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Real-Time Fatigue Reduction in Emergency Care Clinicians: The SleepTrackTXT Randomized Trial

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Abstract

Background—We assessed performance characteristics and impact of a mobile phone text-message intervention for reducing intra-shift fatigue among emergency clinician shift workers.

Methods—We used a randomized controlled trial of 100 participants. All participants received text-message assessments at the start, every 4-hours during, and at end of scheduled shifts over a 90-day period. Text-message queries measured self-rated sleepiness, fatigue, and difficulty with concentration. Additional text-messages were sent to intervention participants to promote alertness. A performance measure of interest was compliance with answering text-messages.

Results—Ninety-nine participants documented 2,621 shifts and responded to 36,073 of 40,947 text-messages (88% compliance rate). Intervention participants reported lower mean fatigue and sleepiness at 4 hours, 8 hours, and at the end of 12-hour shifts compared to controls ($p < 0.05$). Intervention participants reported better sleep quality at 90-days compared to baseline ($p = 0.01$).

Conclusions—We showed feasibility and short-term efficacy of a text-message based assessment and intervention tool.

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AUTHOR CONTRIBUTION STATEMENT: PDP, CWC, DMY, BPS, CGM, and MDW conceived the study idea and framework. PDP, CGM, DJB, JMD, and MDW developed the study protocol, data collection tool, and study methodology. PDP, BPS, MDW, JMD, and KLM carried out the collection of study data. PDP, CGM, JMD, and MDW analyzed study data. All authors/investigators examined study findings, interpreted study findings, and synthesized study findings for reporting in a peer-reviewed manuscript. All authors participated in development and editing of the draft manuscript, providing input and editing for all components, including the introduction, methods, results, discussion and conclusions. Authors agree to be accountable for this research.

COMPETING INTERESTS

The authors report no competing interests or conflicts of interests.

INTRODUCTION

More than one-third of adult workers report fatigue [Ricci et al., 2007]: an “unpleasant symptom incorporating feelings of tiredness to exhaustion creating conditions that interfere with the ability to function in a normal capacity” [Ream et al., 1996]. Shift workers, including emergency medical services (EMS) clinicians, commonly report high levels of fatigue, poor sleep, and difficulty recovering between shifts [Geiger-Brown et al., 2012; Jansen et al., 2002; Patterson, Suffoletto, et al., 2010; Totterdell et al., 1995; Winwood et al., 2006]. The negative effects of sleep loss and fatigue related to shift work include impaired decision-making, reduced alertness, injury, and medical error [Rogers 2008; Williamson et al., 2011]. Few organizations that employ EMS clinician shift workers have a formal workplace program to address fatigue and sleep health.

An EMS shift worker is a healthcare clinician who provides emergent healthcare to the critically ill or injured. In the United States, there are more than 19,000 EMS agencies and between 800,000 to 1 million EMS workers [Chapman et al., 2008; Mears et al., 2011]. EMS work is unpredictable and requires quick decision-making to care for acute and chronic medical conditions outside the hospital setting. Lifting and moving patients, using heavy equipment, and operating ambulances at high-speeds are common tasks of EMS workers. The occupation is stressful and has a high rate of reported burnout [Bowron et al., 1999; Cydulka et al., 1994; Roth et al., 2009]. Standards and regulations for shift work scheduling in U.S.-based EMS systems are limited, with common use of 12-hour and 24-hour shifts [Patterson, Suffoletto, et al., 2010; Patterson, Weaver, et al., 2012]. Some systems use longer shift lengths such as a 48-hour on-duty followed by a 96-hour off duty schedule. In some settings, greater than 80% work multiple jobs and many work overtime [Bauder 2012; Frakes and Kelly, 2007]. More than half of EMS workers report poor sleep quality and work-related fatigue, and one-third report excessive daytime sleepiness [Patterson, Suffoletto, et al., 2010; Patterson, Weaver, et al., 2012; Pirralo et al., 2012]. Research links worker fatigue to workplace injury [Patterson, Weaver, et al., 2012].

Signs and symptoms of fatigue and sleepiness can vary over short time intervals [12], yet few studies have captured this variation prospectively. One study of 47 insomnia and 18 control study subjects utilized handheld computers to capture daytime symptoms of insomnia, including fatigue, four times per day over seven days [Buysse et al., 2007]. Compliance with answering symptom queries was high ($>90\%$, $\pm 12.7\%$), and findings highlighted a hypothesized diurnal variation in symptoms that were previously unidentified with cross-sectional survey and retrospective data collection techniques. Another study recorded self-reported sleepiness among nurses at the start, every 2-hours during, and at the end of 12-hour shift schedules using an electronic watch device [Geiger-Brown et al., 2012]. Findings show a near linear increase in severity of sleepiness over the course of a 12-hour shift. Few studies have used similar techniques and technology to study fatigue and sleepiness in the emergency medicine shift worker population.

Mobile phones are low cost and represent a potentially high yield resource for real-time assessment and intervention of fatigued or sleepy emergency medicine clinicians and other shift workers. Over 90% of Americans own a cell phone or smartphone and 80% send and

receive text-messages [Duggan, 2013; Smith, 2013]. Previous research notes high compliance with text-message based interventions, measurable changes in behavior, and prolonged adherence with activities and behaviors promoted via text-message [Buhi et al., 2012; Donaldson et al., 2013]. Text-message based interventions tailored to fit sleep and alertness-promoting behaviors could benefit shift worker sleep health and impact work related fatigue by overcoming challenges observed in well-organized sleep health interventions (e.g., long-term adherence, loss of motivation, and maintenance) [Alves et al., 2013; Buysse et al., 2011; Riebe et al., 2005; Wing et al., 2005]. Experts have evaluated challenges with fatigue monitoring and management in operational settings [Balkin et al., 2011]. We are unaware of any prior studies that test use of mobile phone text-messages to facilitate real-time assessment and intervention of fatigue or sleepiness symptoms among emergency medicine healthcare shift workers.

We developed a real-time, text-message based assessment and intervention tool for research purposes known as SleepTrackTXT [Patterson, Moore, et al., 2014]. As a first step to determine the usefulness of our tool, we planned a pilot trial to examine the tool's performance, which included assessing participant compliance (responsiveness) with answering text-message queries and participant satisfaction with the study tool. We also sought to explore the impact of our brief intervention delivered by text-message on reducing intra-shift fatigue among EMS shift workers.

