The Tech4Rest Randomized Controlled Trial

Applying the Hierarchy of Controls to Advance the Sleep, Health, and Well-being of Team Truck Drivers

Ryan Olson, PhD, Peter W. Johnson, PhD, Steven A. Shea, PhD, Miguel Marino, PhD, Rachel Springer, MS, Sean P.M. Rice, PhD, Jarred Rimby, MPH, and Courtney Donovan, MPH

Objective: The aim of the study was to evaluate the effectiveness of interventions to improve sleep, reduce fatigue, and advance the well-being of team truck drivers. **Methods:** In a randomized controlled trial (k = 24 teams; N = 49 drivers; 61.3% of planned sample), intervention teams were exposed to baseline (3–4 weeks), cab enhancements (active suspension seat, therapeutic mattress; 3–4 weeks), and cab enhancements plus a behavioral sleep-health program (1–2 months). Control teams worked as usual during the same period. **Results:** Trends in sleep-related outcomes favored the intervention. Large and statistically significant intervention effects were observed for objectively measured physical activity (a behavioral program target). The discussion of results addresses effect sizes, statistical power, intervention exposure, and work organization. **Conclusions:** Trends, effect sizes, and significant findings in this rare trial provide valuable guidance for future efforts to improve working conditions and outcomes for team drivers.

Keywords: safety, health, well-being, Total Worker Health, truck drivers, team drivers, sleep, fatigue, physical activity

From the Oregon Institute of Occupational Health Sciences, Oregon Health & Science University, Portland, Oregon (R.O., S.A.S., S.P.M.R., J.R., C.D.); School of Public Health, Oregon Health & Science University-Portland State University, Portland, Oregon (R.O., S.A.S., M.M., S.P.M.R.); Department of Psychology, Portland State University, Portland, Oregon (R.O.); Department of Environmental and Occupational Health Sciences, School of Public Health, University of Washington, Seattle, Washington State (P.W.J.); and Department of Family Medicine, Oregon Health & Science University, Portland, Oregon (M.M., R.S.)

Funding sources: The Tech4Rest study (R.O. and P.W.J., Multiple Principal Investigators [MPIs]) was a research project within the Oregon Healthy Workforce Center that was funded by the National Institute for Occupational Safety and Health, grant number U19OH010154 (Leslie Hammer and R.O., MPIs). This work was also supported by the Oregon Institute of Occupational Health Sciences via funds from the Division of Consumer and Business Services of the State of Oregon (ORS 656.630). The current project was informed by the Tech4Rest pilot study, which received additional support from a Safety and Health Improvement Project grant from the State of Washington (grant number 2014YH00280, P.W.J. and R.O., MPIs). S.A.S.'s contributions to the project were also supported in part by an award from the National Heart Lung and Blood Institute (grant number R35 HL155681).

Conflicts of interest: P.W.J. is the Chief Executive Officer of Suspension Systems Technologies, a company that owns the intellectual property rights to a vibration-reducing seat technology. This technology was not studied in the current project. Oregon Health & Science University has a significant financial interest in Northwest Education Training and Assessment (or NwETA), a company that may have a commercial interest in the results of this research and technology used in the current article. This potential institutional conflict of interest has been reviewed and managed by Oregon Health & Science University.

Authors' contributions: R.O., P.J., S.A.S., and M.M. did the conceptualization, methodology, and funding acquisition. R.O., S.P.M.R., M.M., and R.S. did the validation. S.P.M.R., R.S., and M.M. did the formal analysis and data curation. R.O., C.D., and J.R. did the investigation. R.O. and P.J. did the resources. R.O. did the writing—original draft preparation—and supervision. R.O., P.J., S.A.S., M.M., R.S., S.P.M.R., J.R., and C.D. did the writing—review and editing. R.O., P.J., S.P.M.R., R.S., and M.M. did the visualization. C.D., and J.R. did the project administration. All authors have read and agreed to the published version of the manuscript.

Ethical considerations and disclosures: The study was reviewed and approved by the Human Subjects Institutional Review Board of Oregon Health & Science University (protocol 15440, approval dates 3/02/2016-current). Informed consent was obtained from all subjects involved in the study.

Address correspondence to: Ryan Olson, PhD, Oregon Institute of Occupational Health Sciences, Oregon Health & Science University, 3222 SW Research Dr, L606, Portland, OR 97239 (olsonry@ohsu.edu).

Supplemental digital contents are available for this article. Direct URL citation appears in the printed text and is provided in the HTML and PDF versions of this article on the journal's Web site (www.joem.org).

DOI: 10.1097/JOM.0000000000002941

LEARNING OUTCOMES

After reading this article, the learner will be better able to:

- Discuss the public health importance of addressing working conditions for truck driving teams to improve their sleep, reduce fatigue, and advance their well-being
- Understand how whole-body vibration exposures and shiftwork schedules relate to team drivers' sleep and fatigue
- Describe trends, effect sizes, and significant results for sleep, fatigue, and physical activity outcomes for enhanced cab interventions alone, and in combination with a behavioral sleep-health program
- Identify several specific opportunities to replicate, extend, and advance this area of research and practice

Occupational scientists have generated increasing evidence that employee safety, health, and well-being are interconnected. Working conditions, and the organization of work, create employees' risk for experiencing injuries, safety incidents, and occupational illnesses. However, work exposures are not limited to physical hazards and can have impacts well beyond physical safety and health. This includes psychosocial hazards, including exposure to job-related stressors. Occupational stress is associated with a range of negative outcomes, including insomnia[1] and cardiovascular disease.[2,3] Furthermore, the organization of work, especially long work hours and shiftwork, can impact employee physiology and health behaviors, including sleep, diet, and exercise.[4] In response to scientific evidence, and as a strategy for shaping the future of occupational health research and practice, the National Institute for Occupational Safety and Health has developed the *Total Worker Health*® approach. *Total Worker Health* (TWH) is defined as "policies, programs, and practices that integrate protection from work-related safety and health hazards with promotion of injury and illness-prevention efforts to advance worker well-being."[5(p1)] The current project adopted a TWH approach to studying and advancing the safety, health, and well-being of truck driving teams.

When considering TWH approaches to advancing worker safety, health, and well-being, sleep is a factor that cuts strongly across all three domains. First, sufficient sleep (duration and quality) is essential for excellent and safe performance. Sleep deficiency is a demonstrated occupational and public safety and health hazard[6–8] that is highly salient for commercial driving occupations. To illustrate, in a retrospective study with commercial truck drivers, excessive daytime sleepiness, sleep debt, and suspected sleep apnea were associated with increased odds for historical crashes and near crashes.[9] Commercial truck drivers with obstructive sleep apnea who are compliant with their continuous positive airway pressure treatment have no elevated crash risk; however, drivers who are not compliant with their treatment have a five-fold increased risk for serious crashes.[10] Second, there are tremendous additional "actions in the interactions" when considering sleep and health. More than 30% of employees exposed to job strain (high demands, low control) experience insomnia.[1] Sleep deficiency is associated with obesity, chronic diseases such as diabetes and high blood pressure,[11–13] and early death.[14,15] Potential ways that sleep deficiency may contribute to obesity and associated health conditions include impacts on metabolism,[11] food cravings and calorie consumption,[16] and tiredness[17] potentially reducing motivation to exercise. Research with commercial drivers confirms, and further elucidates, many such interactions between the occupation, sleep challenges, and a range of health factors.[18,19] For example, in a study of 88,246 commercial drivers' medical examinations, obesity was associated with increased risk for sleep disorders, mental health disorders, high blood pressure, diabetes, and low back pain.[20] Sleep deficiency can have further psychosocial impacts for employees, as sleep deprived individuals experience worsened mood and cognitive performance[17] and are more likely to mistreat others at work.[21]

Sleep deficiency is a special concern for shift workers who perform duties outside of a typical daytime shift (roughly 9:00 AM–5:00 PM). Such work often requires employees to perform job duties, eat, and exercise during their biological night, and attempt to sleep during their biological day. Social events and schedules during home time can also compete with efforts to entrain the body clock for shift work and get sufficient sleep. The misalignment between the body's biological clock time and living/sleeping periods can lead to a range of negative health experiences and outcomes for shift workers. This includes shift worker sleep disorder, which is characterized by difficulties going to sleep, staying asleep, sleeping when desired, and excessive sleepiness.[22]

Sleep challenges are particularly acute for truck driving teams. Such teams are pairs of drivers who take turns driving in the same truck. While one partner is driving, the other is typically off duty in the sleeper berth attempting to sleep in a moving and vibrating vehicle. Companies that employ driving teams as a business strategy typically do so, in part, to transport high value, high priority, or perishable freight. Team driving keeps the truck moving almost continuously, reduces chances for theft during parked periods, and can transport freight to the customer roughly twice as fast as solo driving. The work arrangement requires night driving and day sleeping, and teams typically must negotiate and plan their overall driving and sleeping patterns. Work periods may last a week or longer. Teams may take turns driving night or day shifts for each work period, assume permanent night or day driving roles based on preferences, and/or experience planned or unplanned drift in driving shifts during a particular working period. To illustrate, teams are likely to work on a schedule that is slightly shorter than 24 hours. For example, the first driver could complete an 11-hour driving segment (lasting 11.5 hours with a required 30-minute break included), take 1 hour to eat with their partner and take care of other needs, and then start a 10-hour sleeper berth period as their partner assumes the on-duty driving role. With this swapping sequence, the team would be running on a 22.5-hour day instead of a 24-hour day. If repeated consistently, the start of each driving shift and sleeping opportunity would drift 1.5 hours earlier each day.

