Sleep Health xxx (xxxx) 1–13

Contents lists available at ScienceDirect

Sleep Health

Journal of the National Sleep Foundation

journal homepage: sleephealthjournal.org

Sleep misalignment and circadian rhythm impairment in long-haul bus drivers under a two-up operations system

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ARTICLE INFO

Article history:
Received 30 May 2019
Received in revised form 18 December 2019
Accepted 31 December 2019

Keywords:
Shift-work
Bus drivers
Fatigue
Circadian
Sleep
Alertness

ABSTRACT

Objectives: The objective of the study was to describe working and sleep conditions and to assess how sleep opportunities are associated with obtained sleep and alertness, in a sample of long-haul bus drivers working with a two-up operations system.
Methods: Measures of subjective sleep and sleepiness, actigraphy, circadian temperature rhythm, and psychomotor vigilance tasks were obtained from a sample of 122 drivers from Argentina. Variables were compared between high and low fatigue risk groups, which were formed using a median split of a fatigue risk score. The score was calculated based on drivers' total working hours, maximum shift duration, minimum short break duration, maximum night work per seven days, and long break frequencies.
Results: Considering a standardized one-day period, sleep in the bus accounted for 1.9±0.1 h of total sleep (57±1% efficiency), sleep at destination for 1.6±0.2 h of total sleep (90±1% efficiency), and sleep at home for 3.8±0.2 h of total sleep (89±1% nap efficiency and 90±1% anchor sleep efficiency). In drivers exposed to high-risk working schedules, the circadian temperature rhythm was weaker (lower % of variance explained by the model) (22.0±1.7% vs. 27.6±2.0%, $p < 0.05$) and without a significant acrophase.
Conclusions: Drivers obtained a total amount of weekly sleep similar to the recommended levels for adults, but distributed at different locations and at different times during the day. High-risk working schedules were associated with disruption of circadian temperature rhythms. These results point out to the need of the implementation of shift-work scheduling strategies to minimize sleep misalignment and circadian desynchronization in long-haul bus drivers.

Introduction

Fatigue, conceptualized as sleepiness resulting from factors such as time of the day, duration of wakefulness, and prior sleep duration and quality, is considered a major safety concern in transportation. Sleepiness decreases driving performance by affecting psychomotor performance, alertness, and decision making.[1,2] While daily work hours are regulated to some degree in most countries,[3,4] drivers are often pressured or even required to work beyond these hours, increasing adverse outcomes.[4]

Policy recommendations to prevent fatigue encompass the processes for measuring and mitigating fatigue risk. Fatigue risk management systems (FRMSs) are based on a progressive five-level model of hazard control.[5] Sleep opportunities (level 1) condition actual obtained sleep (level 2), which in turn determines signs and symptoms of fatigue (level 3). Fatigue eventually causes errors (level 4)

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https://doi.org/10.1016/j.sleh.2019.12.011
2352-7218/

that may lead to driving incidents (level 5). Prevention opportunities decrease when the hazard control level increases. Some issues of concern in FRMSs are the compliance of working-rest times with organizations' policies and to what extent self-reported sleep-wake and fatigue data are reliable. As a result, there is a need to identify departures from adequate sleep-wake patterns and to detect fatigue symptoms in populations at risk.[2,6]

Road accidents are a major public health issue in Argentina with an average mortality rate of 10.48 per 100,000 individuals (2014-2016),[7] 6.6% of which is attributable to passenger transport.[8] The long-haul passenger transport system in Argentina is based on a two-up driving system, where drivers alternate driving and rest positions during the trip. In the period 2010-2015, the average labor accident rate was 72.9 per 1,000 drivers, while the average mortality rate (including health conditions) was 3.3 per 10,000 drivers, considering a stable population of around 10,000 long-haul drivers.[9] Argentina's hours of service regulations (collective agreement 460/73 and executive order 692/92) set a maximum of eight hours of daily driving per person (on-duty periods should last up to 16 hours for team drivers). Maximum continuous driving hours are not regulated for passenger drivers, but a maximum of up to five hours is permitted for truck drivers, and a maximum of three hours is encouraged for bus drivers. While on duty, drivers divide at will driving and resting periods, usually on equal terms. Day/night driving is also divided based on team preferences. On-duty periods should be separated by a stationary rest period of at least 12 hours at home or 10 hours at destination. In practice, sometimes trips extend for more than 16 hours, drivers rest at destination for 12 hours, and then return to the departure point, determining out-of-home periods of more than 40 hours.[4,10] The two-up driving system is also found in other countries with extensive territories such as Australia, United States, or Canada, but with different hours of service rules.[3,4] Relief drivers provide an effective fatigue countermeasure. Although few studies have compared single and two-up operations, sleep and fatigue patterns of driving teams and commercial vehicle accident statistics point to a relatively safe practice.[11,12] However, the cumulative fatigue risk resulting from combining long driving times, sleeping in a moving vehicle, and multiple day operations are matters of concern.[11]

Relatively little research has been conducted on sleep and fatigue in long-haul bus drivers[13] when compared with that in long-haul truck drivers[14,15] or short-haul bus drivers.[16–18] Naturalistic studies that used objective methods to measure sleep were conducted mostly in truck drivers.[11,19] For example, in countries such as Canada (hours of service: on-duty maximum = 14 h, driving maximum = 13 h, off-duty minimum = 8 h) and the U.S. (hours of service: on-duty maximum = 14 h, driving maximum = 11 h, off-duty minimum = 10 h), it was found that truck single drivers sleep between 5 and 6.2 hours on workdays and between 6.5 and 7.5 hours on off-duty days, thus accumulating a substantial amount of sleep debt during the working week.[20] In a study that compared two-up drivers with single drivers in the U.S., it was reported that team drivers slept around 7 h while on the road (one hour more of sleep than single drivers). This seemed to compensate the higher number of sleep disturbances also found in this group, mostly attributed to environmental factors such as vibration and noise. Ultimately, team drivers were more successful in avoiding extreme drowsiness and also had a fewer number of driving incidents.[12]

Extensive research remains to be conducted using samples from different demographic backgrounds to know the actual conditions of sleep and fatigue of long distance public transport drivers. Thus, our first objective was to generally describe sleep patterns, circadian rhythm, and alertness (as a proxy of fatigue) in a sample of long-haul bus drivers working under a two-up operations system. In addition, it is not known how hours of service determine actual sleep and fatigue in this population. The FRMS framework allows constructing a fatigue risk score built on different characteristics of the working schedules. Based on this score, our second objective was to describe how two different risk profiles are actually associated with sleep, circadian rhythms, and alertness (as a proxy of fatigue).

Participants and methods

Subjects

Subjects were selected consecutively (nonrandomized), based on the availability of nocturnal trips comprising different preselected corridors. All the subjects were men; female drivers in long-haul passenger transport in Argentina are a rare exception. To optimize the representativeness of the sample, studies were conducted throughout the year, bus companies being selected in relation to their size in terms of the number of trips offered and corridors being defined to cover most of the national territory. A total of 12 bus companies participated in the study. Companies ranged in size from 60 to 1500 employed drivers and served from limited regions (7 of 23 provinces + federal district) to almost the whole country (22 of 23 provinces + federal district).

Inclusion criteria were to have a valid national professional driving license, to have concluded the training period, and to have passed their last psychophysical examination. In Argentina, licensing and medical examination regulations (law 24,449 and resolution 449/99) for passenger drivers include the following requirements: reading and writing ability; psychophysical aptitude (sensorial and motor capabilities and absence of chronic diseases that can jeopardize driving, for example: unstable diabetes or heart disease, epilepsy, psychosis); driving ability; knowledge of citizen education; and ethics, traffic signs, law, vehicle operation, and safety.

Design

Two-driver crews were studied during an outbound or inbound trip (one or another). All of the trips had Buenos Aires City as a departure or arrival point. Destination or starting cities were Tucumán (1,250 km), Neuquén (1,140 km), Mendoza (1,100 km), Posadas (1,000 km), Corrientes (920 km), Córdoba (700 km), Bahía Blanca (650 km), and Mar del Plata (400 km).

