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Short Communication

Describing Physical Activity Patterns of Truck Drivers Using Actigraphy

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ABSTRACT

Background: Truck driving is a highly sedentary occupation that places workers at risk for chronic health conditions, such as obesity and high blood pressure. The primary purpose of this study was to objectively describe truck drivers' typical physical activity (PA) patterns.
Methods: We used ∼7–10-day baseline PA actigraphy data samples from drivers in the Safety & Health Involvement For Truckers (SHIFT) study ($n = 394$). Driver PA patterns (e.g., average number of ≥10 minute Freedson bouts per week, time in bouts, and common days/times for PA) were summarized with descriptive analyses. We also compared objective accelerometer data to self-reports.
Results: Drivers' weekly PA averaged 14.4 minutes (SD = 37.0), and most PA occurred between 5–6 pm on Tuesdays and Wednesdays. Drivers overestimated self-reported weekly exercise by over 60 min/week compared to accelerometer data.
Conclusion: Our results suggest that objective PA assessment may be warranted over self-report when possible, and timing may be key in future PA intervention work with truck drivers.

Obesity rates among truck drivers are over 30% higher than that of the general working population [1]. Numerous structural and systemic factors contribute to truck driver obesity, including long and sedentary driving shifts, food swamps at truck stops, variable schedules, and limited off-duty time and safe environments for physical activity (PA) [2]. Interventions to improve drivers' working conditions, schedules, and health are important, including those that aim to increase PA. However, little is known about truck drivers' actual PA levels and patterns, and opportunities to create or protect time for drivers to maintain or increase PA. Studies of drivers' PA are scarce [1,3,4] and tend to rely on self-report data that often result in overestimates of PA (correlations between objective and subjective measurements range between -0.71 and + 0.96) [5]. There is a need for studies that objectively measure truck drivers' PA to guide and evaluate future health interventions [6].

Actigraphy is a common and reliable method for objectively measuring PA [7], but it is rarely used in research with commercial drivers because vehicular movement and vibrations in trucks can artificially inflate actigraphy estimates of energy expenditure [8–10]. However, focusing on bouts of PA ≥10 minutes in duration—instead of the sum of energy expenditure estimates—decreases the likelihood of artificial inflation due to vehicular movement and vibration. Prior research has shown that this approach does not produce false bouts during workers' driving periods and thus opens the door for conservative and objective measurement of PA among truck drivers [10]. By analyzing patterns of PA bouts in truck drivers and the context in which PA bouts occur, we can better understand how and when to intervene to increase PA and inform employers' approaches to managing drivers' route assignments and schedules. To our knowledge, only five previous studies have used actigraphy to measure PA among truck drivers [11–15], and these studies failed to account for vehicular movement and vibrations and had small sample sizes. As such, the purpose of this study was to apply a bout-based analysis approach

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with PA actigraphy data collected from a large sample of US truck drivers in order to describe their typical patterns of PA during a work week. We aimed to describe the days and times drivers usually engaged in PA, the number and length of activity bouts per week, and contextual characteristics associated with PA. We also compared objective measures of PA from actigraphy data to drivers' PA self-report data.

1. Method

1.1. Participants

This study focuses on baseline data collected from truck drivers (N = 452) who participated in the Safety and Health Involvement for Truck Drivers (SHIFT) randomized controlled trial conducted in the US [3]. All participants provided informed consent prior to participation, and all methods were approved by the human subjects institutional review board at Oregon Health & Science University. Participants included truck drivers at five companies in the Western USA. Descriptions of participant recruitment, demographics, and work and health characteristics of the full sample have been previously published [3]. Table 1 describes characteristics of the participants included in this study. Participants were mostly male (87.0%) with an average age of 48.4 (SD = 11.0). Average tenure as a truck driver was 11.9 years (SD = 10.3), and current company tenure was 5.0 years (SD = 5.7).