Studies of team drivers' sleep and health are extremely limited. However, one study that included driving teams[23] found that team drivers were awakened four times more often in the sleeper berth than when they were at home, with evidence that truck vibrations were the probable cause of such awakenings. Because of required day sleeping and variable schedules, team drivers are at risk for shiftwork sleep disorder and associated problems (e.g., difficulty staying asleep or getting sufficient sleep during main sleep periods). This is a realistic reason why companies have advocated for flexibility in hours of service rules for teams and why the Federal Motor Carrier Safety Administration has supported pilot programs evaluating such flexible rules.[24,25] Finally, limited opportunities for physical activity and high levels of sedentary behaviors (e.g., sitting, laying down) are conditions of concern for all long-haul commercial truck drivers. These constraining conditions are exacerbated for driving teams, whose breaks may be briefer, occur at variable times during the day/night, and must meet the needs of two people.

To address the needs of driving teams and gaps in the literature, the Tech4Rest research program has employed the Hierarchy of Controls applied to TWH to guide the selection and evaluation of interventions.[26] This adjusted hierarchy asserts that the first priority and most effective strategy for protecting workers is to *eliminate* negative working conditions and barriers to safety, health, and well-being. This is followed by the strategies to *substitute* safer and healthier workplace policies, processes, and practices; *redesign* the work environment to enhance working conditions and improve safety, health, and well-being; *educate* all employees and provide resources for improved knowledge; and *encourage* or reinforce adoption of safe and healthy practices. Specifically, the Tech4Rest research has addressed hazard reduction through seat and mattress engineering controls (*redesign*), and complimented changes to the physical environment with a tailored behavioral intervention (*educate, encourage*). The research program includes a published pilot study[27] and a cluster randomized controlled trial. The current article is focused on reporting the results of the randomized controlled trial, but the pilot study and results provide important context and preliminary findings.

The Tech4Rest pilot study involved eight teams ($n = 16$ drivers) from two trucking companies based on the west coast of the United States. Driving teams at the first company primarily transported freight up and down the I-5 corridor with some work into Canada and experienced regular home time about once per week. Teams at the second company transported freight across the United States and experienced home time about every 2 to 3 weeks. The pilot began by evaluating a standard coil spring mattress and a novel therapeutic mattress at the first company with four teams. At the second company, an additional four teams completed the mattress conditions (in a counterbalanced order relative to the first company) and then completed an additional final phase that included the drivers' preferred mattress (100% chose to keep the therapeutic mattress), the addition of an active suspension seat, and participation in a behavioral sleep-health program named Fit4Sleep. The active suspension seat (ClearMotion Active Suspension Seat; ClearMotion, Inc, Billerica, MA) reduces exposures to whole-body vibration (WBV) by up to 50%[28,29] and also reduces indicators of end-of-shift fatigue.[29] The therapeutic mattress studied (ThevoRelief; Thomashilfen, Bremervörde, Germany) was recommended by an industry engineer to researchers because of favorable road testing with teams at an original equipment manufacturer. The Fit4Sleep behavioral program was informed by and adapted from prior effective interventions, including a physical activity–based intervention for insomnia[30] and a multicomponent mobile health intervention for truck drivers.[31] Each mattress evaluation phase lasted for 2 to 3 weeks. The final phase with all intervention components lasted for 3 months. Self-reported outcomes focused on sleep, fatigue, physical activity, and sleep hygiene behaviors and were measured after each phase. Additional actigraphic measures of physical activity and sleep were measured during the first week of each phase. An additional actigraphy sample was collected toward the end of the final phase. Measures of WBV were collected to confirm performance of the active suspension seats and explore for possible vibration altering characteristics of the therapeutic mattress.

Results of the pilot study were very encouraging. For the mattress evaluation phase ($n = 16$), the therapeutic mattress was universally and strongly preferred over drivers' original mattresses and the new coil spring mattress and produced larger improvements in sleep and fatigue outcomes relative to the new coil spring mattress. Effect sizes for the therapeutic mattress relative to the drivers' original mattress for self-reported sleep and fatigue outcomes ranged in magnitude from $d = 0.19$ (sleep duration) to $d = 0.82$ (sleep quality). The increase in sleep duration was also observed in actigraphic measures ($d = 0.31$). The final multicomponent phase produced the largest effect sizes for sleep and fatigue outcomes (d range was 0.37 [sleep duration] to 1.49 [sleep quality]). This final phase also generated large improvements in targets of the behavioral intervention, including self-reported physical activity ($d = 1.83$) and objectively measured weekly time in moderate intensity physical activity bouts ($d = 1.16$ and 0.29) at the beginning and end of the program, respectively.

The current article will summarize methods and results for the Tech4Rest cluster randomized controlled trial (ClinicalTrials registration NCT03108599). This project evaluated cab enhancements (*redesign*) alone and then in combination with a behavioral program (*educate, encourage*) with team drivers. Primary outcomes were focused on sleep (duration, quality) and fatigue. Secondary intervention outcomes addressed targets of the behavioral intervention, including physical activity and sleep hygiene behaviors. A range of additional relevant measures were collected, including optional behavioral intervention targets (e.g., body composition, diet), factors that might be reduced by cab enhancements (e.g., pain), factors that could be affected indirectly by improved sleep and reduced fatigue (e.g., safety), and intervention process and manipulation check variables (e.g., intervention participation, WBV exposures).

METHODS

Setting

The study was conducted in collaboration with a partner company that employed more than 5000 drivers, including a substantial number of driving teams. A safety manager and the vice president of safety were the study champions and secured corporate commitment to the project. The safety manager served as the company point person to work with researchers in implementing the project and helped form a planning team. A particular company division was identified as the focus of driver recruitment, and one specific terminal was identified as the location for completing driver study visits and seat and mattress installations. This company terminal included a shop where regular truck maintenance was performed. The planning team and local leaders from the participating terminal held regular meetings before and during implementation, with relevant leaders and staff from key operational units joining as needed (e.g., operations/driver managers, corporate, and local maintenance personnel).

Participants

Inclusion criteria included currently working as a team truck driver, having a driving teammate who was both willing and eligible to participate, intention to drive with their current teammate for the next 4 months, and ability to visit the terminal involved with the study at least once per month. In addition, if diagnosed with obstructive sleep apnea, drivers had to be treatment compliant (based on self-report). Exclusion criteria were that drivers could not be a lead driver or trainer, or a new driver still being trained by a lead driver. This was due to trainer/trainee relationships typically lasting for 30 or fewer days. We considered a minimum job tenure eligibility requirement but decided against it after deliberation with our organizational partner. In our experience, short job tenure (<1 year) is associated with a higher risk for job turnover in the trucking industry. However, the mixture of team member transitions on top of typical industry job turnover suggested that even a relatively short tenure requirement (e.g., 6 months) could make too many teams ineligible. In other words, a tenure requirement might have reduced potential study attrition but would have severely limited study enrollment.

Two waves of recruitment and implementation occurred. Wave 1 occurred between October 2020 and March 2021. Wave 2 occurred between April and August 2021. A third recruitment wave was initiated but ultimately canceled due to a lower than anticipated response to recruitment messaging (only 4 teams expressed interest) and other logistic considerations. Wave 3 was not rescheduled because of the 5-year grant period ending. Team drivers were recruited through standardized direct satellite text messages to their trucks and emails with the assistance of operations staff and driver managers. Driver managers were briefed on the study before recruitment messages were sent so they could answer questions and encourage participation. During the second wave of recruitment, driver managers were paid $150 in compensation if they had one or more teams volunteer for the study, and an additional $50 if they participated in a one-on-one interview about their experiences managing driving teams. Interested drivers were invited in recruitment messages to call researchers to discuss the study. In general, one member of the team tended to call and serve as the point of communication for the team, but individual calls with each team member sometimes occurred. For teams where both members were interested after the phone call, researchers worked with driver managers to route those teams to the terminal during a targeted enrollment period.

The informed consent process took place at the company terminal in person with each team. The consent form and process contained limited information about interventions, which were addressed separately after data collection was complete for teams that were randomized to the intervention (see Design and Conditions). Drivers in Wave 1 of recruitment were paid $75 for their first study visit and then $100 for each of three primary follow-up visits. Drivers in Wave 2 were paid $120 for completing each primary study visit with researchers.

The study was registered as a clinical trial before participant recruitment (NCT03108599). This registration specified the design and primary and secondary outcomes a priori. All study procedures were reviewed and approved by the Oregon Health & Science University Human Subjects Institutional Review Board. Additional COVID-19–related procedures (e.g., masking, distancing, sanitizing equipment, symptom monitoring, and responses) were followed to conduct the study during the pandemic. Disease transmission prevention procedures for research in the community were reviewed and approved by an ad hoc research committee that operated during modified operations at the university. These procedures were further supported and documented through a letter of support from the vice president of safety at the partner company.

A Priori Power Analysis and Recruitment

A target sample size of 80 drivers was selected based on an a priori power analysis. With this sample size, the planned data collection time points, and study design, the project would possess 80% power to detect a moderate effect size ($d = 0.60$) between groups in primary outcomes. This sample size target assumed 20% attrition by the final measurement time point (i.e., $n = 62$) and an AR(1) correlation structure with $\rho = 0.5$ for repeated observations within each driver. The power analysis also took into account the additional potential correlations between truck drivers within a team by assuming a conservative (i.e., relatively high) intracluster correlation coefficient of 0.25.

Design and Conditions

The study employed a cluster randomized controlled design with randomization at the level of team. Unassigned study IDs for teams were randomized in blocks of four teams by the fourth and fifth authors in advance of each recruitment wave and sealed in envelopes. Half of each block was randomly assigned to the intervention condition. Envelopes were sent to researchers in the field in limited numbers, as needed. After drivers completed the informed consent process at their first study visit, they were assigned a study ID and the relevant envelope revealing their condition was opened by researchers. However, teams were not informed of their randomized condition until after completing baseline data collection. Intervention teams were then informed of their additional activities and given a supplementary schedule summary noting additional events associated with visits, such as active suspension seat installation.