In this study, although with different timings, all crews had similar working schemes. They traveled mostly during the night to their destination (departure time $\geq$ 16.00 h), exchanged rest and driving positions during the trip (alternating night or day driving periods), had time to rest at destination, and went back to the departure city. After the trip drivers had typically one complete day off. All the buses had a sleeper berth with mattress, as part of their standard equipment. Sleep at destination took place in a hotel.

A researcher departing from Buenos Aires accompanied the crew on an assigned passenger seat up to the destination and joined a different crew while going back to Buenos Aires (both with departure times $\geq$ 16.00 h), except for the trip to Mar del Plata (400 km), where the researcher went back with the same crew because of design constraints. Drivers had been invited to participate some days before the assigned trip, and they completed part of the questionnaires. On the day of the trip, the researcher met the drivers at their bus company's hub and placed actigraphy watches and temperature sensors on their nondominant wrist. Drivers also performed an initial psychomotor vigilance task (PVT) to measure alertness. During the trip, the researcher conducted questionnaires and additional alertness tests at the beginning of the drivers' resting period and for not more than 20 min of that period. At the destination, drivers performed a final alertness test, and they were instructed to continue wearing the activity and temperature sensors to fulfill one week of total recording time.

Please cite this article as: J.J. Diez, S.A. Plano, C. Caldart, et al., Sleep misalignment and circadian rhythm impairment in long-haul bus drivers under a two-up operati..., Journal of the National Sleep Foundation, https://doi.org/10.1016/j.sleh.2019.12.011

For analytic purposes and to assess the impact of different working schemes, drivers were divided by the median of a fatigue risk score in two groups, as detailed in Measurements.

Measurements

Questionnaires

Demographic and clinical data included age, family composition, and educational level; body mass index (BMI, calculated from self-reported values of height and weight); self-reported (yes/no) smoking, alcohol consumption, and physical activity status; and self-reported (yes/no) diagnosis of hypertension, diabetes, anxiety, depression, and medication use. Height and weight were not measured directly because of design constraints; to obtain a suitable environment for these measures was not always possible. Overweight was defined as BMI $\geq$ 25, and obesity was defined as BMI $\geq$ 30. The Pittsburgh Sleep Quality Index (PSQI)[21] was used to measure sleep quality, a score > 4 being associated with bad sleep quality. Self-assessed sleep quality obtained from the PSQI as a single item was also reported (0: very good; 1: fairly good; 2: fairly bad; 3: very bad). The Epworth Sleepiness Scale (ESS)[22] was used to measure excessive daytime somnolence. An ESS score > 10 is associated with excessive sleepiness. The Multivariable Apnea Prediction (MAP) Index[23] was used as a relative risk measure for sleep apnea. An MAP Index value > 0.5 is considered as increased risk. The working scheme fatigue risk score was calculated based on the total working hours per seven days, maximum shift duration, minimum short break (a single sleep opportunity at home between work periods) duration, maximum night work per seven days, and long break frequencies (a period of two night sleeps at home with a nonworking day in-between), as detailed in Table 1. The median risk score of 24 was used to divide the sample into low- and high-risk groups.[24]

Sleep-wake cycle

Sleep was assessed by wrist accelerometers (MicroMini Motionloggers Actigraphs, Ambulatory Monitoring Inc). Drivers were asked to complete sleep logs and to wear the devices during seven days in the nondominant wrist. Sleep logs allowed determining the drivers' working situation to analyze sleep at different locations and helped to visually identify “in bed” episodes in actigraphy recordings.[25] For each location (bus, destination, home) reported measures of sleep-wake cycle included the number of occurrences of each location, the mean duration of the stay, the % of nocturnal time (defined between 19 and 07 h) spent at the location, the number of sleep episodes, the % of nocturnal sleep episodes (sleep episodes with 50% or more of the sleep interval comprised between 19 and 7 h), the % of long sleep episodes (sleep episodes $\geq$ 4 h), the mean obtained sleep along all the time spent at the location, and the ratio between obtained sleep and duration of the stay (half duration of the stay in the case of trips). In addition, we described sleep episodes by reporting sleep onset (starting time of the first sleep episode after bedtime), sleep duration (time elapsed between sleep onset and offset), and sleep efficiency (% of sleep in relation to total sleep time). Sleep onset and offset at home or at destination were automatically determined by the software after “in bed” episodes were identified in the recording.[25] Sleep or wake was classified for each one-minute epoch based on the activity score from that minute and weighing the activity score from surrounding minutes, by using the University of California San Diego algorithm[26]. For sleep at home, results are shown segregated by naps (sleep episodes < 4h) and anchor sleep (sleep episodes $\geq$ 4h). Sleep onset and offset in the bus were visually estimated in the actigraphy recordings – also with the help of sleep logs – because the movement of the bus was registered by the devices and interfered with the software sleep scoring algorithms.[27] Within each of these periods, sleep or wake was visually classified using the “best guess”[28] which could be derived from the difference between actual activity and the basal activity line produced by the bus movement.

Sleep durations at different locations were also standardized to a one-day period by dividing sleep values by the total recording time and to a seven-day period by multiplying these results by seven. One-day standardized sleep values are presented to allow an initial comparison between different sleep environments. However, as the home-trip-destination-trip-home cycle encompasses more than one day, these standardized values should be interpreted as hypothetical. Therefore, seven-day standardized values are also provided. As an indication of sleep misalignment over the whole recording period, we reported the standard deviation of sleep duration and sleep efficiency, and the averaged “Composite Phase Deviation” index. For each day, the composite phase deviation is calculated as the square root of the sum of two squared values: the distance of mid-sleep on a given day to an individual reference (in this study, we used the acrophase of the circadian temperature rhythm), and the distance of mid-sleep on the given day to the previous day.[29] Following the description of the “Composite Phase Deviation” index, naps were mostly excluded from the analyses. To maintain consistency with our definition of nap, we consider a sleep duration cutoff point of 4 h instead of the originally proposed cutoff point of 3 h. If a sleep bout was <4 h, it was included as main sleep if it was the only one within 24 h or if it was the only one within a specific location (bus, destination, or home). When more than one bout < 4h and no main sleep episodes were present within a specific location, mid-sleep was calculated as an average between the sleep onset of the first one and the sleep offset of the last one.[29]

Circadian rhythm of peripheral temperature

Temperature samples were obtained every 10 min during the study period, using a 16 mm X 6 mm temperature sensor (Thermochron iButton DS1291H, Dallas Maxim) placed next to the actigraph. Distal skin temperature is considered as a proxy for the circadian rhythm of core temperature; both measures are similar with an approximate 12-h phase difference between them (distal skin temperature reaches its maximum levels during the sleeping period). A cosine curve with a 24-h period was fit to the data (Chronos-Fit software), using the partial Fourier series method. The following measures were derived: midline-estimating statistic of rhythm (the

Table 1
Working scheme fatigue risk score

Score	0	1	2	4	8
Working time per 7 days (h)	< 36	36.1 – 43.9	44 – 47.9	48 – 54.9	>55
Maximum shift duration (h)	< 8	8.1 – 9.9	10 – 11.9	12 – 13.9	> 14
Minimum short break duration (h)	> 16	15.9 – 13	12.9 – 10	9.9 – 8	< 8
Maximum night work per 7 days (h)	0	0.1 – 8	8.1 – 16	16.1 – 24	> 24
Long break frequency (d/month)	> 1 in 7 days	< 1 in 7 days	< 1 in 14 days	< 1 in 21 days	< 1 in 28 days

The working scheme risk score is calculated as the sum of the individual scores of total working hours per seven days, maximum shift duration, minimum short break duration, maximum night work per seven days, and long break frequencies. The median risk score of 24 was used to divide the sample in high and low risk groups.