1.2. Devices and implementation procedure

PA was measured with a tri-axial accelerometer and inclinometer (ActiGraph GT3X+, ActiGraph LLC, Pensacola, FL). Using Actilife software, GT3X + devices were initialized with participant demographics, set with a sampling rate of 30 Hz, and set to begin recording 2 hours after each participant had completed an in-person data collection visit (survey and objective health measures). Participants were provided with an elastic belt to wear the device on their non-dominant hip [16]. Researchers guided participants as they put the belt and ActiGraph on, and provided verbal and written instructions for wearing the device during the sampling period. Participants were asked to only remove device when changing clothes or during activities where the device could get wet. They were also asked to wear the devices for 7–10 consecutive days, including work and non-work days, though some participants wore them for different lengths. Participants returned devices to researchers using a prepaid mailing envelope. All devices were serviced and maintained according to the manufacturer's recommendations during the study period.

1.3. Actigraphy measures and analyses

Wear time was validated with a modified algorithm [17] based on a study of PA in a highly sedentary population [18], changing the requirement from 90 consecutive minutes of zero activity counts to 120 consecutive minutes of zero activity counts to be classified as non-wear time. Using this method, a sample day was considered valid if wear time compliance was equal to or exceeded 8 hours per day. Participants were required to have three or more valid days to be included in the analysis. Due to missing data or insufficient wear time, 58 drivers were excluded from analyses, leaving a total sample of n = 394. Activity bouts were calculated using the Freedson Adult (2011) algorithm [16], with an activity threshold of 1952 counts/minute. Only bouts at least 10 minutes long, inclusive of a 2-minute drop period, were analyzed.

Electronic logbook data were obtained for a subsample of drivers (n = 46), which indicated driving and non-driving periods. We compared these data to records of activity bouts to confirm that bouts of PA observed in actigraphy data were not falsely generated by truck vibrations during driving periods. In this sub-sample, 14 of the 46 drivers generated a total of 79 activity bouts, and all bouts occurred during non-driving times.

1.4. Additional measures and analyses

In the SHIFT trial, participants completed a range of survey measures, including demographics and self-reported PA. Directly measured health factors included blood pressure (Omron HEM-907XL, Kyoto, Japan) and body composition (Tanita TBF-310GS scale, Tanita Corporation, Tokyo, Japan). Self-reported PA was measured using the Healthy Physical Activity Questionnaire [19], and days per week with at least 30 minutes of moderate and vigorous PA in the past month were summed. Average PA minutes per week was conservatively extrapolated by multiplying this sum

Table 1
Participant characteristics

Variables	No freedson bouts (N = 266)	≥1 freedson bouts (N = 128)	Total sample (N = 394)	p
	Mean (SD) or n (%)	Mean (SD) or n (%)	Mean (SD) or n (%)	
Age (years)	48.8 (11.4)	47.5 (10.2)	48.4 (11.0)	0.30
Sex (Female)	37 (14.0%)	14 (10.9%)	51 (13.0%)	0.40
Weight (lb)	258.0 (64.2)	237.2 (46.0)	251.2 (59.6)	<0.01
Tenure (years)				
As truck driver	12.9 (10.9)	9.8 (8.5)	11.9 (10.3)	<0.01
At current company	4.7 (5.5)	5.4 (5.9)	5.0 (5.7)	0.29
Employers in past 3 years	1.3 (1.3)	1.0 (1.0)	1.2 (1.2)	0.03
Driving hours per week*	59.4 (11.8)	59.6 (10.7)	59.5 (11.5)	0.79
Days away from home	3.8 (1.5)	3.8 (1.5)	3.8 (1.5)	0.69
Company				
1	32 (12.0%)	13 (10.2%)	45 (11.4%)	
2	48 (18.0%)	17 (13.3%)	65 (16.5%)	
3	99 (37.2%)	40 (31.3%)	139 (35.3%)	
4	75 (28.2%)	57 (44.5%)	132 (33.5%)	
5	12 (4.5%)	1 (0.8%)	13 (3.3%)	
Self-reported physical activity				
Moderate physical activity (0–7 days)	1.8 (1.8)	1.9 (1.8)	1.8 (1.8)	0.58
Vigorous physical activity (0–7 days)	0.9 (1.5)	1.1 (1.6)	0.9 (1.5)	0.28
Extrapolated physical activity time per week (minutes)	79.0 (86.6)	87.5 (84.5)	81.8 (85.9)	0.36

* Variable compared using Mann–Whitney U test because of substantial skew and kurtosis. All other continuous variables compared using independent samples t-test.

by 30 (i.e., the minimum amount of PA participants could have engaged in according to the prompt). Descriptive statistics (e.g., means and standard deviations) of participants' demographic and work characteristics were computed for the whole sample and compared between those with and without activity bouts, using independent samples t-test for continuous variables and logistic regression for categorical variables (for non-normal continuous variables Mann–Whitney U test was used).