METHODS

Study aims and hypotheses

Our primary aim was to determine the performance characteristics of a text-messaging tool as the primary medium for delivery of a sleep and fatigue intervention for EMS shift workers. We considered compliance with answering text-message queries and qualitative feedback regarding participant satisfaction with text-messages as a tool for assessment and intervention as key characteristics of performance. For our second exploratory aim, we sought to determine if a text-message based program reduced perceived sleepiness, fatigue, or difficulty with concentration during shift work or had an impact on established sleep health and fatigue indicators (e.g., the Pittsburgh Sleep Quality Index and Epworth Sleepiness Scale).

Study Design and Study Sample

We designed a two-arm parallel, randomized, controlled and single blinded trial [Patterson, Moore, et al., 2014]. We were inclusive of all types of U.S. based emergency medicine clinician shift workers that may function in this environment and did not limit recruitment or enrollment to a certain type of clinician (e.g., a paramedic in a busy urban environment). Many work in diverse settings, including systems based in fire departments, air-medical systems, hospital-based models, public utility systems, privately based operations, and many other diverse types of settings. An EMS clinician shift worker may work in diverse clinical settings as part of his or her regular duties or as part of a second job. For example, EMS clinicians based out of a hospital often spend a percentage of their time in the ED or ICU. More than half, and as much as 80%, of EMS clinician shift workers hold multiple jobs

[Frakes and Kelly, 2007]. Given the diversity of EMS employment, we recruited emergency medicine clinicians that work in the prehospital and in-hospital setting as EMS shift workers. We recruited through a publicly available study-designated website hosted on a University computer system. The website contained instructions, which invited individuals to email or call study investigators to schedule a telephone-based screening. We scheduled screening on a first-come, first-serve basis and screened eligible participants through a baseline telephone procedure. Eligibility criteria included: 1) 18 years of age and older; 2) employed in the emergency care setting as an emergency physician, emergency nurse, emergency medical technician or paramedic; 3) currently work shifts as part of employment in the emergency care setting; 4) have a text-message enabled cellphone / smartphone; 5) willing to take part in a research study that requires the sending and receiving of multiple text-messages at the start, during, and end of shift work.

We limited our study to 100 EMS shift workers and randomized each to one of two groups (n=50 each):

- a. The intervention group participated for 90-days and received automated short-message-service (SMS) [aka: text-messages] from a computer-based SMS directed system. Text-messages included questions to EMS workers on their perceived sleepiness, fatigue, difficulty with concentration, and work-related injury. We sent text-messages at the beginning, every 4-hours during, and at the end of scheduled shifts. Intervention participants received one of four additional text-messages, selected at random, if they reported a high level of sleepiness or fatigue at the beginning or during their shift. These additional messages focused on strategies an EMS worker could use during shift work to reduce fatigue and improve alertness.
- b. The control group received the same scheduled text-messages assessments concerning sleepiness, fatigue, and difficulty concentrating at the beginning, every 4-hours during, and at the end of shift analogous to the intervention group for 90 days. Participants in this group did not receive additional alertness promoting text-messages if a high level of sleepiness or fatigue was reported. Our study protocol and design have been published elsewhere and are described below in accordance with the CONSORT statement [Patterson, Moore, et al., 2014]. The University of Pittsburgh Institutional Review Board approved the design and we registered at clinicaltrials.gov (NCT02063737). All subjects gave informed consent.

Randomization

An IRB approved consent procedure was triggered upon initial access to the web-based portal. Randomization occurred when eligible EMS shift workers logged into the secure, web-based participant portal and completed informed consent. We then randomized participants based on an automated adaptive algorithm, assigning participants using a 1:1 allocation (intervention group and control group). An imbalance in sample sizes between the two groups was restricted to no more than 4. An SQL software program embedded in our process created the random number generator.

Intervention

Our intervention was designed to reduce EMS shift worker fatigue and improve alertness during shift work. Upon reporting a high-level of sleepiness, fatigue, or difficulty with concentration, the study participant was sent an opening text-message that links sleepiness and fatigue to bad outcomes “*No joke – Being very sleepy or fatigued on duty can increase your risk of injury.*” This message was followed by one of four randomly selected strategies the authors’ felt would help improve alertness during shiftwork. Strategy messages were developed based on their connection to improved alertness and reduced sleepiness during shift work: 1) naps and rest time [Bonnefond et al., 2001; Garbarino et al., 2004; Petrie et al., 2004; Sallinen et al., 1998; Smith-Coggins et al., 2006; Takahashi et al., 1999; Tempesta et al., 2013]; 2) consumption of caffeine [Ker et al., 2010]; 3) physical exercise [Harma, et al., 1988a; Harma et al., 1988b; Matsumoto, et al., 2002; Yoshida, et al., 1998]; and 4) use of talking/conversation with partners on duty as a form of mental exercise to stay alert [Rosekind, et al., 1996]. Strategy messages included: (1) *If you can, take a short 20–30 minute nap on duty;* (2) *Try drinking a caffeinated beverage like coffee to stay awake;* (3) *Try doing some stretches or other exercise to stay alert;* (4) *Stay alert by talking to your partner when work is slow.* All intervention messages were tracked by our automated system. All participants that received an intervention message were queried at the end of the shift about the effectiveness of the message received. The text-message based query began with: “*During your shift, did you take a nap, drink caffeine, stretch or exercise, OR talk to your partner to stay alert?*” YES / NO. If the participant responded YES, the next message sent was: “*Good For You! What strategy did you adopt?*” After the subject offers a description via text-message, the system responds: “*Did it help reduce your fatigue or sleepiness?*” YES / NO. We have outlined a detailed schedule our protocol for text-messages for both intervention and control participants in a previous publication [Patterson, Moore, et al., 2014].

Control

Control group study subjects received text messages for assessment only at the beginning, during, and end of shifts. We sent no interventional text-messages to control subjects.

Remuneration

All participants received a coffee mug and \$10 gift card at completion of enrollment. Study subjects received a \$10 gift card at completion of 30-days, and again at completion of 60, and 90-days. We entered study participants completing all steps into a drawing for one of five tablet computers.