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rhythm-adjusted mean), amplitude (difference between the maximum and the midline-estimating statistic of rhythm), acrophase (time at which the maximum of the rhythm occurs), and % rhythm (percent of the variance explained by the model).[30,31]

Alertness

A netbook-based five-minute PVT adapted from the Walter Reed Army Institute of Research palm-held PVT was used to assess reaction time as a measure of alertness. Briefly, the subject was instructed to press the response key as soon as possible after the appearance of a visual stimulus, which is presented at a variable interval of 2 s to 10 s. Four different indexes were reported: the mean response times (MRTs) for all trials; the fastest 10% of response times (FRT) for all trials or optimum response domain; the slowest 10% of reciprocal response times (IRT) for all trials, or lapse domain; and the percentage of response times $\geq$ 500 ms (LRT) for all trials, or percentage of lapses.[32,33] Tasks were conducted by the researcher immediately before the trip, in the bus at the beginning of each rest period, and at the end of the trip. Therefore, at least three tests were requested by the researcher to the drivers. To get full advantage of the repeated measures general linear mixed model used for statistical analyses (see the following section), subjects were not list-wise excluded if this request was not fulfilled. Measures were grouped in five consecutive categories based on the time elapsed from the beginning of the trip: 0-2 h, 2-6 h, 6-10 h, 10-14 h, 14-18 h. Except for the trips to Mar del Plata, outbound and inbound crews were composed by different subjects. Measurements were pooled for analyses, and the trip leg was treated as a cofactor (see the following section). In the case of the trips to Mar del Plata, the researcher returned back with the same crew, so these trips were excluded from this analysis.

Statistical analyses

Numerical variables are shown as mean ± standard error. Self-assessed sleep quality obtained from the PSQI as a single item (ordinal variable) is shown as median (range). Categorical variables are reported as frequency (%). Differences of demographic data between risk groups were assessed using a t-test for independent samples in the case of numerical variables, using a Mann-Whitney test in the case of PSQI self-assessed sleep quality, or using a chi-square test in the case of categorical variables (or a Fisher exact test if expected counts were < 5).

With the exception of sleep onset, variables derived from the actigraphic analysis of the sleep-wake cycle were compared between risk groups by means of a t-test for independent samples, segregated by location (bus, destination, home nap sleep, and home anchor sleep). Alternatively, to calculate the mean sleep onset values at each location and to compare differences between risk groups, the use of circular statistics is required. When dividing by location, the few observed values determined that a reliable sleep onset circular mean could not be obtained for each subject. Thus, sleep onset values were pooled for analyses,[34] and the circular mean of pooled values was calculated through a Rayleigh z test.[35] Then, to compare differences between risk groups, circular uniformity was evaluated with a Rayleigh z test (as unimodal clustering), and statistical differences were calculated with a Watson-Williams test for analysis of variance that assumes underlying von-Mises distributions. These tests were conducted using the R package Circular[36] and plotted using the R package Plotrix.[37]

Variables derived from cosinor analysis of peripheral temperature rhythm were compared between risk groups by means of a t-test for independent samples, with the exception of acrophase, that require the use of circular statistics. Unlike sleep onset values, the acrophase is a single value obtained after fitting a cosinor curve to the whole subject's temperature data set, so no pooling was needed. Apart from this, the same circular statistics procedures described previously were applied for the calculation of mean acrophase values and for comparing values between risk groups.[35,38]

A repeated measures general linear mixed model was used to analyze PVT trials. Consecutive task measures were treated as repeated measures. The trip leg and risk groups were included as fixed factors. Interactions between repeated measures and leg and between repeated measures and risk were also analyzed. Significance was assumed when the p value was less than 0.05. All reported tests are two-tailed.

Ethical aspects

All subjects were given detailed information about the procedures and gave written informed consent to participate before the study. The study was approved by the ethics committee of Universidad Austral and was performed in accordance with the Declaration of Helsinki and its amendments.

Results

Demographics

A total of 138 drivers were included in the study. We excluded 16 (13%) drivers who gave incomplete information about their working schedules, regarding variables needed to define risk groups: total working hours per seven days, maximum shift duration, minimum short break duration, maximum night work per seven days, and long break frequencies. The final sample resulted in 122 individuals, who drove to or from the following destinations: Tucumán ($n = 18$, 14.8%), Neuquén ($n = 13$, 10.7%), Mendoza ($n=23$, 18.9%), Posadas ($n = 24$, 19.7%), Corrientes ($n = 18$, 14.8%), Córdoba ($n = 20$, 16.4%), Bahía Blanca ($n = 4$, 3.3%), and Mar del Plata ($n = 2$, 1.6%). In our study, 64% of the drivers were assessed in trips of more than 1,000 km length (Tucumán, Neuquén, Mendoza, Posadas), and 36% of them were assessed in shorter ones (Corrientes, Córdoba, Bahía Blanca, Mar del Plata). Most drivers (77%) were scheduled along the month with trips of similar duration. The length of the assessed trips and the variability of the scheduled trips were not significantly associated with the calculated fatigue risk score.

Table 2 shows the demographic characteristics of the sample and the different risk components. There were no significant demographic differences between groups. Self-assessed sleep quality obtained from the PSQI as a single item showed a median of 1 (fairly good sleep) with a minimum of 0 (very good sleep) and a maximum of 3 (very bad sleep) and no significant differences between risk groups (not shown in the table). The following demographic and self-reported medical conditions prevalence rates were also obtained (not shown in the table): married/ domestic partnership, 86.8%; with children, 96.6%; complete high school, 34.7%; physical activity, 46.7%; smoking status, 34.7%; alcohol consumption, 58.8%; overweight, 88%; obesity, 41%; hypertension, 9.1%; diabetes, 2.5%; anxiety 8.2%; depression, 2.5 %; and medication, 15.8% (mainly antihypertensive drugs). Only physical activity status differed between risk groups (low-risk group, 55.4%; high-risk group 36.4%; $p < 0.05$).

Mean PSQI, ESS, and MAP Index scores were within normal values, with a 17% prevalence of poor sleep quality, 15% prevalence of excessive sleepiness, and 28% prevalence of increased risk of obstructive sleep apnea. One subject (0.8%) reported the use of sleeping pills. There were no significant differences between risk groups. The variables that contributed significantly to higher risk scores were total working hours and minimum short break duration.

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Table 2
Demographics and work characteristics

Variables	Low fatigue risk (risk score ≤ 24)			High fatigue risk (risk score > 24)			Total		
	n	Mean	SEM	n	Mean	SEM	n	Mean	SEM
Age (y)	66	44	1	55	41	1	121	43	1
Body mass index (kg/m^2)	66	29.3	.6	55	29.6	.4	121	29.4	.4
PSQI	55	2.4	.3	40	2.8	.3	95	2.6	.2
ESS	64	6.4	.4	53	6.1	.6	117	6.3	.4
MAP Index	66	.40	.02	55	.38	.02	121	.39	.02
Working time per 7 days (h)***	67	53.0	1.2	55	67.8	1.8	122	59.7	1.2
Maximum shift duration (h)	67	15.3	.4	55	15.9	.2	122	15.6	.3
Minimum short break duration (h)***	67	15.3	1.1	55	8.1	.6	122	12.0	.7
Maximum night work per 7 days (h)	67	47.4	1.4	55	48.3	1.6	122	47.8	1.0
Long break frequency (d/month)	67	6.1	.2	55	5.8	.4	122	6.0	.2
Risk (score)***	67	20.5	.5	55	28.9	.4	122	24.3	.5

All the subjects were men (female drivers in long-haul passenger transport in Argentina are an exception).
PSQI, Pittsburgh Sleep Quality Index; ESS, Epworth Sleepiness Scale; MAP, Multivariable Apnea Prediction Index; short break, a single sleep opportunity at home between work periods; long break, a period of two night sleeps at home with a nonworking day in between.
*** $p < 0.001$, independent samples t-test.

Actigraphic analysis of the sleep-wake cycle

Table 3 shows the results of the actigraphic analysis of the sleep-wake cycle. The sample number was reduced to 74 subjects (61%) because of incomplete or inconsistent sleep diaries (we excluded from the analyses those subjects whose sleep diaries did not allow identifying the location of all sleep episodes as detected by actigraphy) or failures of the actigraphic devices (signal absence, bad quality signal, battery failure, failure to wear or loss of the devices). Mean recording length was 5.3 ± 0.1 days, due to early removal of the device by the driver or premature loss of the signal (not related with limitations in memory). A mean of almost four trips (considering outbound and inbound legs), two stays at destination and two stays at home were registered, with no differences between risk groups (Fig. 1).