Within the group of drivers who had activity bouts, associations between participant characteristics and bouts, average time in bouts, and average PA time per week were assessed via Spearman's rho (ρ), and patterns of PA (e.g., day-of-week and time-of-day) were descriptively analyzed and visualized. Finally, PA self-reports were compared to actigraphy data. Time-of-day of PA was determined by the hour. For example, if some had a bout that lasted between 13:25 and 13:35, then that bout and 10 minutes of activity would be classified as occurring at 1 pm. If, however, a bout occurred between multiple-hour cutoffs (e.g., a bout that begins at 8:50 and ends at 9:05), then that bout was classified as the hour in which the majority of PA occurred (e.g., 8 am). If the bout time is equally spaced between hour cutoffs, (e.g., 8:55–9:05), then we coded that bout as the later hour. The minutes of activity, however, were only classified as occurring in each respective hour (e.g., 5 minutes at 8 am and 5 minutes at 9 am for a bout between 8:55–9:05). Self-reported PA was compared to objective actigraphy data via Spearman's rho and Wilcoxon signed rank test. An alpha level of 0.05 was used to indicate significance from statistical tests; however, interpretations of such results are limited to describing potentially meaningful associations rather than making causal inferences.

2. Results

The sample ($n = 394$) produced a total 389 Freedson bouts over the monitoring period (number of valid days ranged from 3 to 24 days; mean = 10.1, SD = 2.8). The majority of drivers ($n = 266$) did not complete any PA bouts lasting 10 minutes or more. The drivers ($n = 128$) who produced at least one bout of PA completed an average of 3.0 bouts (SD = 3.2) per person, and the mean bout duration was 19.2 minutes (SD = 11.5). A descriptive summary of driver characteristics for those with and without bouts is provided in Table 1. Some identified differences were that drivers who completed at least one bout tended to weigh less (mean difference [MD] = -20.8 lb, $p < 0.01$), have shorter career tenure (MD = -3.1 years, $p < 0.01$), report fewer employers in the past three years (MD = -0.3, $p = 0.03$), and have a lower computed likelihood of cardiovascular disease [20,21] (MD = -2.3 total points, $p = 0.01$). Overall, drivers averaged 14.4 minutes of PA per week (SD = 37.0). Within the activity bout group, this average increases to 44.4 minutes (SD = 53.8).

Within the activity bout group, we computed correlations between activity variables and driver characteristics (see Table 2). Weight was negatively associated with Freedson bouts per week, minutes per bout, and minutes per week of PA. Tenure was positively associated with minutes per bout, but not bouts or minutes per week. Similarly, days away from home were negatively associated with minutes per bout, but had no relationship to bouts or minutes per week. Company tenure was positively associated with minutes in bout and minutes per week, but not bouts per week. Finally, though driving hours per week was only significantly negatively correlated with minutes per week, the correlation size (r = -0.19) was similar to that of bouts per week (r = -0.14) and minutes per bout (r = -0.17).

See Figs. 1 and 2 for visualizations of PA by time-of-day and day-of-week, respectively. Most PA bouts occurred in the 5 pm (total bouts = 40; 10.3%) and 6 pm (total bouts = 38; 9.8%) periods. Further, the majority of bouts occurred mid-week on Tuesdays (total bouts = 70; 18.0%), Wednesdays (total bouts = 61; 15.7%), and Thursdays (total bouts = 64; 16.5%). Patterns in total PA minutes mirrored data on the number of bouts, with a total of 694 (9.6%), 716 (9.9%), and 665 (9.2%) minutes occurring in the 5 pm, 6 pm, and 7 pm hour periods, respectively. Similarly, 1,319 (17.7%); 1,215 (16.3%); and 1,149 (15.4%) total minutes of PA were recorded on Tuesday, Wednesday, and Thursday, respectively.