There were four primary study measurement visits that occurred at baseline and then after each study phase. For self-reported outcomes, the first and second visits were both functionally baseline condition assessments. In the current article, the first visit was used as the source of baseline data unless otherwise specified. Study phases and visits varied in duration to a degree based on the teams' schedules and included baseline (3–4 weeks), cab enhancements (3–4 weeks), and cab enhancements plus the behavioral sleep-health intervention (2 months for Wave 1 and 1 month for Wave 2). The duration of the behavioral program was shortened after Wave 1 in response to higher than anticipated turnover/attrition. Control participants worked as usual during these periods but were offered the mattress and part of the behavioral program after their fourth visit.

Control and Intervention Conditions

Standard seats at the company were Admiral air ride seats (National Seating, Franklin, TN) installed in Freightliner Cascadia 125 model trucks (2019–2022). Mattresses were model MFS (Designs International, Inc, Chatsworth, GA) coil spring mattresses with a foam layer. These are 6-in (15.2 cm) thick and covered with a polypropylene cover. All team drivers at the company had access to fatigue prevention related training during onboarding and as continuing education. This training addressed topics such as sleep schedules, circadian rhythm management, sleep cycles, risk periods, light changes affecting sleep, and health risks after time changes. Most of these trainings were videos with posttests.

Cab Enhancements

At the beginning of the cab enhancement period, intervention teams' trucks had the ClearMotion Active Suspension Seat (ClearMotion, Billerica, MA; formerly the Bose Ride® System II) installed. This seat system includes smart sensors, a linear electromagnetic actuator, and a computer system that detects vibrations and actively dampens their transmission to the driver. The seat also offers three driver-selected vibration dampening options (low, medium, and high). Drivers' standard company issued mattresses were replaced with the ThevoRelief "therapeutic" mattress (Thomashilfen, Bremervörde, Germany). This mattress includes a unique wing suspension system and a mattress with interlocking foams of different densities to support different body regions. The suspension system and mattress are held together in a cover that zips closed. Two mattresses were available for installation based on driver body weights. The ThevoRelief Model 100 (for body weights up to 100 kg) or ThevoRelief Model 135 (for body weights 100–135 kg; 19.1 × 99.1 × 190.5 cm [foam mattress component is 10.9 cm thick]). Both team members had to weigh greater than 100 kg to be assigned Model 135.

Cab Enhancements + Behavioral Program

The behavioral program was adapted from a prior effective mobile health intervention platform for truck drivers.[31] This mobile adaptive web application was modified to deliver a sleep-health program that was further informed by an effective physical activity–based intervention for insomnia.[30] This program, named Fit4Sleep for implementation, focused on increasing physical activity and sleep hygiene behaviors to improve sleep duration and quality, increase energy levels, and reduce fatigue. The Fit4Sleep website facilitated an interteam walking competition that included individual and team goal setting, behavioral self-monitoring, individual and interteam feedback, online training topics, and multiple calls with a health coach. Incentives were also provided for individual participation and for the team that won the walking competition (see Incentives for the Team Competition and Individual Achievement). After the 3- to 4-week cab enhancement phase, intervention teams completed an online Fit4Sleep training orientation, were then set up with a Web site account, and selected their goals with the help of researchers.

Goal Setting

Individual goal setting options for the walking competition included 50, 100, or 150 minutes of walking per week. The team goal was the sum of the two individual goals. Walking minutes were tracked and reported on an honor system and not with a step counter or accelerometer. Sleep hygiene behavioral goals included the following: 7- to 8-hours sleep, relaxing sleep routine, (all electronic) screens off 30 minutes before sleep, pleasant sleep environment (clean bedding, no light, noise control, 60–67°F), avoid caffeine or energy drinks 4 hours before bed, avoid nicotine 2 hours before bed, avoid alcohol 4 hours before bed, and limit naps to 20 to 30 minutes. An optional weight loss goal could also be selected to lose 3, 5, or 7 lb (1.4, 2.3, or 3.2 kg) as well as optional dietary behavioral goals (e.g., eat 5 servings of fruits and vegetables a day, reduce portion sizes).

Weekly Behavioral Self-monitoring With Feedback

Drivers were asked to login to the Web site and submit (track) their physical activity and sleep hygiene behaviors each week. Scores and feedback were updated with each submission. With each tracking submission, a driver reported their total minutes of walking that week, as well as the number of days that week that they achieved their selected additional sleep hygiene goals. Individual and team walking feedback charts showed histograms of weekly walking minutes relative to a goal line. In the team histogram, each team member's contribution to the total minutes each week was shown in a different color. The interteam competition rankings were shown by displaying the number of weeks each team in the competition met their goal using images of trucks with trailers filled in color for each week the team goal was met. Trucks for each team were rank ordered and identified with colors to distinguish a team from their competitors. To add interest to the feedback process, occasional pop-up messages with pictures were displayed when an individual had walked enough minutes to have traveled a particular distance, such as around the entire shoreline of Lake Tahoe. Sleep hygiene behavioral feedback was displayed as a data table with three columns—one for how many days in the last week they had performed the behavior, one for their best week, and one for the total days with the behavior.

Online Training

Drivers completed an online Fit4Sleep orientation training topic with researchers during study visit 3, which outlined the purpose of the challenge, activities, and incentives. Other topics that could be completed during the Fit4Sleep challenge period included "Why Fit4Sleep?" and "Healthy Sleep." Why Fit4Sleep addressed the sleep and health benefits of regular exercise, as well as interactions between health behaviors (e.g., sleep, eating, exercise). Healthy Sleep provided education on sleep physiology, circadian rhythms, and sleep hygiene practices. An additional topic was created and made available for friends and family members of the team drivers. Drivers were asked to invite people they lived with, especially spouses or partners they shared a bedroom with, to complete a topic titled "Fit4Sleep Family: Sleeping with a Shift Worker." This topic provided a very brief overview of the Fit4Sleep program, highlights from the drivers' longer training topics, and emphasized how couples and families could work together with their shift worker to maximize their sleep quantity and quality at home.

Health Coaching

Participants were offered up to four (Wave 1) and up to two (Wave 2) calls with a health coach. An experienced coach who was a member of the Motivational Interviewing Network of Trainers provided the majority of services. This person supervised two additional coaches who each had training in motivational interviewing. Each call followed a study-specific protocol informed by motivational interviewing spirit, principles, and strategies[32] and were requested to take place with drivers during off duty/nondriving time. Coaches called drivers for appointments, and appointments were rescheduled as needed. The purpose of the calls was to help drivers personalize the program to align with their personal motives and priorities. This included discussing the physical activity and sleep hygiene goals they had selected, the reasons for selecting those goals and wanting to make changes in those areas, and helping drivers form specific plans and strategies for accomplishing their goals. Exploring and resolving ambivalence about goals or making changes, eliciting change talk, and helping drivers make commitments (if ready) were all aims of the process.

Incentives for the Team Competition and Individual Achievement

The winning team was the one that achieved their team walking goal on the most weeks during the challenge (8 weeks being the maximum for Wave 1 and 4 weeks being the maximum for Wave 2). During Wave 1, the incentive for winning the interteam competition was $100. Individual drivers could also earn Fit4Sleep certification by logging their goals on the Web site at least six times, passing the three required trainings with a score of at least 80%, and completing four health coaching calls. The incentive for earning certification in Wave 1 was $100. During Wave 2, the incentive for winning the interteam competition was a sleep- or health-related item chosen from a menu of options (e.g., a weighted blanket, white noise machine). Individual drivers earned Fit4Sleep certification in wave 2 by logging their goals on the Web site four times, passing the three required trainings with a score of at least 80%, and completing two health coaching calls. The incentive for earning certification in Wave 2 was $95.

Measures

Demographics

Measures collected to describe the sample addressed sex, race/ethnicity, marital status, relationship with driving partner, education, work hours/miles, work tenure, work-related stress, collision history, and health behaviors/conditions.

Primary Outcomes

Primary outcomes focused on self-reported sleep and fatigue. Sleep duration was measured with item four ("When working and traveling in your truck, how many hours of actual sleep did you get during a typical night [or day, for shift workers]?") adapted from the Pittsburgh Sleep Quality Index.[33] If item four was missing, we calculated total sleep time by subtracting items three ("When working and traveling in your truck, what time have you usually gotten up?") from item one ("When working and traveling in your truck, what time have you usually gone to bed?"), accounting for item two ("When working and traveling in your truck, how long [in minutes] has it usually taken you to fall asleep?"). Sleep quality was measured with item six from the Pittsburgh Sleep Quality Index,[33] which was reversed scored so that higher values indicate better sleep quality, as well as with the eight-item short-form version of the Patient-Reported Outcomes Measurement Information System (PROMIS) sleep disturbance questionnaire.[34,35] PROMIS sleep disturbance items (e.g., "My sleep was restless") were measured on a five-point Likert scale ranging from 1 = "Not at all" to 5 = "Very much" (with one item, "My sleep quality was," measured on a scale from 1 = "Very good" to 5 = "Very poor"), and all items were summed for a total score (control baseline Cronbach $\alpha = 0.94$; intervention baseline $\alpha = 0.82$). Fatigue was measured with the eight-item short-form version of the PROMIS sleep-related impairment questionnaire,[34,35] and the eight-item Swedish Occupational Fatigue Index.[36] Items on the PROMIS sleep-related impairment questionnaire (e.g., "I was sleepy during the daytime") were measured on a five-point Likert scale ranging from 1 = "Not at all" to 5 = "Very much," and all items were summed for a total score (control baseline $\alpha = 0.86$; intervention baseline $\alpha = 0.83$). Items on the Swedish Occupational Fatigue Index were measured on a seven-point Likert scale ranging from 0 = "Not at all" to 6 = "To a very high degree," and all items were summed for a total score (control baseline $\alpha = 0.86$; intervention baseline $\alpha = 0.88$). We asked participants to respond to all self-report items as they experienced them in the past month, or since their last visit with the research team, when working and traveling in their truck.