The mean reported duration of a one-leg trip was around 15 h (69% nocturnal), and drivers made use of around 39% of their time while not driving for sleep. During the trip, drivers slept one episode of approximately three hours with low efficiency (estimated in around 57%). Sleep was mostly composed by nocturnal episodes (mean sleep onset = 01:52 ± 00:06 h) of less than four hours of duration. Drivers exposed to high-risk working schedules slept almost one more hour during trips, and they had almost three times more sleep episodes ≥ 4h than those exposed to low-risk schedules (Figs. 2 and 3, Table 3A).

The mean reported stay duration at destination was around 12 h (21% nocturnal), and drivers slept 52% of their rest time. Most drivers (56%) slept in one episode, another group (30%) slept for more than one episode, and a few of them (14%) sometimes did not sleep. Sleep occurred usually during the day, with a mean onset time at 13:33 ± 00:07 h. The percent of nocturnal time while at destination was higher in the low-risk group (low-risk group, 25 ± 4 %; high-risk group, 12 ± 3 %; $p < 0.01$). We also observed that the percent of nocturnal sleep episodes was higher in the low-risk group, but this tendency was not significant ($p < 0.1$). The average sleep period length was of almost four hours with an efficiency of around 90%, and the total sleep length at this stage resulted in five hours and a half, with no significant differences between risk groups (Figs. 2 and 3, Table 3B).

The mean reported stay at home was around 39 h (39% nocturnal), and drivers took 40% of their free time to sleep. A bimodal distribution of sleep duration was found (Fig. S1). Naps (sleep duration < 4 h) were mostly diurnal with an average length of around two hours and a half and an efficiency of around 90%, with a mean onset time at 14:37 ± 00:06 h. Anchor sleep (sleep duration ≥ 4h) was mostly nocturnal with an average length of around 8 h, an efficiency of approximately 90%, and with a mean onset time at 00:17 ± 00:03 h. No significant differences were found between risk groups (Figs. 2 and 3, Table 3C).

Table 4 shows standardized one- and seven-day sleep duration at different locations and global sleep misalignment. Overall, considering a standardized seven-day period, drivers slept 13.5 ± 0.8 h (1.9 ± 0.1 h/24 h) in a bus, 11.4 ± 1.1 h (1.6 ± 0.2 h 24/h) at destination and 26.4 ± 1.4 h (3.8 ± 0.2 h/24 h) at home. There were no significant differences in standardized sleep duration and misalignment indexes between groups. Sleep misalignment can be visualized in Figs. 2A-D, where pooled data of sleep onset are distributed broadly in the 24 hours of the day. This is especially evident when comparing with anchor sleep at home (Fig. 2D), where sleep onset values are distributed in a narrow band around midnight.

Circadian rhythm of peripheral temperature

Table 5 shows cosinor analysis for the circadian rhythm of peripheral temperature. A total of 19 (16%) temperature recordings were lost mainly because of no retrieval of the sensors or, in a few cases, signal loss (sensor misplacement, displacement or failure). In four cases (one with low risk and three with high risk), a significant circadian rhythm was not evidenced, so amplitude and acrophase could not be calculated. Therefore, sample size differed between variables. Drivers with high-risk working schedules showed lower temperature rhythm strength (as evidenced by a lower fraction of variance explained by the model). Although a significant acrophase (00:15 ± 00:03 h) was obtained when considering the sample as a whole, only low-risk drivers had a significant acrophase at 22:51 ± 00:10 h, while high-risk drivers had a nonsignificant mean resultant vector (Fig. 4, Table 5).

Alertness

Table 6 shows the timing of PVT measurements (shown are pooled values of outbound and inbound trips). A total of 90 (74%) subjects performed at least three tasks. Missing measurements were due to drivers' unforeseen working requirements. The number of the PVT measures was variable, depending on the driver's resting periods. Measurements were taken between 19.4 ± 0.1 and 10.4 ± 0.2 h of the next day, with an average trip duration of 15.8 ± 0.2 h and no significant differences between outbound and inbound trips or risk groups. The MRT value at the beginning of the study was 317 ± 5 ms. This measurement showed no significant changes

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Table 3
Sleep-wake cycle

A: In the bus

Variables	Low fatigue risk (risk score ≤ 24)			High fatigue risk (risk score > 24)			Total		
	n	Mean	SEM	n	Mean	SEM	n	Mean	SEM
Condition description									
Trips (n)	45	3.6	.2	29	3.7	.2	74	3.6	.1
Trip duration (h)	45	15	1	29	16	1	74	15	.5
Nocturnal time (%)	45	69	2	29	70	2	74	69	1
Sleep episodes by trip (n)	45	1.1	.05	29	1.0	.05	74	1.0	.04
Nocturnal sleep (% of sleep episodes)	45	87	3	29	85	5	74	86	3
Long sleep (% of sleep episodes)**	45	10	3	29	29	6	74	18	3
Total sleep duration by trip (h)**	45	2.5	.2	29	3.3	.2	74	2.8	.1
Sleep duration / half trip duration (%)	45	36	3	29	42	2	74	39	2
Sleep episodes description									
Onset mean (clock time)	45	02:19	00:14	29	01:36	00:20	74	02:03	00:12
Duration (h)***	45	2.4	.1	29	3.3	.2	74	2.8	.1
Efficiency (%)	45	58	1	29	56	1	74	57	1

B: At destination

Variables	Low fatigue risk (risk score ≤ 24)			High fatigue risk (risk score > 24)			Total		
	n	Mean	SEM	n	Mean	SEM	n	Mean	SEM
Condition description									
Stays at destination (n)	45	1.8	.1	29	1.5	.2	74	1.7	.1
Stay duration (h)	45	12	1	26	10	2	71	12	1
Nocturnal time (%)**	45	25	4	26	12	3	71	21	3
Sleep episodes by stay (n)	45	1.3	.1	26	1.3	.1	71	1.3	.1
Nocturnal sleep (% of sleep episodes)	45	20	5	26	10	4	71	17	3
Long sleep (% of sleep episodes)	45	44	6	26	34	8	71	40	5
Total sleep by stay (h)	45	5.5	.6	26	6.0	1.6	71	5.7	.7
Sleep duration / stay duration (%)	45	51	6	26	55	5	71	52	4
Sleep episode description									
Onset mean (clock time)	45	13:25	00:37	26	14:06	00:31	71	13:44	00:25
Duration (h)	45	4.0	0.2	26	3.6	0.3	71	3.8	0.2
Efficiency (%)	45	90	1	26	90	1	71	90	1

C: At home

Variables	Low fatigue risk (risk score ≤ 24)			High fatigue risk (risk score > 24)			Total		
	n	Mean	SEM	n	Mean	SEM	n	Mean	SEM
Condition description									
Stays at home (n)	45	1.5	.1	29	1.6	.1	74	1.5	.1
Stay duration (h)	43	36	2	29	43	5	72	39	2
Nocturnal time (%)	43	41	2	29	37	3	72	39	2
Sleep episodes by stay (n)	43	2.5	.2	29	3.0	.2	72	2.7	.1
Nocturnal sleep (% of sleep episodes)	43	51	4	29	46	5	72	49	3
Long sleep (% of sleep episodes)	43	60	4	29	53	5	72	57	3
Total sleep during stay (h)	43	13.5	0.9	29	16.8	1.9	72	14.8	1.0
Sleep duration / stay duration (%)	43	39	2	29	41	3	72	40	2
Naps (sleep episode <4h)									
Onset mean (clock time)	34	14:09	00:20	26	14:38	00:19	60	14:22	00:14
Nocturnal sleep (% of sleep episodes)	34	7	4	26	5	4	60	6	3
Duration (h)	34	2.5	0.1	26	2.2	0.1	60	2.4	0.1
Efficiency (%)	34	90	1	26	88	1	60	89	1
Anchor (sleep episode ≥4h)									
Onset mean (clock time)	41	00:00	00:19	26	00:43	00:21	67	00:19	00:14
Nocturnal sleep (% of sleep episodes)	41	84	5	26	87	5	67	85	4
Duration (h)	41	7.6	0.2	26	8.1	0.3	67	7.8	0.2
Efficiency (%)	41	91	1	26	89	1	67	90	1

Long sleep, % of sleep episodes ≥ 4 hrs; nocturnal sleep, sleep episodes with 50% or more of the sleep interval comprised between 19 and 07 hrs.
** $p < 0.01$.
*** $p < 0.001$. Differences between groups were assessed by independent samples t-tests, with exception of the differences between sleep onset phases, which were assessed through Watson-Williams tests.