According to self-report for the past month, drivers engaged in at least 30 minutes of moderate PA on about 1.8 days per week (SD = 1.8) and vigorous activity on about 0.9 days per week (SD = 1.5). After an extrapolation to standardize these self-reports relative to actigraphy-measured bouts, participants averaged 81.8 minutes (SD = 85.6) of self-reported PA per week. Thus, drivers overestimated their PA by 67.3 minutes per week (SD = 90.5, $p < 0.01$) compared to their more objective actigraphy data. Additionally, self-report and objective measures of total time in PA were not correlated ($\rho = 0.08$, $p = 0.11$). When excluding drivers with 0 bouts, drivers still overestimated their PA by about 43.2 minutes per week (SD = 93.9), $p < 0.01$. In this subsample with bouts, the rho correlation between self-reported and objective PA minutes per week was non-significant ($\rho = 0.13$, $p = 0.16$).

3. Discussion

To our knowledge, this study represents the first actigraphy measurement of truck driver PA patterns using a method that excludes potential false activity generated by truck vibrations. Results from this sample describe truck drivers as a highly sedentary

Table 2
Correlations between driver characteristics and objective physical activity

Variable	1	2	3	4	5	6	7	8	9	10
1. Bouts per week										
2. Min per bout	0.38*									
3. Min per week	0.91*	0.70*								
4. Age	0.11	0.17	0.14							
5. Sex	0.08	-0.11	0.02	-0.11						
6. Weight	-0.29*	-0.18*	-0.28*	-0.06	-0.09					
7. Tenure	0.09	0.20*	0.15	0.48*	0.02	0.03				
8. C tenure	0.14	0.30*	0.23*	0.41*	0.01	-0.01	0.72*			
9. # Employers	0.12	-0.13	0.05	-0.35*	0.11	0.01	-0.07	-0.38*		
10. Driving hours per week	-0.14	-0.17	-0.19*	0.05	-0.05	-0.04	-0.06	-0.19*	0.01	
11. Days away from home	-0.01	-0.18*	-0.09	0.01	0.02	-0.01	-0.11	-0.18*	-0.05	0.50*

Note. All values reflect Spearman's rho. Correlations were computed with the sample that had at least one Freedson bout. Min = minutes. C Tenure = company tenure.
*Significant at $p < 0.05$.

