient sleep and impaired waking function. J. Sleep Res. 23, 240–252. https://doi.org/10.1111/jsr.12158