Measures

Participant level measures—At baseline, we collected age, sex, license/certification, type of work setting, number of clinical jobs, years of experience, full-time employment status, number of shifts worked in previous month, length of shift most commonly worked, self-perceived health status, and height/weight. We collected age, years of experience, and number of shifts worked in previous month as a continuous variable and stratified age into five categories based on previous research [Winwood et al., 2006]. Categories of licensure/

certification include: EMT-Basic, Paramedic, Nurse, Physician, and other. We stratified type of work setting as: ground-based EMS, air-medical EMS, emergency department, intensive care unit, and other. Similarly, we dichotomized the number of jobs (employment) as 1 or >2. We collected employment status as full-time or part-time/volunteer, and the type of shift length most commonly worked, stratifying length as <12-hour shift, 12-hour shift, and >12-hour shift. We collected self-reported health status as excellent, good, fair/poor. We created the variable Body Mass Index (BMI) based on the participant's self-reported height (feet / inches) and weight in pounds. Categories of BMI include: Underweight (<18.5), Normal (18.5–24.9), Overweight (25.0–29.9), and Obese (>30.0).

We used standard measures of sleep quality, sleepiness, and fatigue at baseline, including the Pittsburgh Sleep Quality Index (PSQI) [Buysse et al., 1989], the Epworth Sleepiness Scale (ESS) [Johns, 1991], and the Chalder Fatigue Questionnaire (CFQ) [Chalder et al., 1993]. The CFQ was used previously in emergency workers and was shown reliable and valid [Patterson, Jones, et al., 2010; Patterson, Weaver, et al., 2012]. We measured attitudes about shift scheduling with five select items from the Schedule Attitudes Survey (SAS) [Dunham et al., 1986]. Higher SAS scores on selected items signify negative views (dissatisfaction) towards one's current schedule. We used the Occupational Fatigue, Exhaustion, Recovery Scale (OFER) to measure chronic fatigue, acute fatigue, and intershift recovery [Winwood et al., 2005]. The OFER includes three sub-scales with higher OFER scores indicating more chronic and acute fatigue, and better ability to recover between shifts.

We also measured an EMS worker's intent to engage in behaviors that improve alertness using the Sleep, Fatigue, & Alertness Behavior Survey (SFAB) [Patterson, Buysse et al., 2014]. The SFAB is a content-valid tool based on the Integrated Model of Behavioral Prediction [Fishbein et al., 2003]. The SFAB is comprised of eight domains and 50-items. Domains include; 1) *attitudes* about improving or maintaining alertness on duty; 2) *perceived norms* regarding what the person or others (peers) think or feel about being sleepy or fatigued while at work; 3) *self-efficacy* regarding improving or maintaining alertness while on duty; 4) *knowledge* of behaviors for improving or maintaining alertness on duty; 5) *salience* (perceived importance) of specific alertness behaviors; 6) *habits* linked to sleepiness, fatigue, and alertness; 7) *environmental constraints* to performing specific alertness promoting behaviors; and 8) *intention* to perform one or more behaviors [Patterson, Buysse, et al., 2014].

Shift level measures and primary outcome—All participants, regardless of group status, received four text-message queries at the start of every scheduled shift: 1) “*How many hours did you sleep in past 24 hours?*” 2) “*Rate SLEEPINESS now (0–5) with 0=Not At All, and 5=Very Much. Text ‘slp’ for definition of sleepiness.*” 3) “*Rate FATIGUE now (0–5) with 0=Not At All, and 5=Very Much. Text ‘ftg’ for definition of fatigue.*” 4) “*How difficult is it to CONCENTRATE now (0–5) with 0=Not At All, and 5=Very Much. Text ‘cct’ for definition of concentration.*” All participants received the above listed text-messages 2 – 4 every four hours during scheduled shifts. At the end of scheduled shifts, all participants were asked six questions via text-message. The first message was: “*How many hours did you sleep DURING your shift? (Example, 0 hours).*” This message was followed by messages 2 – 4 listed above, and a question about patient volume: “*Estimate total number of*

patients you saw during your shift.” The final text-message question asked of all participants was: *“Were you injured during your shift? Text ‘inj’ for definition of injury.”* Participants that reported an injury were asked to rate their fatigue, sleepiness, and difficulty with concentration at the time of injury. They were also sent a final text-message: *“Be sure to follow your employer’s protocol for injury reporting. These text messages are for research purposes only.”* We programmed our data collection system to accept a participant’s text-message response within 60-minutes of the first query and within 15-minutes of subsequent queries. The following text-message was sent if a respondent exceeded the time limit: *“Sorry we missed your response. We will check in next shift.”* We outlined the schedule of all shift-level text-messages in a previous publication of the study’s protocol [Patterson, Moore, et al., 2014].

We treated fatigue reported at the end of scheduled shifts as our primary outcome of interest. Self-reported work-related injury was a second measure of interest. Participants could report work-related injury by: 1) answering the end shift text-message question about injury; or 2) by submitting an unsolicited text-message to the study designated phone number while on-duty (during shiftwork) or while off-duty. We chose to use single-item measures of fatigue, sleepiness, and difficulty with concentration based on principles of Ecological Momentary Assessment (EMA) research [Shiffman et al., 2008; Stone et al., 2007], and based on prior EMA research of patients with insomnia [Buysse et al., 2007].

For the purpose of presenting study findings in a format relevant to EMS employers, we stratified shift schedules into three categories (<12 hours, 12 hours, and >12 hours), and defined a <12 hour shift as any shift 599 minutes, a 12 hour shift as any shift 600 minutes and 840 minutes, and a >12 hour shift as any shift 841 minutes and 1500 minutes. Extended shifts are those 1501 minutes or >25 hours in length. We base this approach to stratification on: 1) the most common shift durations in EMS are 12 and 24-hours [Patterson, Suffoletto, et al., 2010; Patterson, Weaver, et al., 2012; Patterson, Weaver, Weaver, et al., 2012]; 2) eight-hours or less is widely considered a standard work day [Caruso et al., 2004]; 3) shifts lasting between 8 and 10-hours in duration are not common in EMS and most likely the result of overtime on an irregular basis; 4) shifts lasting between 10 and 12-hours most likely represent cases where a worker left work early for a regularly scheduled 12-hour shift; 5) shifts lasting between 12 and 14-hours may represent overtime associated with a regularly scheduled 12-hour shift; and 6) shifts lasting longer than 14-hours are most likely intended to be a shift scheduled for 16-hours, 24-hours, or longer as shown in previous research [Patterson, Suffoletto, et al., 2010; Patterson, Weaver, et al., 2012].