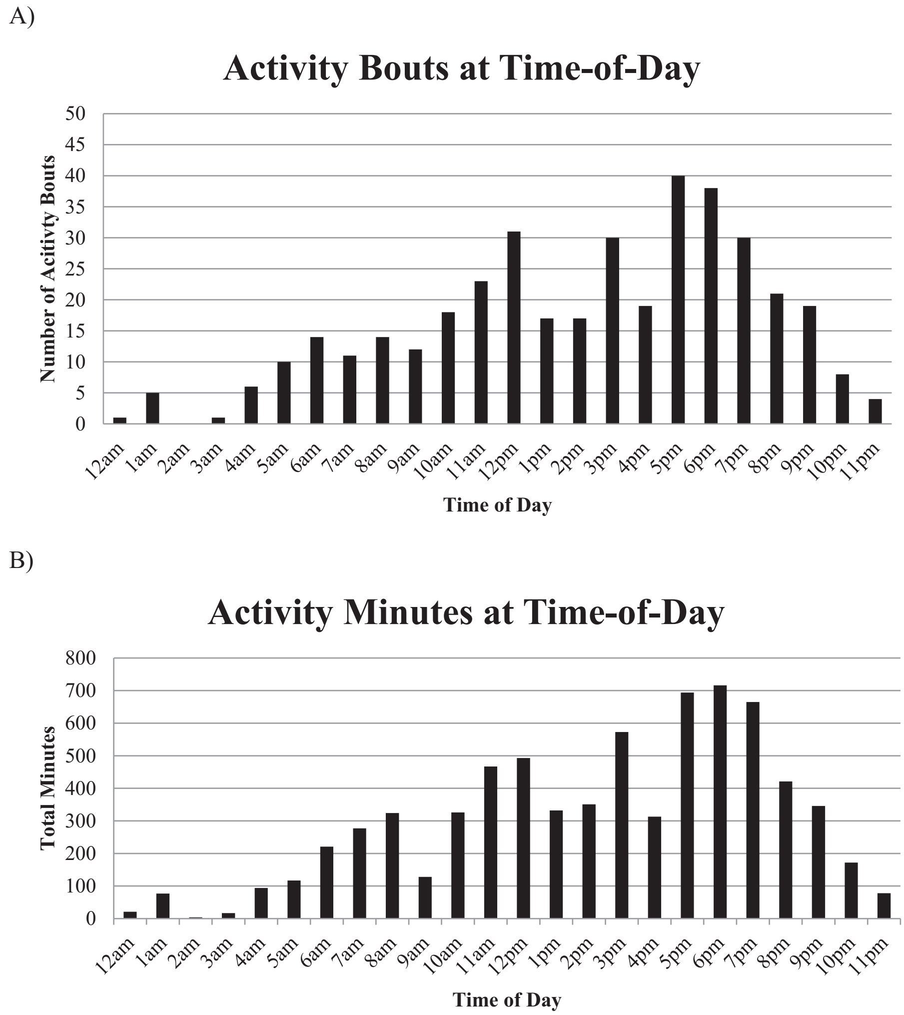

Fig. 1. Physical activity and time-of-day.

population in need of improvements to working conditions, scheduling support from employers, and access to additional health promotion programs. In this study, two-thirds of the sample did not engage in any PA bouts of 10 minutes or greater during a work week, and the average total minutes of PA per week was less than 30 minutes. When drivers engaged in PA, they tended to do so in the early evening (around 5–6 pm) on mid-weekdays (Tuesday and Wednesday). Results also indicated that drivers substantially overestimated their level of PA in a self-report measure.

Future intervention work may benefit from these findings in a few ways. First, given that PA on driving days is more likely to occur in the evening after a driving period, employers and supervisors (dispatchers) should work to manage driver schedules in ways that protect early mid-week evening off-duty time, as well as access to truck or rest stops that provide safe places to walk or exercise. On this theme, it is possible that with progressive days on duty, or when work hours extend to late in the evening, driver fatigue increases and motivation for engaging PA reduces. While we did not collect indicators of consecutive days on duty in this study, it is possible that the predominance of early mid-week PA and limited presence of later week and weekend PA could indicate progressive fatigue, recovery on weekends, and then higher motivation to exercise after off-duty recovery time at the beginning of a work week. In trucking a typical work week many not start Monday and end Friday, but this observed pattern and possible relationship between consecutive work days and PA may warrant future investigation.

Observed patterns in PA may also inform health programs or systems, which could utilize ecologically timed reminders (or other motivational tools) to prime drivers during their usual peak PA times (i.e., Tuesdays and Wednesdays between 5–6 pm). Increasing motivational prompts in temporal proximity to normal activity bout opportunities may make it more likely for drivers to engage in PA and may make them more motivated to exercise for longer. The more tailored an intervention is to one's motivational readiness, the more exercise they are likely to engage in [22]. Interventions involving just-in-time adaptive prompts to engage in PA were reviewed in 2019 [23]. Most of the studies reviewed ($k = 19$) were self-described as intervention pilots, and thus likely underpowered. Outcomes across the studies were mixed, yet promising. To illustrate, one of two workplace interventions reviewed monitored participants' step counts and locations using wearable technology and then provided "context-aware" coaching via smartphone to encourage PA at opportune moments [24]. In the active intervention phase, participants in the context-aware coaching group showed a larger increase in daily step counts (about 600 steps greater) compared to control.