during the outbound or inbound trip and also no significant differences between risk groups. In the outbound trip, we observed a decrease in alertness in the 2nd measurement (elapsed trip time [ETT]: 4.1 ± 0.2 h; clock time [CT]: 23.0 ± 0.2 h) and 3rd measurement (ETT: 8.1 ± 0.1 h; CT: 3.4 ± 0.2 h) as evidenced by an increase in FRT index ($p < 0.001$), and in the 4th measurement (ETT: 12.1 ± 0.2 h; CT: 7.1 ± 0.2 h) as evidenced by an increase in the LRT index ($p < 0.001$). In the inbound trip, a decrease in alertness was observed in the 1st measurement (ETT: 0.41 ± 0.04 h; CT: 19.4 ± 0.1 h) and 5th measurement (ETT: 15.7 ± 0.1 h; CT: 10.4 ± 0.2 h), as evidenced by a decrease in the IRT index ($p < 0.008$). Interestingly, the low-risk group showed lower alertness values in the outbound trip as evidenced by higher mean LRT index values ($p < 0.045$). Finally, alertness variations were more evident in the inbound trip of the high-risk group, as evidenced by significant variations of the IRT index (Fig. 5, $p < 0.001$).

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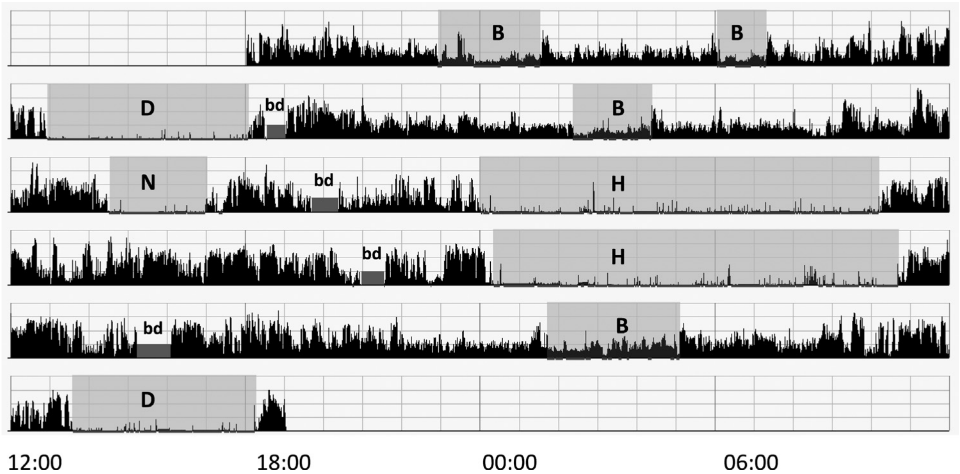

Figure 1. Representative actigraphic recording of a bus driver. Each row represents a 24-h period, and black lines represent activity. Sleeping periods occur at different times during the day and are distributed at different locations (B: sleep in bus, D: sleep at destination, N: nap at home, H: long sleep period at home). bd, bad data.

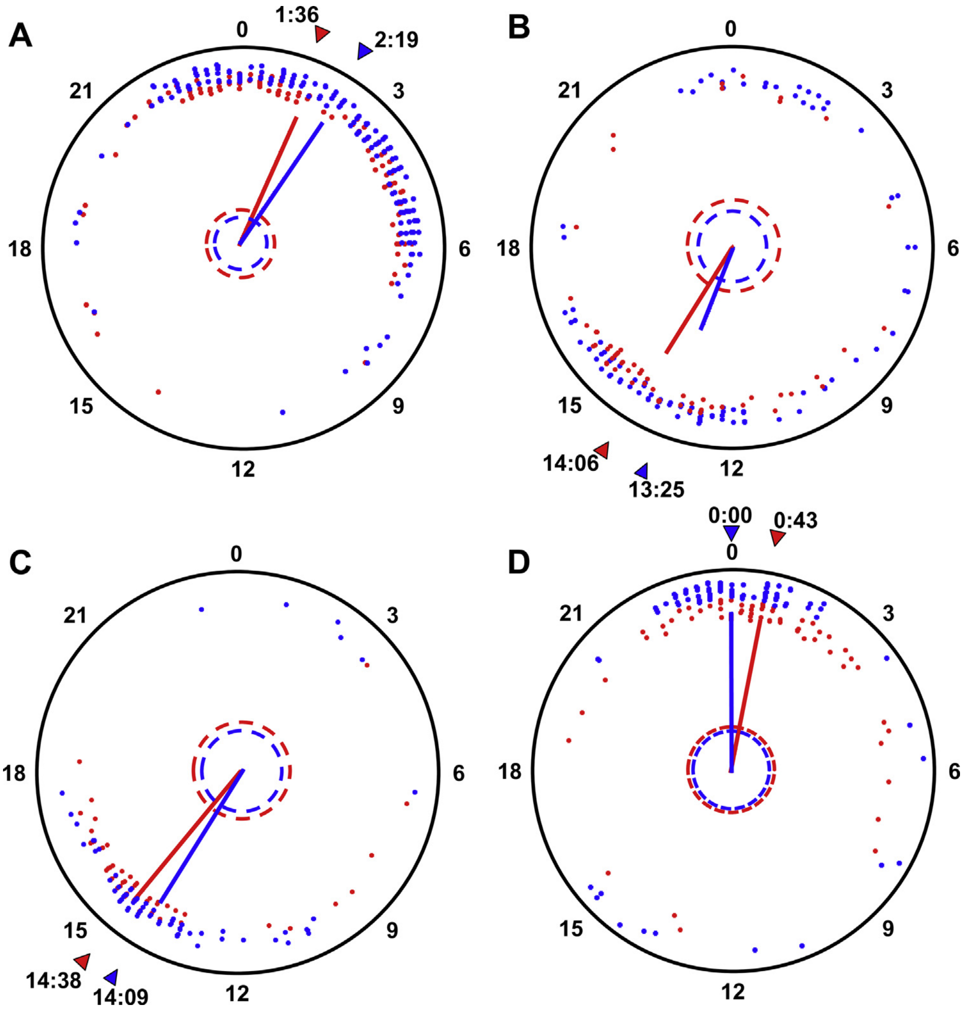

Figure 2. Temporal distribution of the drivers' pooled sleep onsets. Each dot denotes the timing of a sleep onset. Rayleigh z test determines if sleep onsets are significantly grouped around a mean vector. The position of the vector indicates the timing of the mean onset, and its length, the degree of clustering of sleep onsets. Nonsignificant vectors do not surpass the dotted inner circles. Triangles outside the circle denote the mean vector phase. Shown are pooled sleep onset phases at each location (A: in the bus, B: at destination, C: anchor sleep at home, D: nap sleep at home), divided by low (blue) and high (red) risk.