Follow-up measures—Study participants completed a web-based survey and in-depth telephone interview after 90-days. The web-based survey included the following survey instruments: the PSQI, CFQ, SAS, OFER, and SFAB. The in-depth telephone interview collected the following qualitative information: 1) problems experienced during study period; 2) opinions on use of text-messaging to capture sleepiness and fatigue during shift work; 3) perceptions on the number of text-messages per shift, per day, per week; 4) estimated number of shifts that were not entered into our data collection system and number of text-messages missed during the study period; 5) the participant’s willingness to answer text-messages while off-duty (when not working); 6) the participant’s perceived impact of

the study on his/her opinions of sleep and fatigue; 7) the study's impact on the study participant's sleep health habits while on-duty and off-duty; and 8) opinions on how best to improve sleep and reduce fatigue among EMS workers.

Sample size and analysis

We based sample size justification on 'proof-of-concept' hypothesis testing [Patterson, Moore, et al., 2014]. We used summary statistics and bivariate tests to describe and compare baseline information between intervention and control groups. We compared compliance in answering text messages using Student's t-test or Wilcoxon Rank Sum. Due to the hierarchical nature of our data (multiple measures within a shift, multiple shifts within a participant), we used linear mixed model analyses to examine the change in fatigue across shifts. Our model contained a fixed effect for experimental group, a fixed effect of time (beginning vs. end of shift), and a random effect for subjects to account for correlation among multiple shifts within each person. We used contrasts at each time point within a shift to compare intervention and control without adjustment for multiple comparisons due to the exploratory nature of our study.

The secondary participant outcomes included sleep quality, alertness behaviors, and fatigue. We compared the change in these measures from baseline to the end of the study and between treatment arms using ANCOVA for continuous measures and using chi-square (or Fisher's exact) test for categorical measures. All statistical testing was two-sided and with $\alpha=0.05$ using SAS version 9.4 (SAS Institute Inc., Cary, NC).

RESULTS

Screening and Randomization

Figure 1 illustrates the flow of participant screening, enrollment, and participation. Forty-eight study participants were randomized to the intervention group and 52 were randomized to the control group, respectively.

Participant level measures

Our sample included EMS shift workers from all four major U.S. Census regions. Nearly half (46.0%) were located in the Northeast U.S. Census region, 37% in the Midwest, eight percent in the South, and nine percent in the West. The demographics of our study sample are similar to U.S. EMS workforce and analogous to demographics reported in other observational and experimental studies [Brown et al., 2002; Chapman et al., 2008; Davis et al., 2007; Patterson, Huang, Fairbanks, Simeone, et al., 2010; Patterson, Huang, Fairbanks, Wang, 2010; Patterson, Weaver, Weaver, et al., 2012]. At baseline, mean age of all study participants was 35.5 years (SD 10.0) and mean years of EMS shift work experience 13.1 (SD 9.1; Table I). In line with our recruitment focused on EMS shift workers, most all participants were certified/licensed as a paramedic and worked in a ground-based EMS system. In reference to all participants, most worked >12-hour shift schedule, reported good health status, and were overweight or obese. At baseline, a majority of study participants (85%) were classified as having mental and/or physical fatigue while at work according to the CFQ, 74% had poor sleep quality according to the PSQI, and 51% had situational

excessive sleepiness according to the ESS. Mean scores for the OFER sub-scales and SAS items are reported in Table I. Tests indicate no differences between intervention and control study participants on demographic and baseline measures (Table I).

Participation

Fifteen participants (15%) withdrew or were lost to follow-up (Figure 1). Eighty-five participants completed end of study in-depth interviews and survey-based assessments.

Shift level measures

Ninety-nine participants documented 2,621 total shifts over the 90-day study period. The median number of shifts per participant was 24 shifts (IQR 19–34) with no difference identified between intervention and control groups ($p=0.92$). Half of scheduled shifts (48.4%, $n=1,268$) were >12-hours, of which 33 (1.2% of total shifts) were >25-hours in length. Twenty percent of scheduled shifts were <12-hours in duration and most (53%) started in the AM [between 0000 and 1159 hours] (Figure 2). One third of scheduled shifts were 12-hours in duration, of which most (63%) started in the AM. Ninety-two percent of shifts >12-hours started in the AM. Our text-message system sent a total of 40,947 text-messages that requested a text-message response (Table II). Participants responded to 36,073 text-messages, for an overall response rate of 88.1%. Of the 40,947 text messages, 8,779 were sent at the beginning of scheduled shifts, 19,738 were sent during shift work, and 12,430 were sent at the end of scheduled shifts. Participants replied to 7,955 (90.6%) of text-messages sent at the beginning of shifts, 16,656 (84.4%) text-messages sent during shifts, and 11,462 (92.2%) sent at the end of shifts. The response rate was not different between the intervention and control groups at the beginning of shifts ($p=0.06$), during shifts ($p=0.93$), or at the end of shifts ($p=0.27$). We detected differences between intervention and control participants in how quickly text-message queries were answered overall and during shifts, but not at the beginning or end of shifts (Table II). The overall median response time in seconds for intervention participants was 70-seconds (IQR 40–158) compared to 60-seconds (IQR 40–153) for control participants ($p=0.0001$). The median response time in seconds for text-messages sent during shifts (every 4-hours) was 89-seconds (IQR 49–181) for intervention participants compared to 60-seconds (IQR 40–153) for control participants ($p<0.0001$).