Self-reported sleep measures were supplemented with actigraphs worn on the wrist for 1-week periods (Actigraph GT3x + or GT3x-BT; Actigraph, Pensacola, FL). The Actigraph ActiLife software algorithm includes downweighting of vibrations/movements outside the typical human cycles per second generated by walking or jogging.[37] In our preliminary studies, this feature also seemed to benefit the accuracy of software coding of sampled intervals as sleep or wake in vibrating sleeper berths. Electronic log books obtained from the partner company and sleep diaries were used to help identify sleeper berth periods and rest intervals (bed and wake times). A study-specific sleep scoring protocol was created, informed by several past actigraphy projects, that involved inspecting a visualization of log book, sleep diary, and ActiLife sleep/wake epochs together to manually set rest intervals for main sleep periods for each driver day. Resulting actigraphic outcomes calculated for rest intervals included total sleep time and sleep efficiency during main sleep periods.

Secondary Outcomes

Secondary outcomes focused on factors targeted by the behavioral intervention and general health and well-being. Sleep hygiene practices were measured with the 13-item Sleep Hygiene Index.[38] Items (e.g., "I went to bed at different times from day to day") were measured on a five-point Likert scale ranging from 0 = "Never" to 4 = "Always," and items were summed for a total score (control baseline $\alpha = 0.64$; intervention baseline $\alpha = 0.82$). Note that one item ("I slept on an uncomfortable bed") was omitted from this total score because of the inherent bias introduced by the intervention mattress. Self-reported physical activity was measured with two items from the International Physical Activity Questionnaire–short form.[39,40] Participants were asked to report on how many days in the past week they engaged in at least 10 minutes of moderate and vigorous physical activity, respectively.

Objectively measured physical activity was measured with hip worn accelerometers worn for 1-week periods (Actigraph GT3x + or GT3x-BT; Actigraph). As noted previously, the Actigraph ActiLife software algorithm includes downweighting of vibrations/movements outside the typical cycles per second generated by human activity.[37] To further minimize contamination by false activity generated by vibrating trucks, physical activity actigraphic analyses focused on the occurrence of bouts of moderate or vigorous physical activity lasting 10 or more minutes[41] using settings available in ActiLife software. In unpublished preliminary studies,[42] we found that moderate-intensity physical activity bouts were never falsely generated by trucks during driving time as recorded in electronic driving logs. Days with excessive nonwear time (>240 continuous min) were excluded from analyses. Objective physical activity outcomes were average bouts per week and average minutes per week spent in activity bouts.

Self-assessed physical and mental health were measured with the PROMIS Global Health scale.[43,44] Although response anchor labels varied across items, all items were measured on a 1 to 5 scale. Total physical (control baseline $\alpha = 0.60$; intervention baseline $\alpha = 0.33$) and mental health (control baseline $\alpha = 0.85$; intervention baseline $\alpha = 0.76$) scores were computed by summing each subscale's four items, respectively.

Other Outcomes

Additional outcomes in the study, which are included in this article primarily for their potential descriptive value for future studies of team drivers, were composed of self-reported collisions with and without truck or property damage, minor (first aid treatment only) and major (resulting in lost work time) injuries at work, pain intensity and interference with normal home and work activities, and health factors related to optional goals in the behavioral program (e.g., body composition, blood pressure, dietary behaviors). Collisions were measured with three items ("How many times have you struck a curb or object with no property damage?", "While operating your work vehicle, did you have any safety incidents or collisions involving another vehicle that resulted in vehicle/property damage?", and "While operating your work vehicle, did you have any safety incidents or collisions involving only your own vehicle that resulted in vehicle/property damage?") measured on a scale from 0 to 5+ incidents, adapted from previously developed safety items for truck drivers.[31] Minor (first aid only) and major (lost work time) injuries were measured with two respective items on a scale from 0 to 5+ injuries, adapted from a previously developed common set of occupational injury items.[45] The time anchor for collision and injury questions was in the past month or since we last saw you. Informed by the Nordic Musculoskeletal Questionnaire and similar Nordic-style assessments using body maps,[46–48] pain intensity was reported at its worst in the past seven days, ranging from 0 = "No pain" to 10 = "Worst pain imaginable," in the past week for the following five body areas, respectively: neck/shoulders, forearm/wrist, low back, upper back, and lower extremities. Pain intensity items were summed for a total score. Also informed by Nordic-style assessments, pain interference was measured on a five-point Likert scale, ranging from 1 = "Not at all" to 5 = "Extremely" for each of the five body areas, during the past month or since the last study visit. Items were summed for a total score. Body weight and percent body fat were measured with a Tanita TBF-310GS scale (Tanita Corporation, Tokyo, Japan). Body mass index was calculated from measured body weight and measured height with a SECA 213 stadiometer (SECA, Hamburg, Germany). Blood pressure was measured with an Omron Intellisense Digital Blood Pressure Monitor HEM-907XL (Omron Healthcare, Inc, Bannockburn, IL) as the average of three consecutive measurements. Dietary measures included the frequency (0 = "Never" to 9 = "5 or more times per day" in the past month or since the last study visit) of consumption of sugary snacks, sugary drinks, fast food meals, and meals brought from home.[49] Each item was treated as a separate outcome. A single item assessing the usual number of servings of fruit and vegetables consumed per day was also administered, with serving size examples informed by Thompson et al.[50]

Process/Manipulation Checks

To confirm that the active suspension seats were turned on and reducing WBV exposures, we collected triaxial accelerometer samples (AX3; Axivity Ltd, Newcastle, United Kingdom) of vibrations from the truck floor and seat top during baseline and cab enhancement periods. Additional exploratory samples were collected from the mattress top under the pillow, on the bed frame, and on the floor near the mattress. Axivity devices sampled at 400 Hz for approximately four days. GPS data (Model CR-Q1100P; Qstarz Co, Taipei, Taiwan) were collected to identify driving periods for analysis. Electronic log book data were also collected from our partner company.

For the WBV analysis, LabVIEW programs (Version 2016; National Instruments, Austin, TX) were used to align acceleration data with GPS data and combine them into one file for each team. Using the GPS data, a 1-hr segment of the aligned data was identified for analysis for each team where the truck was traveling at freeway speed (approximately 105 km/h). A LabVIEW program then applied weighting to the raw, unweighted acceleration data in each file segment as described in ISO 2631-1.[51] Finally, additional LabVIEW programs were used to calculate daily vibration exposure, or A(8) from the selected 1-hr data segments, which was the predominant, *Z*-axis average weighted vibration exposures standardized to an 8-hr day.

To evaluate intervention dose or exposure for the behavioral intervention we assessed number of tracking submissions completed, number of training topics completed with 80% correct, number of coaching calls completed, and whether individuals earned Fit4Sleep Certification.

Intervention Effectiveness Analysis Methods

Intervention effectiveness was evaluated with an intent-to-treat analysis using data from baseline, cab enhancement, and cab enhancement + behavioral program conditions. By definition, intent-to-treat analysis "…is a method for analyzing results in a prospective randomized study where all participants who are randomized are included in the statistical analysis and analyzed according to the group they were originally assigned, regardless of what treatment (if any) they received."[52(p1075)] This is a criterion standard analysis approach for clinical trials that uses available data from all participants at all time points. Specifically, as we planned a priori in our research protocol, we modeled the outcomes using generalized linear mixed models (GLMM), which offer a method for handling missing data without requiring imputation. Generalized linear mixed models extend the basic linear model through the addition of random effect terms, which account for the dependence between observations, as with repeated measures for the same individual over time. Mixed models are well suited to dealing with missing data due to dropout, as they do not require the same number of observations per subject, so that inferences made about the sample can be based on all available measurements.[53] The intent-to-treat analysis is thus conservative and maximizes use of contributed data.

RESULTS

Of the 49 participants who enrolled the study, 32 completed all 4 primary study visits (65.3% retention). The most common reason for leaving the study was job turnover. Other common reasons included the breakup of a driving team and one member not following up or continuing (see Fig. 1 for the CONSORT diagram). This experienced sample size after attrition was half of the study's target sample size after estimated attrition (32 vs 64).

The sample averaged 41.0 years (SD = 12.8 years) and was predominantly male (81.2%), White (46.9%), and unmarried or not living with a partner (64.3%). Reported relationships with driving partners were predominantly company assigned (34.7%) or "other" (40.8%; presumed to be a self-selected or chosen partner from within the company). The remaining quarter of the sample worked with their spouse or boyfriend/girlfriend as their team member. Reported average tenure as a team truck driver was less than 2 years, and tenure with their current team driver partner was close to 1 year on average (although the average partnership tenure for intervention teams was less than half a year). Notable levels of health-related factors in the sample included 54.2% reporting being current smokers and 30.6% reporting chronic pain. The majority of drivers were categorized as being low or intermediate risk for obstructive sleep apnea based on the STOP-BANG assessment. See Table 1 to review additional sample demographics.