Further, day-of-week patterns in PA for drivers also suggest there is a need for addressing and encouraging PA during weekend

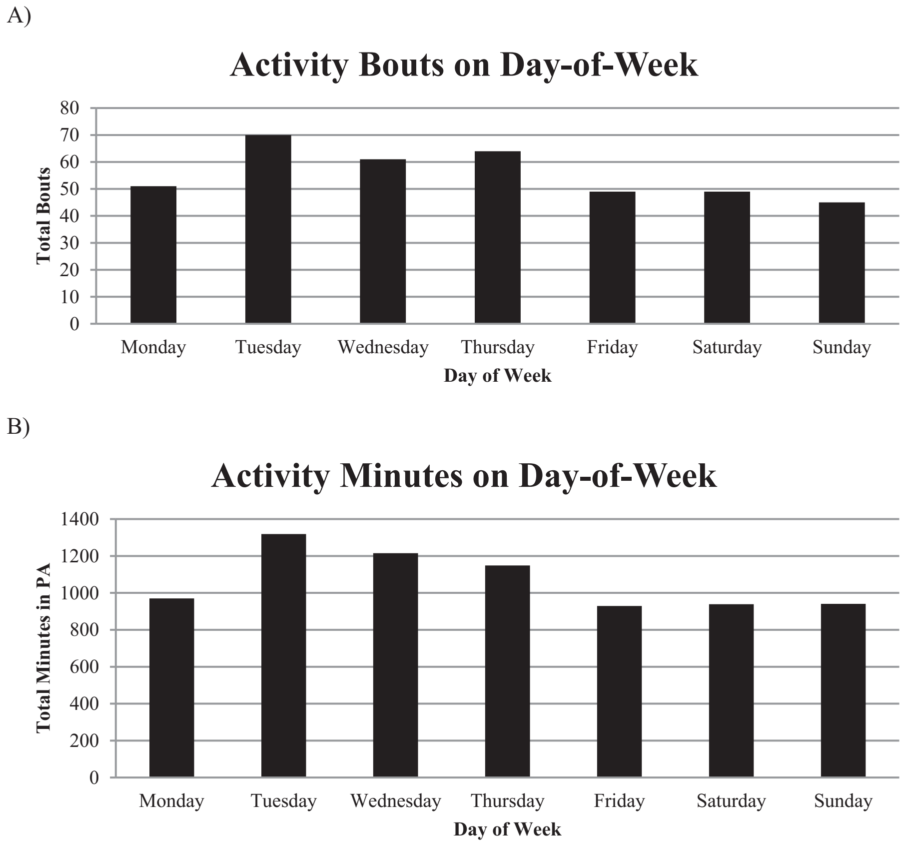

Fig. 2. Physical activity and day-of-week.

or restart periods, perhaps by involving friends and family members in health program educational and motivational components. In total, the patterns observed in truck drivers' PA may serve to guide employers' efforts to organize and schedule work to support driver well-being, as well as to improve the tailoring and efficacy of future PA-promoting educational and motivational programs.

3.1. *Strengths and limitations*

Strengths of the study include the objective measurement of PA, utilization of a method that minimized potential for false PA from vehicular movement and vibration, a large sample of workers from a priority occupation for health interventions, and the novelty of the PA pattern assessment with this occupational group. There are often large discrepancies between self-report and objective measures of PA in general population samples [5], and our own findings support this divergence in a sample of truck drivers as well. Typically, and as was found in our results, individuals will overestimate their usual PA. Using actigraphy to measure PA objectively presents a more accurate picture of how much, how often, and when individuals are active. Truck drivers are at particularly high risk for health issues as a result of the characteristics of their work, and the results of this study provide an important incremental step forward for guiding future interventions at trucking companies that benefit driver health and wellbeing.

To place findings in context, the current study provides measurements based on a substantially larger sample size and contributes additional information about the timing of PA compared to other relatively recent accelerometer-based studies of commercial drivers. In a small pilot study of team truck drivers ($n = 8$) using the same actigraph and bout-based analysis as the current study, Olson et al. found drivers at baseline averaged 4.40 (SD = 7.36) minutes per week in moderate-intensity PA bouts [14]. Gilson et al. used the same actigraph devices as the current study, but worn on the wrist, to cross-sectionally measure driver PA [13]. Drivers in this sample ($n = 21$) averaged less than one 10+ minute bout of PA per day, with fewer bouts on non-workdays compared to workdays. Verela Mato et al. [11] reported moderate to vigorous stepping behavior of 0.1 (SD = 0.1) hours per day among 43 truck drivers using the activePAL3 monitor placed on the thigh. Gilson et al. used a wrist-worn GENEActiv accelerometer and reported that drivers (n = 44) spent 5% to 9% of their on-duty and off-duty workday time, respectively, being physically active (walking or running) [12]. Additionally, Clemes et al. reported a significant post-intervention difference in daily step count as measured by wrist-worn Fitbit devices, resulting from a decrease in step count in the control group and maintenance of step count in the intervention group [15]. However, these studies did not address how their particular devices may have been affected by large truck vibrations or driving tasks (e.g., operating steering wheel and shifting gears).