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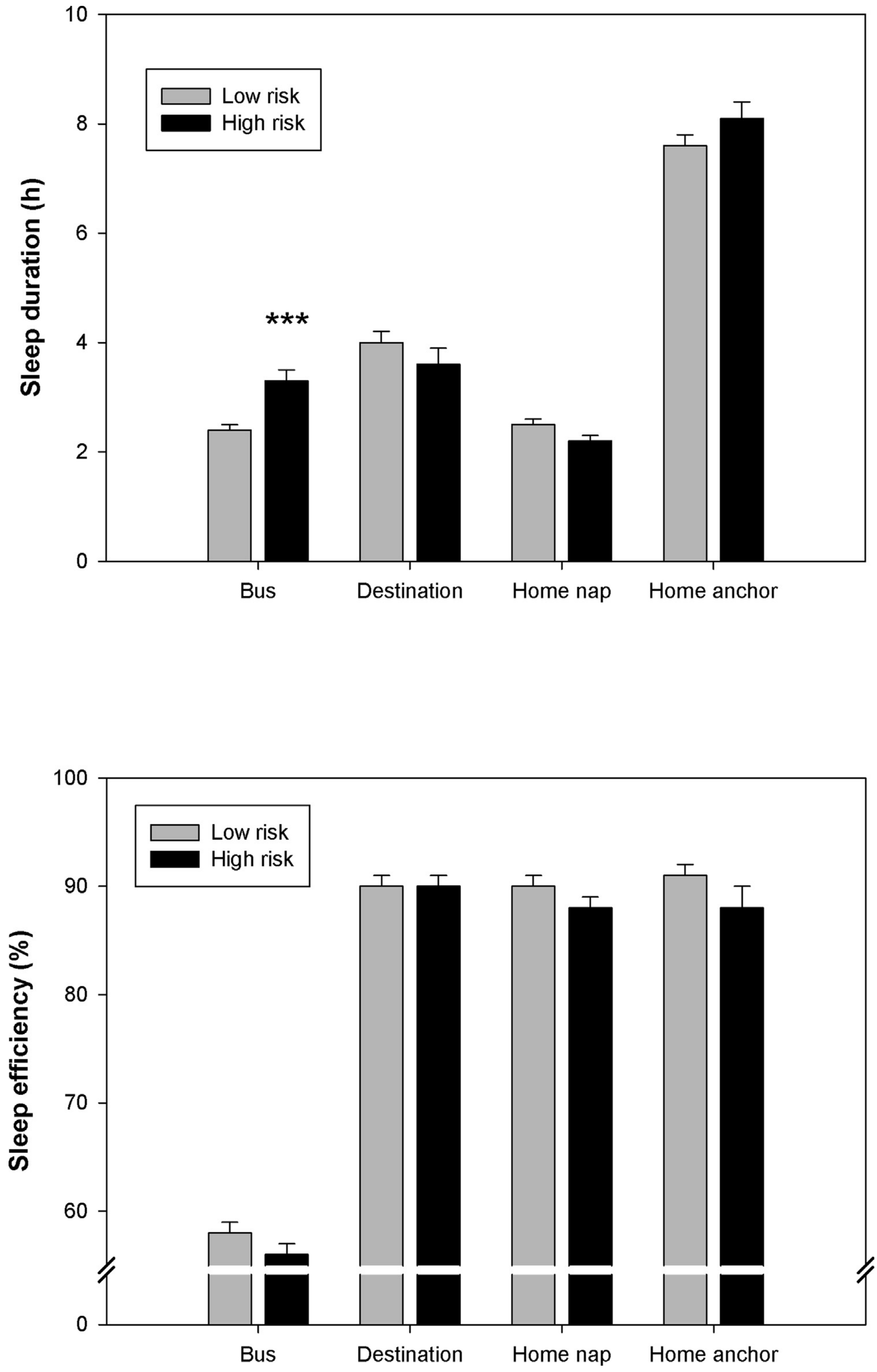

Figure 3. Sleep duration (top panel) and sleep efficiency (bottom panel) at different locations. Drivers exposed to high-risk working schedules slept almost one more hour during trips ($p< 0.001$, t-test for independent samples). All other values were similar between risk groups.

Discussion

The main results of this study are the description of a misaligned sleep in a naturalistic setting of professional long-haul drivers under a two-up operations system and the association of a weaker circadian temperature rhythm and a nonsignificant acrophase with high-risk work schedules. Alertness showed significant changes, but without a clear pattern being discernable.

The demographic characteristics of the sample showed a middle-aged male population, mostly married or in domestic partnership and with children. One-third of the sample had complete secondary education. Although race/ethnicity was not measured, it is known

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Table 4
Standardized sleep duration at different locations and global sleep misalignment

Variables	Units	Low fatigue risk (score ≤ 24) n = 45		High fatigue risk (score > 24) n = 29		Total n = 74	
		Mean	SEM	Mean	SEM	Mean	SEM
Duration							
Trip	(h per 7 day)	12.3	.9	15.4	1.4	13.5	.8
	(h per 24 h)	1.8	0.1	2.2	0.2	1.9	.1
Destination	(h per 7 day)	12.8	1.3	9.2	1.9	11.4	1.1
	(h per 24 h)	1.8	0.2	1.3	0.3	1.6	0.2
Home	(h per 7 day)	25.1	1.7	28.6	2.2	26.4	1.4
	(h per 24 h)	3.6	0.2	4.1	0.3	3.8	0.2
Destination + Home	(h per 7 day)	37.8	1.2	37.8	1.9	37.8	1.0
	(h per 24 h)	5.4	0.2	5.4	0.3	5.4	0.1
All	(h per 7 day)	50.1	1.2	53.2	1.5	51.3	0.9
	(h per 24 h)	7.2	0.2	7.6	0.2	7.3	0.1
Misalignment							
Composite phase deviation	(d)	.36	.01	.37	.02	.37	.01
Duration SD	(h)	2.6	.1	2.7	.1	2.6	.1
Efficiency SD	(%)	18.5	.6	18.4	.6	18.4	.4

Sleep duration values are standardized to one-day and seven-day periods.

that the population of Argentina is the result of the intermixing between several groups, being the average genetic ancestry for Argentine population, 65% European, 31% Indigenous American, and 4% African.[39] Drivers' health habits (physical activity, 46.7%; smoking status, 34.7%; alcohol consumption, 58.8%) were different from those reported in a large study (n = 10,101) conducted in the state of São Paulo, Brazil (physical activity, 23.0%; smoking status 20.8%; alcohol consumption 33.5%).[40] Interestingly, in our study, the proportion of drivers who reported the practice of physical activity was lower in the high-risk group, pointing out the impact of demanding working schedules on healthy habits. The prevalence of overweight (88%) and obesity (41%) was high, similar to figures of overweight (81%) and obesity (33%) reported in short-haul drivers (n = 1,023) from Argentina[18] and far from figures of overweight (58%) and obesity (21%) found in the Argentine general population.[41] The prevalence of hypertension (9.1%) and diabetes (2.5%) was lower than the prevalence of hypertension (17.9%) and diabetes (7.3%) reported in a large sample of commercial drivers (n = 88,246) from the U.S., but the prevalence of obesity (53.2%) in US workers was also higher.[42] Mental health issues (anxiety, 8.2%; depression, 2.5%) showed lower levels than those reported in a study of 316 male truckers in the U.S. (anxiety, 14.5%; depression, 26.9%);[43] yet, the presence of a significant rate of under diagnosis or underreport cannot be excluded in our sample.

The working schedules revealed extended journeys with a weekly average of 60 working hours, mainly occupying night periods. In accordance with the FRMS risk profiles, the high-risk group (median risk score > 24) was comprised by individuals with higher working hours and lower short break durations. Subjective measures of sleep quality and sleepiness were within normal values. It cannot be discarded that self-reported values of sleep quality and sleepiness were subject to some kind of confirmatory bias that induced respondents to answer what is expected to find in a good driver (i.e. good sleep and little sleepiness). In addition, the PSQI may not be a suitable measure of sleep quality for drivers with this kind of working schedules. Prevalence of high risk of obstructive sleep apnea (28%) was higher than the prevalence of apnea described in the general population (6.2 -11%) and comparable with the prevalence of apnea of other risk groups (28-78%).[15,44,45]

Studies often report sleep-wake cycle data in terms of hours of sleep in working or nonworking days. The term “day” could be misleading in long-haul operations because during a typical service of three working days, the driver could have sleep periods of very different durations. Taking the reported means of this study as an example, a driver usually sleeps 2.8 h in the night period of the first day (outbound trip), a 3.8h sleep period at destination during the daytime of the second day, and 2.8 additional hours during the nighttime of that day (inbound trip). When coming back to their home on the third working day, the driver sleeps a daytime sleep period of 2.4 hours and a night sleep period of 7.8 hours. When standardizing sleep duration values to one week, it is observed that drivers sleep 13.5 h during trips (1.9 h/24 h), 11.4 h at destination (1.6 h/24 h), and 26.4 h (3.8 h/24 h) at home. This leads to almost only 37.8 h of weekly sleep in a bed (5.4 h/24 h) and 51.3 h (7.3 h/24 h) of weekly total sleep. Thus, we can conclude that drivers made good use of the opportunities that they have for sleeping, as the total amount of sleep is similar to the recommended sleep durations for adults. However, it must be noted that they sleep approximately 25% of their total amount of weekly sleep in buses (with reduced sleep efficiency, estimated in 57%), 25% in hotels, and 50% at home, at different times during the day.