Results for Primary and Secondary Outcomes

In the intent-to-treat analysis differences between groups in both primary and main secondary outcomes were predominantly nonsignificant, with the exception of significant differences between groups in objective physical activity during the final phase (Table 2). Therefore, trends in results are discussed with an emphasis on descriptive effect sizes of $d = 0.20$ or greater. Directional trends for four of five self-reported primary outcomes favored the intervention group at the final visit (the sufficiency of data samples for actigraphic sleep outcomes were limited and were therefore excluded from intent-to-treat analyses). Effect sizes greater than $d = 0.20$ were observed in favor of the intervention group for sleep quality ($d = 0.39$), sleep

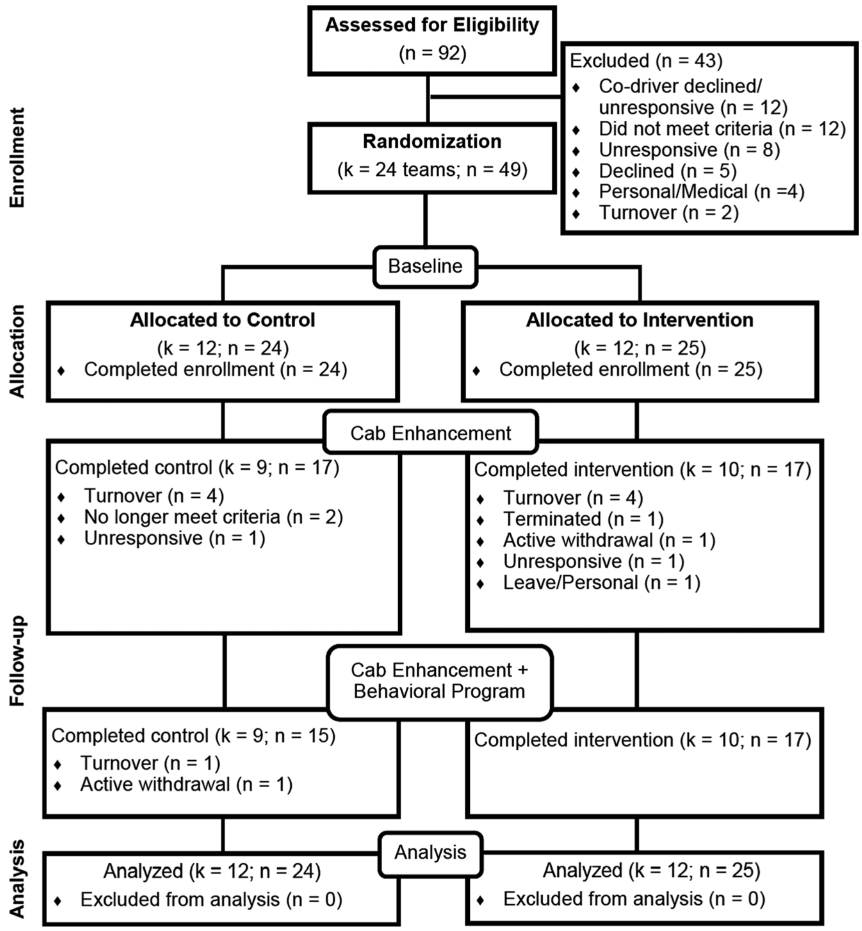

FIGURE 1. Consort Diagram: Tech4Rest Randomized Controlled Trial. Note. In Wave 2, one of the codrivers on an intervention team left the company and study after baseline. The new codriver of that team was recruited and enrolled in the study during the cab enhancement visit. This is the reason for an odd number of drivers in the intervention arm at baseline.

disturbance (d = −0.42), and sleep-related impairment (d = −0.41). Trends in secondary outcomes were more mixed. To illustrate, consider trends in the behavioral intervention targets. Changes in self-reported moderate physical activity and sleep hygiene behaviors favored the intervention group after the cab enhancement condition but then changed to favor the control group at the final time point when the intervention would be expected to achieve its peak effects. This pattern was different for objectively measured moderate intensity physical activity bouts, with results favoring the control group after the cab enhancement phase, but then strongly favoring (at a statistically significant level) the intervention group during the final condition. General physical health favored the intervention group at the final time point (d = 0.20), however, reported general mental health favored the control group at the same time point (d = −0.50).

Given the observed study attrition rate of 34.7%, a descriptive analysis of only study "completers" (n = 32) was conducted for primary and main secondary study outcomes (see Table S1, http://links.lww.com/JOM/B379). The rationale was to examine descriptive statistics for those who completed all study time points and compare results to the intent-to-treat GLMM analysis. The results of this analysis for self-reported primary outcomes roughly mirrored the GLMM analysis for sleep and fatigue outcomes (4 of 5 differences favored the intervention group at the final time point). Effect sizes in favor of the intervention group for self-reported sleep duration, sleep disturbance, and sleep-related impairment were all slightly larger for completers compared with the intent-to-treat analysis. A subsample of drivers (n = 11) had sufficient sleep actigraphy, electronic log, and/or sleep diary data at the relevant three time points (minimum of 2 days of data at each time point) to be included in completers' analyses. Intervention effects on actigraphic sleep duration were substantially larger in magnitude than those observed with self-reported outcomes for both post–cab enhancement (d = 1.93) and post-behavioral program (d = 1.87) time points. However, actigraphic sleep efficiency effects trended in the unexpected direction at post–cab enhancement (d = −0.37) and post-behavioral program (−1.03). For additional outcomes in the completers' analyses, trends were similar but with very large effect sizes in favor of the intervention group for actigraphically measured minutes per week in moderate intensity activity bouts (d = 14.59) and total bouts per week (d = 5.33).

Results for Other Outcomes and Process Measures

The results for other outcomes relevant to driver safety, health, and well-being were predominantly nonsignificant (see Table S2, http://links.lww.com/JOM/B380). Factors related to optional goals in the behavioral program included body weight and dietary behaviors. Body weight was relatively stable during the intervention period across both groups. The majority of trends in dietary behavioral outcomes favored the control group at the final time point with small-to-medium effect sizes. Two statistically significant differences were observed among optional goal related factors, and included changes favoring the control group post–cab enhancement in percent body

TABLE 1. Sample Demographics: The Tech4Rest Randomized Controlled Trial

Variable	Intervention (*n* = 24) Mean (SD) or *n* (%)	Control (*n* = 25) Mean (SD) or *n* (%)	Total Sample (*N* = 49) Mean (SD) or *n* (%)
Age, yr	40.22 (11.05)	41.71 (14.550)	40.98 (12.84)
Sex (% female)	4 (16.67)	5 (20.83)	9 (18.75)
Race			
American Indian/Alaskan Native	1 (4.17)	2 (8.00)	3 (6.12)
Asian	0 (0.00)	1 (4.00)	1 (2.04)
Black/African American	4 (16.67)	6 (24.00)	10 (20.41)
Native Hawaiian/Pacific Islander	1 (4.17)	0 (0.00)	1 (2.04)
White/Caucasian	12 (50.00)	11 (44.00)	23 (46.94)
>1 race	4 (16.67)	3 (12.00)	7 (14.29)
Other	2 (8.33)	2 (8.00)	4 (8.16)
Ethnicity (% Hispanic)	6 (25.00)	4 (16.67)	10 (20.83)
Household			
Married or living with partner	11 (45.83)	7 (28.00)	18 (36.73)
Dependent children ≥1	8 (33.33)	7 (29.17)	15 (31.25)
Relationship with driving partner			
Company assigned	9 (37.50)	8 (32.00)	17 (34.69)
Spouse	2 (8.33)	1 (4.00)	3 (6.12)
Boyfriend, girlfriend	3 (12.50)	6 (24.00)	9 (18.37)
Other	10 (41.67)	10 (40.00)	20 (40.82)
Education			
Grades 1–8 (elementary)	1 (4.17)	0 (0.00)	1 (2.04)
Grades 9–11 (some high school)	1 (4.17)	1 (4.00)	2 (4.08)
Grade 12 or GED (high school graduate)	7 (29.17)	12 (48.00)	19 (38.78)
College 1–3 yr (some college/technical school)	12 (50.00)	8 (32.00)	20 (40.82)
College 4 yr or more (college grad)	3 (12.50)	3 (12.00)	6 (12.24)
Graduate school (masters or doctoral)	0 (0.00)	1 (4.00)	1 (2.04)
Work hours/miles			
Total weekly driving hours	59.95 (12.86)	57.48 (20.117)	58.66 (16.90)
Total weekly on-duty hours	67.64 (11.04)	64.50 (18.23)	66.00 (15.14)
Work-related stress			
(Job) stress in general (7–35)[a]	20.34 (5.54)	19.88 (7.49)	20.11 (6.50)
Tension with driving partner (0–5)[a]	0.44 (0.61)	0.28 (0.60)	0.36 (0.60)
Tenure, yr			
Industry	1.40 (1.75)	2.77 (7.38)	2.10 (5.40)
Current company	1.04 (1.64)	1.83 (7.03)	1.44 (5.11)
As a team truck driver	1.12 (1.66)	2.21 (6.02)	1.68 (4.44)
With current driving partner	0.44 (0.46)	1.80 (6.92)	1.14 (4.95)
Collisions and injuries in last 5 yr			
≥1 Collision w/ property damage only	3 (12.50)	6 (24.00)	9 (18.37)
≥1 Collision w/ injury	0 (0.00)	1 (4.17)	1 (2.08)
Health behaviors and conditions			
Smoked within past week	13 (54.17)	13 (54.17)	26 (54.17)
Used alcohol within past month	12 (50.00)	7 (29.17)	19 (39.58)
High blood pressure	1 (4.17)	4 (16.00)	5 (10.20)
High blood pressure medication	0 (0.00)	3 (75.00)	3 (60.00)
High cholesterol	1 (4.17)	1 (4.00)	2 (4.08)
High cholesterol medication	1 (100.00)	0 (0.00)	1 (50.00)
Osteoarthritis/arthritis	4 (16.67)	1 (4.00)	5 (10.20)
Arthritis medication	1 (25.00)	0 (0.00)	1 (20.00)
Asthma	3 (12.50)	1 (4.00)	4 (8.16)
Asthma medication	1 (33.33)	0 (0.00)	1 (25.00)
Diabetes	0 (0.00)	1 (4.00)	1 (2.04)
Diabetes medication	NA	1 (100.00)	1 (100.00)
Anxiety	3 (12.50)	3 (12.50)	6 (12.50)
Anxiety medication	3 (100.00)	3 (100.00)	6 (100.00)
Depression	2 (8.33)	1 (4.00)	3 (6.12)
Depression medication	2 (100.00)	1 (100.00)	3 (100.00)
Chronic pain	8 (33.33)	7 (28.00)	15 (30.61)
Chronic pain medication	4 (50.00)	1 (14.29)	5 (33.33)
Obstructive sleep apnea risk			
Low risk	17 (70.83)	15 (60.00)	32 (65.31)
Intermediate risk	4 (16.67)	7 (28.00)	11 (22.45)
High risk	3 (12.50)	3 (12.00)	6 (12.24)

Note. Sample sizes for some variables were less than the maximum possible due to occasional missing data.