The mean hours of pre-shift sleep over the 90-day study period was 6.3 hours for intervention and 6.8 hours for control groups, respectively ($p=0.08$). Mean scores for fatigue, sleepiness, and difficulty with concentration increased (worsened) over the course of scheduled shifts, with the pattern of increase varying based on length of shift (Figure 3). Among participants working shifts <12-hours in length, increases in fatigue, sleepiness, and difficulty with concentration did not vary by intervention or control group. Fatigue at the start of 12-hour shifts was similar for participants in the control and intervention groups ($p=0.19$), whereas sleepiness was lower among participants in the intervention group ($p=0.03$). Participants in the control group showed greater increases in mean fatigue and sleepiness over 12-hour shifts than did participants in the intervention group ($p<0.05$). Participants in the intervention group reported lower mean fatigue and sleepiness at four hours, eight hours, and at the end of shift (12-hours) than participants in the control group

($p < 0.05$). Among participants that worked shifts > 12 -hours, fatigue, sleepiness, and difficulty with concentration increased in a curvilinear pattern from the start to the end of shift work, peaking at 20-hours before decreasing at 24-hours. With the exception of this one time-point (at 20-hours), fatigue, sleepiness, and difficulty with concentration were not different between intervention and control participants who worked > 12 -hour shifts ($p > 0.05$).

Forty-one of 48 participants in the intervention group reported a high level of fatigue, sleepiness, or difficulty with concentration at the start or during one or more scheduled shifts (Mean = 3.7 shifts, SD 4.3). Intervention messages were sent at the start or during 175 scheduled shifts. The most common intervention message sent was: “If you can, take a short 20–30 minute nap on duty” at 28%, followed by “Stay alert by talking to your partner when work is slow” at 27%, “Try doing some stretches or other exercise to stay alert” at 27%, and “Try drinking a caffeinated beverage like coffee to stay alert” at 18%. Among the 41 participants that received an intervention message, 85% ($n = 35$) replied YES to the end of shift question (*During your shift, did you take a nap, drink caffeine, stretch or exercise, OR talk to your partner to stay alert?*). Three participants replied NO and nine of the 41 participants that received an intervention message did not answer the question. Among participants that adopted an alertness strategy, 91% ($n = 35$) replied YES to a follow-up question (*Did it help reduce your fatigue or sleepiness?*). At the shift level, participants indicated they adopted an alertness strategy for 73% ($n = 128$) of the 175 shifts. In 71% of these shifts ($n = 91$), participants reported YES the strategy helped reduce their fatigue or sleepiness.

One participant in the intervention group reported two injuries via text-message during the study period. The participant documented 45 total shifts over 90-days and reported the first injury at the end of the 3rd shift (a 12-hour shift). The participant described the injury as “Abrasion to right knee.” Scores for fatigue, sleepiness, and difficulty with concentration reported at the time of the first injury were 1, 1, and 0, respectively. These scores are on the lower end of the 0–5 response scale and imply low levels of fatigue, sleepiness, and difficulty with concentration. The second injury was documented on the participant’s 28th shift (a 12-hour shift) and described as “strain left foot.” For this injury, scores for fatigue, sleepiness, and difficulty with concentration reported at the time of injury were 3, 3, and 2, respectively. These scores are at the midpoint of the 0–5 response scale and imply moderate levels of fatigue, sleepiness, and difficulty with concentration. Four different participants used the text-message injury-reporting feature at the end of four unique shifts. The text description of injuries provided indicated the injury-reporting feature was used in error and there was no injury to report.

Follow up measures of interest

Tables III and IV highlight changes in follow-up outcomes of interest from baseline to 90-day follow-up. The mean PSQI sleep quality scores for intervention and control participants taken at baseline were similar to scores detected in prior research and indicated poor sleep quality for both groups [Patterson, Suffoletto, et al., 2010; Patterson, Weaver, et al., 2012]. Mean sleep quality scores from baseline to 90-days improved (showed a decrease) for

participants in the intervention group but not control group ($p=0.01$). The proportion participants classified with poor sleep quality (a PSQI >5) at baseline and 90-days was similar to proportions observed in prior research [Patterson, Suffoletto, et al., 2010; Patterson, Weaver, et al., 2012]. The proportion of intervention participants classified with poor sleep quality showed a slight, yet non-significant decrease from baseline to 90-days, whereas the proportion of control group participants with poor sleep quality increased by five percentage points ($p=0.0526$). Baseline values for the ESS measure of daytime sleepiness measure were similar between intervention and control groups and similar to values detected in other healthcare shift workers [Waage et al., 2014; Geiger-Brown et al., 2014]. We detected no change in mean ESS daytime sleepiness scores from baseline to 90-days for participants in the intervention or control group ($p=0.5872$). Baseline and 90-day measures of chronic fatigue (OFER-CF), acute end of shift fatigue (OFER-AF), and inter-shift recovery (OFER-IR) are comparable to nurses in the hospital setting [Winwood et al., 2006]. We detected no changes in measures of chronic fatigue, acute fatigue, and inter-shift recovery from baseline to 90-days for intervention or control participants ($p>0.05$).

We used the SFAB survey tool to capture follow-up measures of interest related to a worker's alertness behavior while at work. With the exception of the SFAB environmental constraints domains, higher scores indicate a positive change in behavior, and suggest the worker has adopted or intends to adopt behaviors that may improve his/her alertness at work [Patterson, Buysse et al., 2014]. Table IV highlights mean SFAB scores for all eight domains take at baseline and 90-days. These scores are similar to a convenience sample of 355 EMS workers on which the SFAB was initially tested [Patterson, Buysse et al., 2014]. From baseline to 90-days, attitudes towards behaviors that help maintain alertness at work improved among intervention participants and decreased among participants in the control group ($p=0.0114$; Table IV). Mean scores for seven of eight domains were similar for intervention and control participants at baseline and 90-days. No additional differences were detected between intervention and control participants or from baseline to 90-days.

Secondary outcomes

We received qualitative feedback from 86 of the 99 participants during telephone follow-up interviews. A majority of participants (99%; $n=85$) reported satisfaction with use of text-messages to assess sleepiness and fatigue during shift work and supported its use for intervening in real time on EMS worker fatigue and sleep health. Participants favored text-message queries at the beginning, every 4-hours during, and at the end of scheduled shifts; however, 23% of participants favored spacing out the interval for text messages during shifts to every 6-hours for longer shifts such as 24-hour shifts. Our study sent and received text-messages during scheduled shifts. Most participants (95%; $n=82$) reported a willingness to answer text-messages while off-duty (not at work): with a mean of 2.6 text-messages as the optimal number of text-messages per day on days when not working. Two-thirds of participants ($n=59$) suggested future interventions should include more information about sleep health and how to schedule sleep based on different shift schedules.