Table 5
Peripheral temperature rhythm

Variables	Low fatigue risk (risk score ≤ 24)			High fatigue risk (risk score > 24)			Total		
	n	Mean	SEM	n	Mean	SEM	n	Mean	SEM
% rhythm*	58	27.6	2.0	45	22.0	1.7	103	25.1	1.4
Midline-estimating statistic of rhythm (°C)	58	33.2	.1	45	33.3	.1	103	33.2	.1
Amplitude (°C)	57	.53	.04	42	.48	.04	99	.51	.03
Acrophase (clock time)	57	00:50	01:02	42	22:52#	02:08	99	00:15	01:00

* $p < 0.05$, independent samples t-test.
\# Nonsignificant acrophase. Differences between groups were assessed by independent samples t-tests. Differences between sleep onset phases could not be assessed because high-risk driver's acrophase was nonsignificant (Rayleigh z test).

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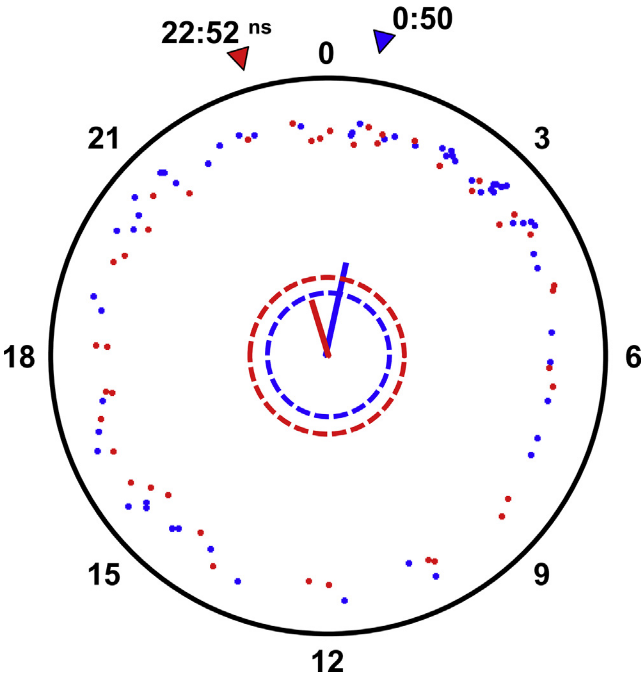

Figure 4. Temporal distribution of the drivers' temperature acrophases divided by low (blue) and high (red) working schedule risk. Each dot denotes the acrophase timing. The position of the vector indicates the acrophases timing, and its length, the acrophases degree of clustering. Nonsignificant vectors do not surpass the dotted inner circles. The triangles outside the circle denote the mean acrophase. (ns) Only low-risk drivers had a significant acrophase at 00:50 ± 01:02 h, while high-risk drivers had a nonsignificant mean resultant vector.

Our results are consistent with a previous report from an observational field study of long-haul truck drivers, who averaged 7.5 h of sleep per night, but with 50% of their daily sleep obtained mainly during work-shift hours in sleeper berths, suggesting a state of partial sleep deprivation.[46] In addition, sleeping in new environments such as hotels has been identified as a potential sleep disruptor.[47] As a measure of sleep misalignment, we calculated the "composite phase deviation," obtaining mean values of near nine hours. These values were similar to the maximum values of sleep timing misalignment seen in early chronotypes after night shifts and in late types before morning shifts, reported in studies of industrial shift workers.[29] Interestingly, these industrial workers maintained the sleep location varying the sleep onset, while in the first-mentioned study of truck drivers, workers slept in different locations maintaining the sleep timing. In our study, drivers seem to be exposed to the amplifying effect of both pervasive effects on sleep, sleeping at different times and in different locations. This unique sleep pattern presents a bimodal configuration of sleep onset corresponding to (a) sleep at destination and naps at home and (b) sleep in the bus and nighttime sleep at home. In addition, high-risk drivers showed a delayed sleep onset at home of almost 1.25 h when compared with low-risk ones. It was shown that individuals with late sleep timing exhibit increased misalignments between endogenous circadian rhythms and the sleep-wake cycle, due to differences between sleep preference and work schedule.[48] Even though no significant differences of sleep misalignment were found between risk groups, sleep duration during the trips was longer in the high-risk group. This could be explained as a compensation mechanism for the disruption of circadian rhythms, also observed in this group and discussed in the following section.

It must also be mentioned that sleep in the bus was of low efficiency, estimated in around 57%. In agreement with our results, a study that used subjective and objective measures of sleep reported that truck crews had less sleep quality than single drivers who stop to sleep. This was attributed to the noise and vibration typical of sleeper berths of moving trucks.[12] In addition, sleeping in either a moving or stationary vehicle was associated with reduced sleep quality when compared with sleep at home. The recording device used in this former study combined a signal produced by the deformation of a flexible piezoelectric film of an eyelid sensor, with the signal produced by the shifting of a mercury droplet within a head movement sensor.[12] In our study, the actigraphic signals obtained in the bus were mixed with a component originated from its movement, so sleep onset and offset were visually estimated. Therefore, reported values of sleep timing, duration, and efficiency at this location should be taken as estimations of the real sample values. This could be an issue especially in the estimation of sleep efficiency, as sleep onset, offset, and duration values were estimated cross-checking with sleep logs. Thus, although it would be expected that vibrations affecting actigraphy data would have led to an underestimated sleep efficiency, values reported by Dingus et al.[12] in the cited article were around 40%, so our results might be, conversely, above real values. To the best of our knowledge, there are no descriptions of sleep characteristics as assessed by actigraphy, in commercial moving vehicles. However, an actigraphic study of sleep in train extended freight-haul operations showed that rest opportunities in the crew van were associated with reduced sleep efficiency, estimated in 80%. The difference with our results is likely due to train crew vans are rather quarters than berths, with better space and recreation facilities.[49]

Drivers exposed to high-risk working schedules showed a decreased robustness of circadian temperature rhythms and — as a group -— a nonsignificant acrophase. In addition, the lower proportion of night rest time at destination observed in high-risk drivers may explain the dampening in circadian temperature rhythm robustness, as it is known that daytime naps may modify these rhythms.[50] Indeed, shift workers are also prone to disruptions in the relationship between the sleep-wake cycle and the circadian rhythm of temperature. The circadian clock has evolved to synchronize physiological rhythms to changing environmental conditions named zeitgebers. When zeitgebers are inverted as in shift work, the stability of the circadian rhythm phase and amplitude may be compromised, especially when zeitgeber changes are frequent. For example, it was shown that a mixed routine followed by nurses, consistent in morning classes and night shift work, was associated with a reduced amplitude of the wrist temperature rhythm during the school period, when compared with the vacation term.[51] In addition, in a study that assessed circadian rhythms of transmeridian pilots, a conflicting situation

Table 6
Timing of PVT measurements

Variables	1st			2nd			3rd			4th			5th		
	n	Mean	SEM	n	Mean	SEM	n	Mean	SEM	n	Mean	SEM	n	Mean	SEM
Day time (h)*	111	19.4	.1	48	23.0	.2	57	3.4	.2	62	7.1	.2	71	10.4	.2
Travel time (h)*	111	.41	.04	48	4.1	.2	57	8.1	.13	62	12.1	.2	71	15.7	.1
Trip fraction (%)*	111	2.7	.3	48	26	1	57	55	2	62	81	2	71	95	1

* $p < 0.001$, all measurements differ between each other. Shown are pooled values of outbound and inbound trips. Linear mixed model followed by post-hoc Bonferroni test.