[a]Higher score = higher stress or tension. Job stress was measured with the Stress in General Scale.[47] Tension was measured with a question created for a daily sleep diary and was a single or average rating per person based on the question "How much tension was there with your driving partner yesterday?"

GED, General Educational Development Test; NA, not applicable.

TABLE 2. Intent-to-Treat Analysis of Intervention Effects (*N* = 49): The Tech4Rest Randomized Controlled Trial

Outcomes	Intervention, Mean (SE)	Control, Mean (SE)	Diff. in Diff. (SE)	Effect Size[a]	*P*
Primary outcomes					
Sleep duration (hr)					
Baseline	6.58 (0.36)	7.27 (0.36)			
Post–cab enhancement	7.11 (0.42)	7.46 (0.42)	0.34 (0.59)	0.19	0.565
Post-Fit4Sleep	7.44 (0.40)	7.87 (0.43)	0.27 (0.63)	0.14	0.671
Sleep quality (0–3)					
Baseline	1.76 (0.14)	1.63 (0.14)			
Post–cab enhancement	1.87 (0.15)	1.77 (0.15)	−0.03 (0.18)	−0.03	0.867
Post-Fit4Sleep	2.06 (0.15)	1.64 (0.17)	0.28 (0.21)	0.39	0.199
Sleep disturbance (8–40)					
Baseline	18.99 (1.36)	23.13 (1.39)			
Post–cab enhancement	17.32 (1.53)	20.69 (1.54)	0.77 (1.87)	0.02	0.685
Post-Fit4Sleep	15.67 (1.53)	21.99 (1.61)	−2.18 (1.92)	−0.42	0.264
Sleep-related impairment (8–40)					
Baseline	14.92 (1.07)	17.38 (1.09)			
Post–cab enhancement	13.72 (1.19)	15.89 (1.20)	0.28 (1.33)	0.01	0.834
Post-Fit4Sleep	12.56 (1.27)	16.96 (1.31)	−1.95 (1.56)	−0.41	0.220
Fatigue (0–48)					
Baseline	11.76 (1.91)	16.23 (1.95)			
Post–cab enhancement	10.47 (2.13)	14.09 (2.15)	0.86 (2.48)	0.10	0.732
Post-Fit4Sleep	11.22 (2.17)	12.74 (2.23)	2.95 (3.05)	0.34	0.340
Secondary outcomes					
Sleep hygiene (0–48)					
Baseline	17.32 (1.40)	20.00 (1.43)			
Post–cab enhancement	16.41 (1.57)	17.62 (1.58)	1.47 (1.88)	0.25	0.439
Post-Fit4Sleep	16.62 (1.51)	20.32 (1.55)	−1.03 (1.81)	−0.15	0.574
Moderate physical activity (0–7 d)					
Baseline	1.68 (0.40)	1.38 (0.42)			
Post–cab enhancement	2.85 (0.48)	1.89 (0.48)	0.66 (0.78)	0.25	0.401
Post-Fit4Sleep	1.76 (0.51)	1.69 (0.53)	−0.16 (0.70)	−0.10	0.822
Vigorous physical activity (0–7 d)					
Baseline	1.56 (0.44)	1.27 (0.45)			
Post–cab enhancement	1.90 (0.50)	1.58 (0.50)	0.03 (0.69)	−0.01	0.970
Post-Fit4Sleep	1.77 (0.52)	1.62 (0.53)	−0.19 (0.70)	−0.11	0.782
Minutes per week in bouts					
Baseline	2.38 (5.46)	10.33 (5.32)			
Post–cab enhancement	1.01 (5.91)	15.39 (6.08)	−6.42 (10.68)	−0.46	0.550
Post-Fit4Sleep	19.43 (6.84)	2.64 (6.58)	24.82 (11.92)	3.24	0.041
Freedson bouts per week					
Baseline	0.16 (0.19)	0.63 (0.19)			
Post–cab enhancement	0.09 (0.45)	1.20 (0.46)	−0.66 (0.80)	−0.75	0.410
Post-Fit4Sleep	0.65 (0.26)	0.22 (0.25)	0.89 (0.45)	1.58	0.050
Physical health (4–20)					
Baseline	15.16 (0.43)	14.67 (0.44)			
Post–cab enhancement	15.20 (0.49)	14.78 (0.49)	−0.07 (0.61)	−0.03	0.911
Post-Fit4Sleep	15.75 (0.48)	14.91 (0.49)	0.35 (0.63)	0.20	0.580
Mental health (4–20)					
Baseline	14.88 (0.63)	13.04 (0.64)			
Post–cab enhancement	14.24 (0.71)	13.50 (0.71)	−1.10 (0.84)	−0.35	0.200
Post-Fit4Sleep	14.71 (0.69)	14.54 (0.71)	−1.67 (0.82)	−0.50	0.049

[a]Effect size calculation: (Mean change in intervention group / standard deviation [raw] of pre-score in intervention group) − (Mean change in control group / standard deviation [raw] of pre-score in control group). Sleep quality was measured with a single item on a scale from 0 ="Very bad" to 3-"Very good," such that higher scores indicate better sleep quality. Sleep disturbance and sleep-related impairment were computed as the sum score of eight items, respectively, on a scale from 1 = "Not at all" to 5 = "Very much," such that higher scores indicate greater sleep disturbance and impairment. Fatigue was computed as the sum score of eight items on a scale from 0 = "Not at all" to 6 = "To a very high degree," such that higher scores indicate greater fatigue. Sleep hygiene was computed as the sum score of 12 items on a scale from 0 = "Never" to 4 = "Always," where higher scores indicate worse sleep hygiene (Note: the item, "I slept on an uncomfortable bed," was omitted from the calculation because of the inherent bias of the introduction on the new mattress for intervention participants). Mental and physical health were computed as sum scores of four items, respectively, on a variety of scale anchors ranging from 1 to 5, such that higher scores indicate better health.

fat and fruit and vegetable intake. However, bioelectric impedance measurement of percent body fat is affected by hydration levels, and thus the more stable body weight outcomes should be considered the more reliable assessment of body composition. Trends in pain outcomes were also stable across groups with effect sizes smaller than 0.10. Collisions and injuries have low base rates, and within a 3- to 4-month study protocol, it was not expected that we would see between group differences in these outcomes. As expected, frequencies were very low and these outcomes are reported in Table S2 (http://links.lww.com/JOM/B380) mainly for descriptive purposes.

A subsample of trucks with the most complete WBV data samples were selected for manipulation check analyses for truck seats (5 trucks). Results confirmed that the active suspension seats were installed and functioning as designed, with A(8) WBV exposures extrapolated from the 1-hour of measurement being lower when compared the standard air ride seat. The mean (SD) exposures from the original seat were 0.26 m/s^2 (±0.05 m/s^2) compared with the active suspension intervention seat 0.16 (±0.03). In other words, the active suspension seat reduced WBV exposure by 38.5% relative to the original seat. Analyses of mattress tops relative to the floor were explored but were not deemed reliable enough to report (e.g., large standard deviations, less objective methods for confirming occupancy compared with the seat).

Fit4Sleep participation varied across waves, with higher general participation in the smaller Wave 1. Intervention participation data analyses focused on the subsample of 17 intervention drivers who remained in the study at visit 3, which is when the Fit4Sleep program was initiated. In Wave 1, all four drivers completed at least one coaching call and averaged 3.0 (SD = 0.8) of 4 possible sessions. In Wave 2, 12 of 13 drivers completed at least one health coaching call, and the group average calls completed was 1.4 (SD = 1.0) of 2 expected sessions. Wave 1 drivers averaged 6.8 (SD = 2.5) of 8 possible weekly logs. Participation in weekly logging was limited to one driver in Wave 2 who completed 2 of 4 possible logs, producing a group average in Wave 2 of 0.2 (SD = 0.6) logs submitted.

Both intervention implementation waves could complete three possible training topics. All 17 drivers completed the orientation training and averaged 46.0% and 93.0% in pretest and posttest, respectively. The average total number of training topics completed was 1.4 (SD = 0.7), with Waves 1 and 2 averaging 2.0 (SD = 1.2) and 1.2 (SD = 0.4), respectively. In Wave 2, only two drivers completed the Why Fit4Sleep training and no drivers completed the Healthy Sleep training.

DISCUSSION

Although trends in primary sleep-related outcomes favored the intervention group, these differences were predominantly nonsignificant and effect sizes were generally smaller than those observed in the Tech4Rest pilot study. All results considered, the favorable trends and descriptive effect sizes for sleep-related outcomes should be viewed as encouraging. The study was underpowered, and thus the risk for type 2 errors was elevated (falsely retaining null hypotheses). Among secondary outcomes, we observed large and statistically significant intervention effects on actigraphically measured physical activity levels (a target of the behavioral intervention) during the final intervention phase. Patterns in other outcomes were mixed, with some nonsignificant trends and one significant difference in a secondary outcome favoring the control group (e.g., mental health).

One possible explanation for the observed smaller or mixed effects is that the interventions are actually not effective and that the previously observed pilot effects were due to random chance variation. We believe that this explanation is unlikely to be true given the strength and consistency of pilot results, the established benefits of the active suspension seat alone, the evidence-based history of the behavioral intervention, the trends observed in the current randomized controlled trial for sleep-related outcomes, and large and significant effects on objective physical activity observed in the trial. Another explanation is that the interventions were less effective and produced smaller effect sizes than in the pilot due to such factors as shorter condition durations, the foam layer in the standard mattress at the participating company, and lower levels of participation in the behavioral intervention. These factors, in combination with the underpowered sample size due to recruitment and attrition challenges, are a more likely set of explanations for the results observed.