DISCUSSION

Our study demonstrated the usefulness of a real-time fatigue assessment platform that uses text-messages to track self-reported fatigue and sleep symptoms among shift workers in a high-risk emergency healthcare setting. This study also provides early evidence that real-time behavioral support delivered through text-messages can reduce fatigue and sleepiness for shift workers.

Few studies have investigated use of text-messages to facilitate real-time assessment of fatigue or sleepiness with shift workers. We detected a near linear increase in sleepiness and fatigue for shifts 12-hours or less (Figure 3). Participants that worked shifts >12 hours experienced some benefit from the intervention, specifically at 20-hours into their shift, but did not show benefit at any other time point, including the end of shift. These findings may be explained by the interaction of homeostatic and circadian regulation of sleepiness and alertness [Dijk and Czeisler, 1994; Dijk and Czeisler, 1995], yet further study with EMS workers is needed.

Our findings add to prior literature in several ways. First, we show high levels of compliance (response) with text-message queries of participant self-reported fatigue, sleepiness, and difficulty with concentration in real-time. Prior reports of compliance with real-time fatigue assessment are limited. The high response rate we observed may influence others to use real-time technologies that are both cost-effective and attractive to participants. Second, our findings provide insight into use of brief fatigue-reduction interventions for emergency healthcare shift workers. Previously tested fatigue risk management strategies in EMS incorporated limiting shift length or restricting work hours [Boudreaux et al., 1998]. Our study is one of the first to test a brief, real-time, intra-shift intervention focused on alertness behaviors and inclusive of shift workers scheduled for diverse shift lengths. Prior studies included participants who worked a limited number of short (<12-hours) or extended shifts (>12-hours). In fact, studies using real-time assessment have almost exclusively been limited to nurse shift workers scheduled for 12-hour shifts [Geiger-Brown et al., 2012]. Our study has the advantage of addressing questions and concerns of participation of shift workers scheduled for shifts that vary in length. Finally, qualitative feedback of participants reinforces our high response/participation rate and offers support for future studies that seek to use text-messages as a vehicle for fatigue assessment and/or intervention. Future studies may wish to investigate brief as well as enhanced fatigue reduction interventions with shift workers that adhere to diverse shift lengths and varied patterns of shift rotation; which may further elucidate the utility of real-time interventions using text-messages.

While our findings show promise for brief interventions delivered in real-time, the impact of these interventions may be of greatest benefit for shift workers scheduled for 12-hour shifts. Sleepiness increased across all shift durations, as predicted by accumulating homeostatic sleep pressure. Consistent with a circadian effect, participants reported reduced sleepiness at the very end of 24-hour shifts, which in 95% of cases ended between 0600 and 0900 hours. Workers concluding their 24-hour shifts may also have experienced direct alerting effects from sunlight exposure [Cajochen, 2007]. Notably, the effect of the text-message

intervention appeared to be greatest for both the 12-hour and >12-hour shift groups when levels of sleepiness and fatigue were highest.

There are numerous potential benefits to real-time assessment and intervention for fatigue risk management systems (FRMS) [Balkin et al., 2011]. Previously tested real-time fatigue assessment tools include ocular-based monitoring, electroencephalography (EEG), wrist-mounted actigraphy, and video-capture systems mounted in vehicles [Balkin et al., 2011]. Ocular-based tools have questionable reliability, problematic calibration, and susceptibility to loss of data. Wrist actigraphy provides reliable measures of sleep/wake timing, but do not directly measure fatigue. Video-capture systems such as those mounted on rear-view mirrors in vehicles are designed to capture fatigue-related indicators immediately prior to an “event” of interest and may not capture fatigue states not associated with a particular “event” of interest. Disadvantages of text-message based assessment tools include the burden of response on the worker and risk of texting while driving. Many shift workers may not have the time or ability to respond in a timely manner. Many shift workers may face employer enforced policies or procedures restricting use of mobile phones or smartphones while working. In these settings, there may be limited utility of interventions that use a dialogue between the employee and a mobile technology for fatigue assessment and intervention.

Limitations

Our sample includes emergency workers from across the U.S. who visited the study website and approached the study team voluntarily. Our participants may differ from those that chose not to participate by one or more demographic variables. The demographics of our study sample are similar to the U.S. EMS workforce and similar to study samples of other observational and experimental studies [Brown et al., 2002; Chapman et al., 2008; Davis et al., 2007; Patterson, Huang, Fairbanks, Simeone, et al., 2010; Patterson, Huang, Fairbanks, Wang, 2010; Patterson, Weaver, Weaver, et al., 2012].

We are limited by the self-report nature of our momentary and cross-sectional survey based assessments. Our data are subject to bias from the participants who may over or under report fatigue or sleepiness symptoms or other factors measured via self-report. Participants may have altered their responses – were reactive – due to their knowledge of being followed as part of a research study [Hufford, 2007; Kirmeyer, 1985]. One of several strengths of this study is we did not use direct observation [Kirmeyer 1985]. Further, research shows that the threat of reactivity is limited because participant behaviors tend to regress to normal within the first few hours or days of follow up or study participation [Hufford, 2007; Kirmeyer, 1985].

We chose EMA-based measures of fatigue, sleepiness, and difficulty with concentration. We developed our measures by: 1) adapting item stems and response options used in previous research that assessed fatigue and sleepiness [Buysse et al., 2007], and 2) adhering to the principles of EMA research [Shiffman et al., 2008; Stone et al., 2007]. There are numerous measures of fatigue, with no clear consensus on a gold standard measure (single-item or multi-item) [De Vries et al., 2003]. Single-item measures of sleepiness like the Karolinska Sleepiness Scale (KSS) are widely used, correlated with objective measures, and considered valid [Akerstedt et al., 1990; Kaida et al., 2007].

Some may consider certain demographic characteristics as important drivers of study findings. We assessed the marginal associations between general health, BMI, number of jobs, sex, age, and years of experience with each of the of the end of shift measures for sleepiness, fatigue, and concentration [Winwood et al., 2006]. The only variable that was significant at the 0.1 level was self-reported general health, where participants with excellent health reported lower fatigue, sleepiness, and difficulty with concentration than persons with fair/poor health. We have not controlled for health status in our models testing the intervention given that general health status was not different between the two groups at baseline (Table I).