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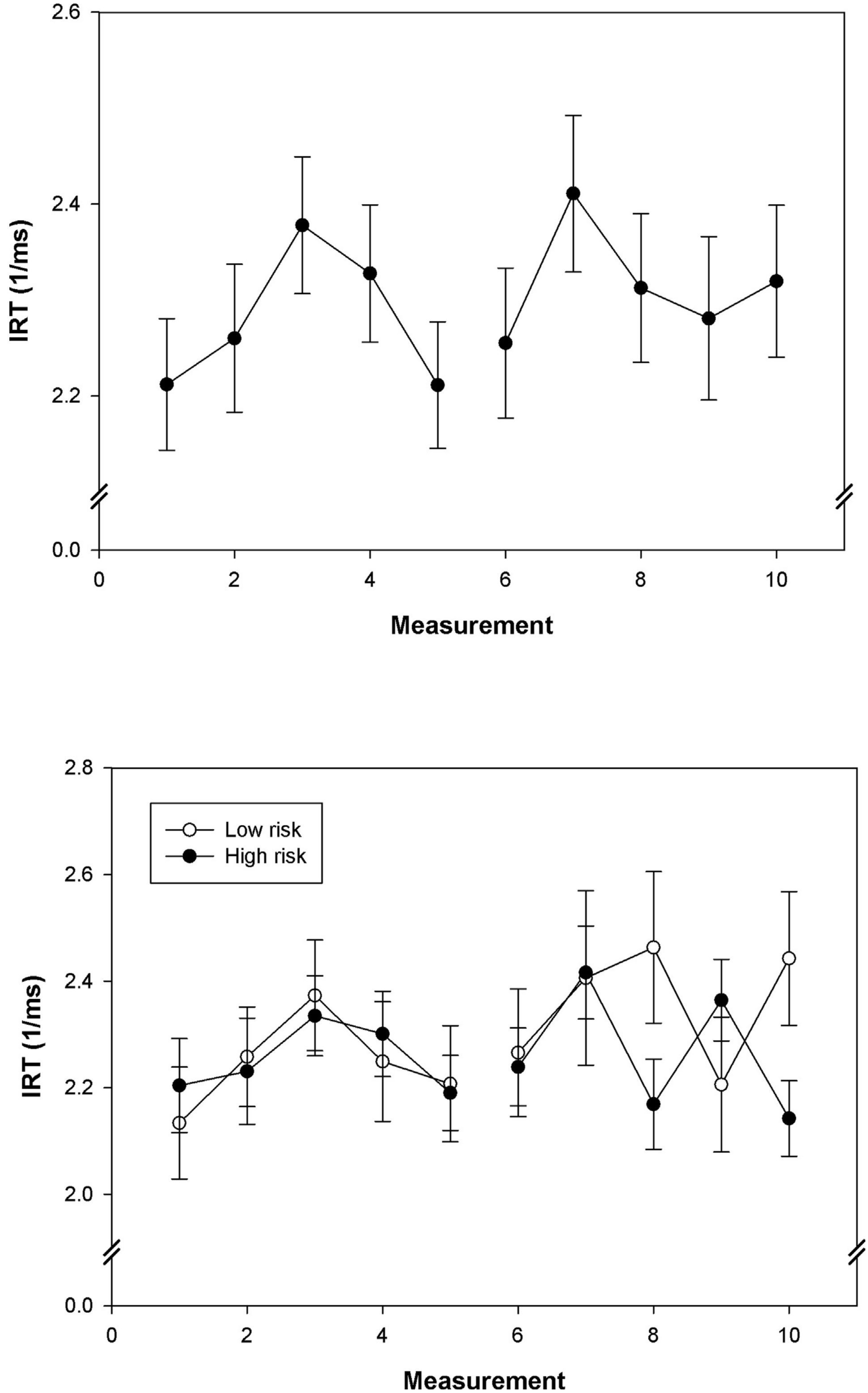

Figure 5. Lapse domain (IRT) during outbound and inbound trips, considering the whole sample (top panel) and divided by risk groups (bottom panel). IRT is calculated as the slowest 10% of reciprocal response times for all trials. Higher IRT values (lower reaction times) reflect an increase in alertness. A repeated measures general linear mixed model was used to analyze psychomotor vigilance task trials. Outbound variations were nonsignificant, while low alertness values are seen at the beginning and at the end of the inbound trip ($p = 0.008$; 1st and 5th < 2nd). Differences between legs were nonsignificant. Inbound variations were different between groups ($p = 0.001$), with significant variations only in the high-risk group ($p = 0.001$; 5th < 2nd and 4th; 3rd < 4th).

between the internal temporal order and the external time cues experienced by the pilots was strongly suggested.[52] Eventually, circadian rhythms desynchronization may lead to sleep disturbances, sleep medication consumption, persistent fatigue and mood disorders, and/or burn out, which could compromise safety and health.[53]

As for the alertness measurements, MRT values were similar to those reported in a sample of 195 professional drivers with no neuropsychological disturbances.[54] The observed variations in alertness (as assessed by the FRT, LRT, and IRT indexes) should be interpreted with caution, as changes were very variable, and could be explained by a combined effect of time on duty (homeostatic regulation of sleep) and time of day (circadian rhythm regulation of sleep). These effects are difficult to separate. On one hand, trips in where alertness was measured lasted an average of around 15.7 h and included rest opportunities that allowed around 2.8 h of sleep. On the other hand, measurements were taken in the period between 19.4 h and 10.4 h of the next day, which includes both an expected circadian alertness trough at 05:00 and an expected circadian alertness peak at 10:00.[33] When comparing risk groups, it was seen that the high-risk group showed higher alertness values in the outbound trip, while presenting a larger variability in the inbound trip. It is difficult to explain this pattern, but some clues could be inferred by analyzing the shift characteristics of the risk groups. One of our significant findings is that the high-risk group showed a higher amount of night work per seven days. If this entailed a better adaptation to the shift, it could explain the observed initial higher alertness levels.

Several limitations of the present study should be taken into account. Working schedules were reported by the subjects and not verified by independent observers. To overcome possible inaccuracies, only full and consistent reports were included in the study. The use of alertness promoting agents (including caffeine), driver's relationship with their team member (codriver), and other factors that can impact sleep (sleep hygiene behaviors) were not asked. The impact of sleep duration, efficiency, and misalignment on health conditions was not investigated. Safety performance was not measured, which is also a weakness of this study. Actigraphy provide an indirect measure of sleep and cannot measure sleep architecture, so sleep measures should be interpreted with care, especially when obtained in the bus, as described previously. Peripheral temperature rhythm during wake may be masked by factors as ambient temperature, daily activity levels, and food ingestion. However, it was demonstrated that the iButton provides an accurate and reliable proxy of core temperature in field settings. For example, Sarabia et al.[51] reported a cross correlation between wrist temperature and oral temperature of $r = -0.79$, with an inverse phase relationship and a phase advance of 1 h of wrist temperature with respect to oral temperature. Thus, the method is considered a valid alternative to traditional measures of circadian temperature in sleep field research, where participants should follow normal living conditions and continuous measurements are needed.[50,55] When assessing alertness, the participants of the outbound stretches were different from those of the inbound stretches. Even though the factor was statistically controlled, this may limit the scope of the conclusions derived from the measurement. To capture the complete pattern of the rest-activity cycle in this population, recordings should have comprised 14 days, so the presented results should be interpreted accordingly.

This research was focused on the objective study of the association of sleep opportunities (level 1 of the FRMS framework) with actual sleep (level 2) and fatigue (level 3), in a sample of long distance bus drivers with a two-up driving system. Specifically, our study identified the variables that are more affected by the lack of sleep opportunities. Further naturalistic studies of this kind should address associations between other FRMS levels, as the impact of obtained sleep (level 2) on alertness (level 3) and safety (levels 4 and 5). In addition, the impact of sleep characteristics on long-haul drivers' health conditions is a future research line that should be taken into account. Our results highlight the need of minimizing sleep misalignment and circadian desynchronization by implementing appropriate shift-work scheduling strategies, as well as the convenience of monitoring sleep and fatigue to assess the impact of these measures. In this regard, as this study provides useful descriptive empirical information, it could be a valuable tool for implementing FRMSs or for developing primary prevention "circadian health" policies in the passenger transport industry. A second implication of our work is the need to develop educational strategies to increase the knowledge about the impact of sleep misalignment in safety and health. A final implication of our study concerns the need of adopting secondary prevention measures for chronic diseases related to shift work in transport workers.

Acknowledgments

The authors report no conflicts of interest.

We wish to thank Yesica Ponte for her technical assistance.

This work was supported by Superintendencia de Riesgos del Trabajo (SRT) EXP- 3228/09, and partially by grants from the Agencia Nacional de Promoción Científica y Tecnológica (ANPCyT) PICT Start-up 2013-710, PICT 2012-0984 and PICTO-CRUP 2005-31390.

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Appendix A. Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleh.2019.12.011.

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