Qualitative observations and interviews with drivers provide some possible reasons why study attrition was higher than expected, and intervention participation was lower than expected. Teams were highly stable and participated through a longer study protocol without any turnover during the pilot study. In the current project during Wave 1 higher within team and company turnover was observed, and thus adjustments were made to the duration of the behavioral program and driver manager incentives were added to protect against attrition in Wave 2. Corporate culture, organizational systems, and methods for matching team members together are possible explanations for the higher turnover. In addition, demands on team drivers were very high in general during the study period due to seasonal holiday demands and also general high demand for transportation services during the COVID-19 pandemic. These demands seemed to suppress intervention participation beyond completing the online orientation and coaching calls. Wave 1 began during the holiday peak transportation season. Drivers reported working very long hours and corporate incentives were in place to work through the holidays. For drivers participating in Wave 2, many reported extreme weather as a barrier to participation (ranging from floods to temperatures reaching 110 degrees) in addition to stressful workloads (e.g., being given too many loads of freight to drop off and not enough time). Drivers shared that these demands impacted their ability and/or desire to spend time outside of work logging their behaviors on the Fit4Sleep Web site or completing the online training. In addition, some drivers cited not being very tech savvy and/or having difficulty accessing the Web site to log their behaviors as barriers.

Strengths, Limitations, and Future Directions

Strengths of the study include the randomized controlled design, interventions prioritized by the Hierarchy of Controls, evidence-based intervention components that included changes to physical working conditions, baseline measures collected before drivers were informed of randomization, objective measurement of physical activity, and measurement of intervention exposure or dose. Favorable trends in sleep-related outcomes, large and significant improvements to objective measures of physical activity, the effectiveness of the active suspension seat at reducing WBV, and drivers' strong preferences for the therapeutic mattress are all encouraging of future replications and extensions of cab enhancements and behavioral sleep-health programs for truck driving teams.

Limitations suggest areas for future research, including issues to address in replications and extensions. First, the current project did not achieve its target sample size of 80 drivers, which was based on an a priori power analysis. There is a need for future research studies with fully powered samples. In this regard, effect sizes observed in the Tech4Rest pilot and randomized trial may inform future power analyses, study designs, and target sample sizes. While studies with larger samples are desirable, there is also scientific value in replication or repeatability of descriptive effect sizes. Smaller studies that reproduce effects are of value. Furthermore, the project did not alter work schedules to be more consistent or stable, or measure circadian disruption. Circadian disruption due to work and sleep variability is highly probable in the team driving arrangement. Although very difficult to implement with a mobile workforce, future research would benefit from measuring biological clock time of team drivers at baseline using in-lab measures such as dim light melatonin onset from salivary samples.[54] This biological clock time could then be analyzed in relation to drivers experienced schedules and sleep and fatigue outcomes. We believe that it is particularly critical for future research with team drivers to measure and investigate sleep regularity, which is emerging as an important correlate with negative health outcomes and poor performance.[55,56]

Although a study strength was that physical technology in the cab was enhanced, the project did not address other potentially disrupting factors for sleep, such as noise, temperature, and potential light pollution. Future research would benefit from measuring exposures to factors such as light from screens or studying interventions to reduce factors such as noise through improved vehicle insulation. Furthermore, while the therapeutic mattress seems to be preferred by driving teams, there remains great opportunity for innovation in this area. For example, it might be feasible to develop active suspension or partial active suspension bed platforms that would be more effective at reducing disturbing vibrations and jostling in the sleeper berth (analogous to the major advances in seat technology) than a therapeutic mattress alone. On this theme, future translational research and outreach are needed to increase adoption of active suspension seats, which have been demonstrated to substantially reduce WBV exposures[28] and reduce indicators of end-of-shift fatigue.[29]

Furthermore, the inclusion of objective actigraphic measures of bouts of moderate-intensity physical activity was a strength of the study. This bout analysis approach increased confidence that large truck vibrations were not generating false physical activity. However, at the same time, the bout approach excluded lower-intensity physical activity. Future researchers are encouraged to experiment with the integration of additional biometric measures through other types of wearable sensors to accurately measure lower-intensity physical activity, as well as to more easily or accurately assess sleep duration and quality with commercial drivers. In the domain of sleep measurement and analysis, actigraphic measures of sleep were collected during the study, but sufficient data were available for only a small subset of drivers. Actigraphic sleep analyses are particularly challenging to complete for participants who sleep in a vibrating environment, and in the current project, electronic log book and sleep diary data sources were integrated into the study-specific sleep scoring protocol. In future studies, complimenting sleep actigraphy with measures such as head position, respirations, or heart rate would all help increase the ease of scoring and accuracy of outputs. In preliminary studies a head-worn single channel electroencephelogram device (Sleep Profiler; Advanced Brain Monitoring, Carlsbad, CA) was evaluated, but it was polluted too severely by vehicle vibrations to use in the study. To our knowledge, the now unavailable Nightcap,[23] which measured head position, eye movements, and eyelid activity, is perhaps the most reliable method in the literature for assessing sleep among teams in a vibrating sleeper berth.

Finally, the strong Tech4Rest pilot results considered in combination with encouraging findings from the randomized trial (criterion standard design, yet underpowered) indicate a need for research that adapts, replicates, or extends evaluation of these various intervention components. This could include research to further delineate if and how the therapeutic mattress alters vibration exposures and specific reasons why it has been so well received by team drivers. The behavioral intervention would also benefit from further study to understand whether low participation was due to transient or unique factors present during the pandemic, particular transportation seasons, or persistent characteristics of the team driving occupation. Given the relatively strong levels of participation in the pilot, it is possible that the behavioral program is a relatively good fit with teams that are highly stable and long lived, but not such a good fit for teams that are shorter lived or at companies with higher turnover rates. Given the safety sensitive nature of the work, future research and practice to maximize participation in tailored sleep and health interventions for teams is desirable.

CONCLUSIONS

The safety, health, and well-being of commercial truck drivers are socially important topics. The commercial truck driving workforce is essential and integral to global economies, yet these people experience a range of challenging working conditions that increase their risk for many negative health outcomes. We believe that TWH approaches are called for when addressing commercial driver health, including the application of the Hierarchy of Controls to selecting and evaluating interventions. Interventions to improve sleep sufficiency are perhaps central for commercial drivers, as it is a factor that cuts strongly across safety, health, and well-being. Sleep is particularly salient for truck driving teams who sleep in moving and vibrating vehicles and also experience highly variable shiftwork schedules. Trends observed in the Tech4Rest pilot and randomized controlled trial encourage future replications and extensions of both cab enhancements and behavioral sleep-health programs for team drivers. Evidence is strong for the benefits of active suspension seats for reducing WBV and improving other outcomes among commercial drivers. Future research is encouraged to study seats, mattresses, and additional cab enhancements, as well as studying and altering work schedules and job design. Research and practice related to tailored behavioral programs is also needed to compliment changes to working conditions as they are likely to provide further benefits for workers. Results observed in the current study supported the effectiveness of the Fit4Sleep intervention for increasing physical activity. Trends in sleep-related outcomes were encouraging. Employers can use such behavioral programs to fulfill their obligations to inform employees about known hazards in their jobs—especially those hazards that are poorly controlled or difficult to control—and also educate and encourage employees to work in ways that minimize their exposures and maximize their safety, health, and well-being.

ACKNOWLEDGMENTS

The authors thank Dr Josef Loczi for his passion for driver well-being, introducing the PIs (Drs Olson and Johnson), and his collaboration developing early ideas for the project. The authors also thank the following research staff for their contributions: Dr Kelsey Womack for project management of earlier stages of the project; Dr. Fangfang Wang for contributions to vibration data analyses in earlier stages of the project; Caitlyn Trullinger-Dwyer, Jason Malach-Fuller, Josie Valesco, Alan Rodriquez Tiburcio, and Ivanna de Anda for data collection and implementation work; Ivana de Anda and Alan Rodriguez Tiburcio for sleep actigraphy data processing and scoring; Alan Rodriquez Tiburcio for managing in-text citations and the reference list; and Dr Stacy Stoffregen for assistance with figures and manuscript editing. The authors thank Carol DeFrancesco for providing motivational interviewing coaching services and supervision, and Caitlyn Trullinger-Dwyer for providing coaching services. Finally, The authors thank leadership and staff at our partnering company, as well as the volunteering drivers, for their efforts that made the study possible.

Total Worker Health® is a registered trademark of the US Department of Health and Human Services (HHS). Participation by the Oregon Healthy Workforce Center in this project does not imply endorsement by HHS, the Centers for Disease Control and Prevention, or the National Institute for Occupational Safety and Health.