Finally, our participation and attrition characteristics may have impacted our findings; however, we do not believe the impact is high given an overall low level of attrition and reported high levels of participant response in the follow-up interview and survey.

CONCLUSIONS

In this first step investigation, we showed feasibility and short-term efficacy of a text-message based assessment and intervention tool. Given the exploratory nature of this work, future investigation should determine if real-time tools that use text-messages are scalable and have meaningful impact on shift worker sleep health and fatigue.

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Ethics Review and Approval: The University of Pittsburgh Institutional Review Board approved this study (IRB# PRO13120428). This study and protocol was registered with ClinicalTrials.gov (identifier: NCT02063737). The IRB approved a waiver for the requirement to obtain written informed consent. In this study, participants documented informed consent using an IRB-approved secure electronic/online process that began with participants watching a short video that contained all elements of a written consent document. The process concluded with the participant confirming informed consent by clicking on "I ACCEPT" to participate in this study.

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Figure 1.
Consort Diagram

Figure 2.
Proportion of scheduled shifts that started in the AM (between 0000 and 1159 hours)

Figure 3. Real-time Measures (Means & 95% CIs) of Fatigue, Sleepiness, and Difficulty with Concentration during work shifts of <12-hours, 12-hours, and >12-hours in duration

Table I

Demographic characteristics of study sample

	Total Sample (n=100)	Intervention Group (N=48)	Control Group (N=52)	p-values
Age Mean (SD)	35.5 (10.0)	35.0 (9.7)	36.1 (10.2)	0.570 [#]
<i>Sex</i>				
Male	71%	62.5%	78.9%	0.082 [@]
Female	29%	37.5%	21.1%	
<i>Certification/License</i>				
EMT-Basic	9%	10.4%	7.7%	0.358 [@]
Paramedic	65%	64.6%	65.4%	
Nurse	17%	20.8%	13.5%	
Physician/Other [*]	9%	4.2%	13.5%	
<i>Clinical Setting</i>				
Ground-based EMS	63%	62.5%	63.5%	0.483 [@]
Air-Medical EMS	25%	29.2%	21.2%	
ED/Other setting ^{**}	12%	8.3%	15.4%	
<i>Yrs of Experience</i>				
Mean (SD)	13.1 (9.1)	12.7 (8.8)	13.5 (9.5)	0.667 [#]
<i>Numb. of Jobs</i>				
>2 jobs	48%	47.9%	48.1%	0.987
<i>Employment Status^{\$}</i>				
Full-Time	93%	93.8%	91.7%	1.000 [@]
Part-Time/Volunteer	7%	6.2%	8.3%	
<i>Numb. of Shifts Worked Last Month</i>				
Mean (SD)	14.2 (6.2)	14.7 (6.2)	13.8 (6.2)	0.474 [#]
<i>Most Common Shift Length Worked</i>				
>12-hr	65%	60.4%	69.2%	0.377 [@]
12-hr	23%	29.2%	17.3%	
<12-hr	12%	10.4%	13.5%	
<i>General Health</i>				
Excellent	31%	33.3%	28.8%	0.873 [@]
Good	65%	62.5%	67.3%	
Fair/Poor	4%	4.2%	3.9%	
<i>BMI^{&}</i>				
Underwt/Normal weight	24%	19.6%	23.1%	0.899 [@]
Overweight	42%	45.6%	40.4%	

	Total Sample (n=100)	Intervention Group (N=48)	Control Group (N=52)	p-values
Obese	34%	34.8%	36.5%	
<i>Sleep Quality</i>				
PSQI Mean (SD)	7.3 (2.7)	7.5 (2.6)	7.1 (2.8)	0.377 [#]
% Poor Sleep Quality (PSQI >6)	74%	81.2%	67.3%	0.170 [@]
<i>CFQ Fatigue Scale</i>				
% Fatigued	85%	79.2%	90.3%	0.162 [@]
<i>ESS Results</i>				
ESS Mean (SD)	10.0 (4.3)	10.1 (4.7)	9.8 (4.1)	0.667 [#]
Excessive Sleepiness (ESS >16)	7%	10.4%	3.9	0.659 [@]
Situational Sleepiness (ESS 10-15)	51%	47.9%	53.8	
Average Sleepiness (ESS 8-9)	11%	10.4%	11.5	
Unlikely Abnormally Sleepy (ESS 0-7)	31%	31.3%	30.8	
<i>OFER Results</i>				
Mean (SD)				
Chronic Fatigue	27 (22.0)	24.8 (21.3)	28.5 (22.4)	0.404 [#]
Acute Fatigue	56 (23.4)	55.1 (21.9)	56.1 (24.9)	0.840 [#]
Inter-Shift Fatigue	60 (22.0)	61.6 (23.2)	58.5 (20.8)	0.494 [#]
<i>SAS score</i> Mean (SD)	41 (22.5)	39.9 (22.8)	43.1 (22.3)	0.483 [#]

NOTES: SD=standard deviation.

* Other category includes patient care technicians.

** indicates a combining of 12 study subjects who identified their primary work location to be the ED (n= 9) or Other setting (n=3). Other settings include Fire Departments (n=2) and a 911 communications center (n=1).

\$ indicates that n=4 study subjects failed to indicate their employment status on the baseline survey.

[#] indicates use of a student's t-test.

[@] indicates use of a Fisher's exact test.

[&] indicates that two study subjects in the intervention group failed to record their weight at baseline.