The dissimilarity of measurement anchors in our comparison of objective and subjective PA is one limitation of this study. The nature of the survey scale required that we make an extrapolation from two self-report items in order to transform answers into minutes per week of PA. Those two items asked participants to report days per week of at least 30 minutes of moderate and vigorous PA in the last month. It may be more valid for future research to use a self-report measure of PA that is directly anchored in minutes of activity per week (e.g., the International Physical Activity Questionnaire [IPAQ] [25]) for comparisons to objective data. Additionally, we asked participants about their general activity in the past month and compared it to a single week of objective data (the self-report period also came before the actigraphy data collection period). Activity levels may vary week-to-week, so future research may benefit from using the same time period for subjective-objective comparisons (e.g., IPAQ uses "the past 7 days" as the time anchor). Similarly, another limitation was its focus on a specific context and population which is long-haul truck drivers in the USA. The patterns identified may not be generalizable for different kinds of truck drivers (e.g., short-haul) or drivers from different countries. For example, federal driving regulations in the USA allow up to 11 hours on-duty per day (for property-carrying drivers), requiring 30 minutes of rest every 8 hours of driving [26]. As such, evenings as a time where many drivers will engage in most of their PA makes sense (i.e., after a full day of driving). In the European Union, in contrast, there is a limit of 9 hours per day (and 56 hours per week), with requirements of 45 rest minutes every 4.5 hours of driving [27]. European drivers may therefore have more opportunities to engage in PA throughout the work day. In general, there are many factors that may impact the generalizability of the present study's results and conclusions (e.g., geography, climate, local and federal laws). Future research should investigate these potential impacts in more depth. A final limitation of the study is our inability to note off-duty and on-duty days, as well as consecutive days on duty during the sampling periods, for the full sample of drivers. Future research may benefit from collecting electronic logbook data for every participant, or from utilizing daily diary survey methods during the sampling period, to investigate deeper questions about PA as it relates to daily work hours, consecutive work days, off-duty PA opportunities, and work and non-work days.

3.2. Conclusions

Overall, our results suggest that truck drivers tend to engage in PA infrequently but do have certain patterns to their PA (e.g., during evenings) that may be leveraged to guide future intervention work. Results also strongly encourage the use of actigraphy instead of, or as a supplement to, driver self-reports of PA. Driver self-reports greatly overestimated their PA levels. In the absence of analysis algorithms that strongly account for or exclude non-human vibrations, future research on PA with truck drivers should employ activity bouts as an outcome variable to prevent attributing truck-generated activity to drivers. Patterns in driver PA, as well as exploratory analyses related to driver sleep quality, encourage future research on the relationship between driver work exposures, fatigue, sleep quality, and PA. Such work could be facilitated by actigraphy studies employing both hip and wrist-worn devices to measure both PA and sleep in the same study. The priority for future interventions should be placed upon improving drivers' working conditions and creating or protecting time and space for them to be physically active. Such work can then be supplemented with tailored educational and motivational programs to support increases in PA and improved overall driver health.

Data statement

Data will be provided upon request from qualified researchers.

Conflicts of interest

The authors declare they have no conflicts of interest.

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https://clinicaltrials.gov/ct2/show/NCT02105571?term=SHIFT+truck&rank=1. The authors would like to thank Kevin Bransford, Sydney Running, Melanie Koren, Katrina Bettencourt, Jessica Sanata, Louis Moore, Kristy Luther, Noal Clemons, Emma Robson, Annie Buckmaster, Annie Cannon, Rossmary Vasquez, Diane Elliot, Nancy Perrin, and Kent Anger for their contributions to the study.

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