REFERENCES

1. Kalimo R, Tenkanen L, Härmä M, Poppius E, Heinsalmi P. Job stress and sleep disorders: findings from the Helsinki Heart Study. *Stress Med* 2000;16:65–75.
2. Backé EM, Seidler A, Latza U, Rossnagel K, Schumann B. The role of psychosocial stress at work for the development of cardiovascular diseases: a systematic review. *Int Arch Occup Environ Health* 2012;85:67–79.
3. Sara JD, Prasad M, Eleid MF, Zhang M, Widmer RJ, Lerman A. Association between work-related stress and coronary heart disease: a review of prospective studies through the job strain, effort-reward balance, and organizational justice models. *J Am Heart Assoc* 2018;7:e008073.
4. Apostolopoulos Y, Lemke M, Sönmez S, Hege A. The obesogenic environment of commercial trucking: a worksite environmental audit and implications for systems-based interventions. *Am J Health Educ* 2016;47:85–93.
5. Tamers SL, Chosewood LC, Childress A, Hudson H, Nigam J, Chang CC. *Total Worker Health®* 2014–2018: The novel approach to worker safety, health, and well-being evolves. *Int J Environ Res Public Health* 2019;16:321.
6. Colten HR, Altevogt BM, Institute of Medicine (US) Committee on Sleep Medicine and Research (Eds.). The National Academies Collection: reports funded by National Institutes of Health. In: *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem*. Washington, DC: National Academies Press (US). 2006.
7. Lockley SW, Barger LK, Ayas NT, Rothschild JM, Czeisler CA, Landrigan CP. Effects of health care provider work hours and sleep deprivation on safety and performance. *Jt Comm J Qual Patient Saf* 2007;33(11 suppl):7–18.
8. Garbarino S, Nobili L, Beelke M, De Carli F, Ferrillo F. The contributing role of sleepiness in highway vehicle accidents. *Sleep* 2001;24:203–206.
9. Garbarino S, Durando P, Guglielmi O, et al. Sleep apnea, sleep debt and daytime sleepiness are independently associated with road accidents. a cross-sectional study on truck drivers. *PLoS One* 2016;11:e0166262.
10. Burks SV, Anderson JE, Bombyk M, et al. Nonadherence with employer-mandated sleep apnea treatment and increased risk of serious truck crashes. *Sleep* 2016;39:967–975.

11. Buxton OM, Cain SW, O'Connor SP, et al. Adverse metabolic consequences in humans of prolonged sleep restriction combined with circadian disruption. *Sci Transl Med* 2012;4:129ra143.
12. Cappuccio FP, D'Elia L, Strazzullo P, Miller MA. Quantity and quality of sleep and incidence of type 2 diabetes: a systematic review and meta-analysis. *Diabetes Care* 2010;33:414–420.
13. McAllister EJ, Dhurandhar NV, Keith SW, et al. Ten putative contributors to the obesity epidemic. *Crit Rev Food Sci Nutr* 2009;49:868–913.
14. Grandner MA, Hale L, Moore M, Patel NP. Mortality associated with short sleep duration: the evidence, the possible mechanisms, and the future. *Sleep Med Rev* 2010;14:191–203.
15. Wingard DL, Berkman LF. Mortality risk associated with sleeping patterns among adults. *Sleep* 1983;6:102–107.
16. Brondel L, Romer MA, Nougues PM, Touyarou P, Davenne D. Acute partial sleep deprivation increases food intake in healthy men. *Am J Clin Nutr* 2010; 91:1550–1559.
17. Dinges DF, Pack F, Williams K, et al. Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4–5 hours per night. *Sleep* 1997;20:267–277.
18. Apostolopoulos Y, Sönmez S, Shattell MM, Belzer M. Worksite-induced morbidities among truck drivers in the United States. *AAOHN J* 2010;58:285–296.
19. Garbarino S, Guglielmi O, Sannita WG, Magnavita N, Lanteri P. Sleep and mental health in truck drivers: descriptive review of the current evidence and proposal of strategies for primary prevention. *Int J Environ Res Public Health* 2018;15:1852.
20. Thiese MS, Moffitt G, Hanowski RJ, et al. Commercial driver medical examinations: prevalence of obesity, comorbidities, and certification outcomes. *J Occup Environ Med* 2015;57:659–665.
21. Rajaratnam SM, Barger LK, Lockley SW, et al. Sleep disorders, health, and safety in police officers. *JAMA* 2011;306:2567–2578.
22. Cleveland Clinic. Shift work sleep disorder. Available at: https://my.clevelandclinic.org/health/diseases/12146-shift-work-sleep-disorder. Published 2021. Accessed August 23, 2023.
23. Dingus T, Neale V, Garness S, et al. *Impact of Sleeper Berth Usage on Driver Fatigue, Final Project Report*. Virginia Tech Transportation Institute: Virginia; 2001.
24. Short J. *Technical Memorandum: Hours-of-Service Flexibility.* American Transportation Research Institute: Atlanta, GA; 2018.
25. Federal Motor Carrier Safety Administration. Hours of service of drivers; pilot program to allow commercial drivers to split sleeper berth time. In: Administration FMCS, ed: Federal Register; 2017:26232–26237. Available at: https://www.govinfo.gov/content/pkg/FR-2017-06-06/pdf/2017-11642.pdf. Accessed August 23, 2023.
26. National Institute for Occupational Safety and Health. Hierarchy of controls applied to NIOSH Total Worker Health. Centers for Disease Control and Prevention. Available at: https://www.cdc.gov/niosh/twh/guidelines.html. Published 2020. Updated December 28, 2020. Accessed August 23, 2023.
27. Olson R, Johnson P, Shea SA, et al. Advancing the safety, health, and well-being of commercial driving teams who sleep in moving semi-trucks: the Tech4Rest pilot study. *J Occup Environ Med* 2020;62:1082–1096.
28. Johnson PW, Zigman M, Ibbotson J, Dennerlein JT, Kim JH. A randomized controlled trial of a truck seat intervention: part 1—assessment of whole body vibration exposures. *Ann Work Expo Health* 2018;62:990–999.
29. Du BB, Bigelow PL, Wells RP, Davies HW, Hall P, Johnson PW. The impact of different seats and whole-body vibration exposures on truck driver vigilance and discomfort. *Ergonomics* 2018;61:528–537.
30. Wang J, Yin G, Li G, Liang W, Wei Q. Efficacy of physical activity counseling plus sleep restriction therapy on the patients with chronic insomnia. *Neuropsychiatr Dis Treat* 2015;11:2771.
31. Olson R, Wipfli B, Thompson SV, et al. Weight control intervention for truck drivers: the SHIFT randomized controlled trial, United States. *Am J Public Health* 2016;106:1698–1706.
32. Miller WR, Rollnick S. *Motivational Interviewing: Helping People Change*. 3rd ed. New York, NY: Guilford Press; 2013.
33. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index (PSQI): a new instrument for psychiatric research and practice. *Psychiatry Res* 1989;28:193–213.
34. Yu L, Buysse DJ, Germain A, et al. Development of short forms from the PROMIS™ sleep disturbance and sleep-related impairment item banks. *Behav Sleep Med* 2012;10:6–24.
35. Cella D, Riley W, Stone A, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005–2008. *J Clin Epidemiol* 2010; 63:1179–1194.
36. Ahsberg E. Dimensions of fatigue in different working populations. *Scand J Psychol* 2000;41:231–241.
37. ActiGraph Software Department. *ActiLife 6 User's Manual*. Pensacola, FL; 2012.
38. Mastin D, Bryson J, Corwyn R. Assessment of sleep hygiene using the Sleep Hygiene Index. *J Behav Med* 2006;29:223–227.
39. Lee PH, Macfarlane DJ, Lam TH, Stewart SM. Validity of the International Physical Activity Questionnaire short form (IPAQ-SF): A systematic review. *Int J Behav Nutr Phys Act* 2011;8:115.
40. Craig CL, Marshall AL, Sjostrom M, et al. International Physical Activity Questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003; 35:1381–1395.
41. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. *Med Sci Sports Exerc* 1998;30:777–781.
42. Wipfli B, Olson R, Uba U, et al. Physical activity actigraphy among truck drivers: accounting for seat vibrations. Poster presented at: the American College of Sports Medicine Conference; May 27–31, 2014; Orlando, FL.
43. Hays RD, Bjorner JB, Revicki DA, Spritzer KL, Cella D. Development of physical and mental health summary scores from the Patient-Reported Outcomes Measurement Information System (PROMIS) global items. *Qual Life Res* 2009;18:873–880.
44. Cella D, Yount S, Rothrock N, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS): progress of an NIH roadmap cooperative group during its first two years. *Med Care* 2007;45:S3–S11.
45. Hanson GC, Rameshbabu A, Bodner TE, et al. A comparison of safety, health, and well-being risk factors across five occupational samples. *Front Public Health* 2021;9:614725.
46. Kuorinka I, Jonsson B, Kilbom A, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon* 1987;18:233–237.
47. Dennerlein JT, Hopcia K, Sembajwe G, et al. Ergonomic practices within patient care units are associated with musculoskeletal pain and limitations. *Am J Ind Med* 2012;55:107–116.
48. Hedge A, Morimoto S, Mccrobie D. Effects of keyboard tray geometry on upper body posture and comfort. *Ergonomics* 1999;42:1333–1349.
49. Buxton OM, Quintilliani LM, Yang MH, et al. Association of sleep adequacy with more healthful food choices and positive workplace experiences among motor freight workers. *Am J Public Health* 2009;99:S636–S643.
50. Thompson FE, Subar AF, Smith AF, et al. Fruit and vegetable assessment: performance of 2 new short instruments and a food frequency questionnaire. *J Am Diet Assoc* 2002;102:1764–1772.
51. International Organization for Standardization. *ISO 2631-1(1997): Mechanical Vibration and Shock—Evaluation of Human Exposure to Whole-Body Vibration—Part 1: General Requirements*. Geneva, Switzerland: International Organization for Standardization; 1997.
52. McCoy CE. Understanding the intention-to-treat principle in randomized controlled trials. *West J Emerg Med* 2017;18:1075–1078.
53. Chakraborty H, Gu H. *A Mixed Model Approach for Intent-to-Treat Analysis in Longitudinal Clinical Trials with Missing Values*. Research Triangle Park, NC: RTI Press; 2009.
54. McHill AW, Phillips AJ, Czeisler CA, et al. Later circadian timing of food intake is associated with increased body fat. *Am J Clin Nutr* 2017;106:1213–1219.
55. Lunsford-Avery JR, Engelhard MM, Navar AM, Kollins SH. Validation of the sleep regularity index in older adults and associations with cardiometabolic risk. *Sci Rep* 2018;8:14158.
56. Phillips AJK, Clerx WM, O'Brien CS, et al. Irregular sleep/wake patterns are associated with poorer academic performance and delayed circadian and sleep/wake timing. *Sci Rep* 2017;7:1–13.