Table II

Response rates with answering text-messages at the beginning, during, and end of shift

Measures of feasibility	Intervention	Control	p-value
Response with answering text-messages			
text messages sent (total)			
N=total	19,295	21,652	
N=median	386	412	
(IQR)	(243-515)	(269-523.5)	0.893%
text messages received (total)			
N=total	16,968	19,105	
N=median	353	367	
(IQR)	(196-481)	(228-472.5)	0.880%
Response Rate (overall)	87.9%	88.2%	
Response time in seconds (median, (IQR))	70, (40-158)	60, (40-153)	<0.001#
text messages sent (beginning of shift)			
N=total	4,134	4,645	
N=median	87	79	
(IQR)	(48-120)	(63-115)	0.891%
text messages received (beginning of shift)			
N=total	3,720	4,235	
N=median	76	69	
(IQR)	(43-109)	(55-99)	0.816%
Response Rate (beginning of shift)	90%	91.2%	
Response time in seconds (median, (IQR))	70, (41-160)	67, (40-150)	0.068#
text messages sent (during shift)			
N=total	9,118	10,620	
N=median	188	212	
(IQR)	(107-255)	(124-256)	0.659%
text messages received (during shift)			
N=total	7,692	8,964	
N=median	150	180	
(IQR)	(81-207)	(98-222)	0.683%
Response Rate (during shift)	84.4%	84.4%	
Response time in seconds (median, (IQR))	89, (49-181)	70, (40-168)	<0.001#

Measures of feasibility	Intervention	Control	p-value
text messages sent (end of shift)			
N=total	6,043	6,387	
N=median	114	104	
(IQR)	(73-177)	(68-165)	0.713%
text messages received (end of shift)			
N=total	5,556	5,906	
N=median	90	95	
(IQR)	(65-165)	(56.5-157.5)	0.767%
Response Rate (end of shift)	92%	92.4%	
Response time in seconds (median, (IQR))	59, (40-128)	60, (40-130)	0.660 [#]

NOTES: Frequency counts of text-messages and measures of compliance (response) are based on the schedule of text-message assessments standard for both intervention and control study subjects. These include four text-message queries at the beginning, three queries at every 4-hours during a shift, and six text-message queries at the end of shifts. See Table 1 and Figure 2a in a prior publication of the study protocol for more details of these assessments. [Patterson, Moore, et al., 2014]. One study subject randomized to the intervention group completed enrollment but did not register any shifts or receive any text-messages.

[#] indicates use of a test of medians.

[%] indicates use of a student's t-test.

Table III

Change in follow-up measures of sleep quality, daytime sleepiness, acute and chronic fatigue, and scheduling attitudes

Standard measures of sleep and fatigue		Baseline Score		End of Study Score at 90-days		p-value
		N=	Score (SD) or Percentage %	N=	Score (SD) or Percentage %	
Pittsburgh Sleep Quality Index (PSQI) (Scale scores range 0 to 21)	Intervention	48	7.5 (2.6)	44	6.0 (2.1)	P=0.012
	Control	52	7.1 (2.8)	41	7.0 (3.0)	
PSQI – poor sleep score (% with PSQI >5)	Intervention	48	52.7%	44	47.3%	P=0.053
	Control	52	47.3%	41	52.7%	
Chalder Fatigue Questionnaire (CFQ) Percent Fatigued	Intervention	48	79.2%	44	77.3%	P=0.429
	Control	52	90.3%	41	78.1%	
Epworth Sleepiness Scale (ESS) (Scores range from 0 to 24. Scores 10 imply excessive sleepiness)	Intervention	48	10.0 (4.3)	44	9.3 (4.1)	P=0.587
	Control	52	9.8 (4.1)	41	8.9 (4.5)	
OFER-Chronic Fatigue sub-scale (Scores range 0 to 100. Scores 0 to 50 imply low-to-moderate chronic fatigue)	Intervention	48	24.8 (21.3)	44	33.9 (22.1)	P=0.620
	Control	52	28.5 (22.4)	41	36.5 (25.1)	
OFER-Acute Fatigue sub-scale (Scores range 0 to 100. Scores 0 to 50 imply low-to-moderate acute fatigue)	Intervention	48	55.1 (21.9)	44	54.2 (16.8)	P=0.595
	Control	52	56.1 (24.9)	41	55.3 (22.6)	
OFER-Intershift Fatigue sub-scale (Scores range 0 to 100. Scores 0 to 50 suggest low-to-moderate recovery)	Intervention	47	61.6 (23.2)	44	59.6 (21.3)	P=0.992
	Control	52	58.5 (20.8)	41	54.3 (19.7)	
SAS score with select items (Scores range 0 to 100 with no cut point for select items)	Intervention	48	39.9 (22.8)	44	44.3 (22.2)	P=0.554
	Control	52	43.1 (22.3)	41	46.5 (23.9)	

NOTES: SD=standard deviation. Missing data at baseline of study (n=1 for OFER). Missing data at end of study (n=15 for PSQI, CFQ, ESS, OFER, and SAS).

Table IV

Change in Secondary Measures (Behavioral)

Sleep, Fatigue, and Alertness Behaviors (SFAB) survey tool	Baseline Score	End of Study Score at 90-days	p-value
	N=	Score Mean (SD)	
Attitudes Scale (ATT-Scales)	42	Intervention	P=0.011
		ATT-one subscale (Range 0 to 100)	
	47	Control	P=0.989
		ATT-two subscale (Range 0 to 100)	
Normative Beliefs Scale (NB-Scales)	42	Intervention	P=0.093
		NB-one subscale (Range 0 to 100)	
	47	Control	P=0.058
		NB-two subscale (Range 0 to 100)	
Self-Efficacy Scale (SE-Scale)	42	Intervention	P=0.691
		SE-Scale (Range 0 to 100)	
	47	Control	P=0.654
		KNOW-one subscale (Range 0 to 100)	
Knowledge Scale (KNOW-Scales)	42	Intervention	P=0.947
		KNOW-two subscale (Range 0 to 100)	
	47	Control	P=0.205
		IMPORT-Scale (Range 0 to 100)	
Importance Scale (IMPORT-Scale)	42	Intervention	P=0.513
		EC-one subscale (Range 0 to 100)	
	47	Control	P=0.287
		EC-two subscale (Range 0 to 100)	
Environmental Constraints Scale (EC-Scales)	42	Intervention	P=0.093
		EC-three subscale (Range 0 to 100)	
	47	Control	P=0.562
		HABIT-Scale	

Sleep, Fatigue, and Alertness Behaviors (SFAB) survey tool	Baseline Score		End of Study Score at 90-days		p-value
	N=	Score Mean (SD)	N=	Score Mean (SD)	
	47	42.7 (20.9)	41	39.3 (21.6)	
Intentions Scale (INTENT-Scale)	42	75.4 (17.1)	44	77.4 (17.0)	P=0.200
	47	73.8 (15.7)	41	72.3 (14.7)	

NOTES: SD=standard deviation. Missing data at baseline of study (n= 11 for SFAB). Missing data at end of study (n=15 for SFAB).