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Real-time text message intervention to mitigate workplace fatigue in emergency medical services: A cluster-randomized trial

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A B S T R A C T

Objectives: To test the effectiveness of a mobile phone text message-based intervention to mitigate fatigue and improve indicators of sleep health in a nationally representative sample of emergency medical services clinician shift workers.

Methods: We conducted a cluster-randomized trial of emergency medical services agencies in the United States. Agencies (clusters) were randomized to intervention or the attention control group. Individual emergency medical services clinician shift workers used a mobile app to complete monthly surveys for 6 months and answered text message queries 1 out of every 4 weeks. Intervention text messages promoted adoption of fatigue mitigation behaviors. All attention control group text messages focused on teamwork improvement.

Results: In total, 108 emergency medical services agencies and 708 emergency medical services shift workers were enrolled. Participants responded to > 77% of monthly surveys and text message queries. The proportion of emergency medical services shift workers reporting severe fatigue declined over the study period; however, differences by intervention and attention control group status were not statistically significant. The proportion of participants with a clinically meaningful reduction in daytime sleepiness at 6 months was greater in the intervention group vs. the attention control group ($p = .04$).

Conclusions: Mobile phone text message-based assessments followed by immediate intervention are engaging, scalable on a nationwide level, and effective for addressing some indicators of sleep health like daytime sleepiness. Interventions combining behavioral sleep recommendations with fatigue mitigation strategies could result in larger effects on sleep health and fatigue.

Trial registration number: ClinicalTrials.gov ID# NCT04456764 registered on June 29, 2020. First enrollment/consent on December 8, 2020.

Background

Emergency medical services (EMS) clinicians and other first responders often report poor sleep, excessive daytime sleepiness, and fatigue.[1] These are common problems for EMS clinicians in the

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What was known

Two-thirds of public safety personnel working in emergency medical services operations do not have a formal fatigue risk management program. Pilot trial data show that real-time assessment and intervention with mobile phone text messaging can reduce fatigue symptoms in this population, the technology is scalable, and likely suitable for workplace fatigue risk management. Large-scale, nationwide testing has not yet been attempted.

What this study adds

Data from this nationwide trial show that while text message-based assessments followed by immediate intervention are engaging, scalable, and effective for mitigating daytime sleepiness among emergency medical services personnel, it may not be adequate, in isolation, for fatigue reduction in this population. Multimodal interventions with behavioral sleep recommendations and diverse fatigue mitigation strategies could result in larger effects.

United States and internationally.[2] Inadequate sleep, irregular sleep patterns, and inadequate recovery between shifts are likely contributors, which are linked to common EMS shift scheduling practices that include frequent use of long-duration shifts (e.g., 24+ hours), rotating shifts, and night shifts.[3-5] In the United States, many EMS clinicians work multiple jobs, which can exacerbate sleep problems and fatigue.[1,6] Increased concern for EMS clinician fatigue in recent years and its link to safety contributed to the Evidence Based Guideline (EBG) for Fatigue Risk Management in EMS.[7-9] Complementary work by prominent sleep medicine organizations outlined evidence-based approaches to shift scheduling to help mitigate fatigue-related outcomes.[10] Despite this guidance, there are no widely accepted best practices or gold standard interventions for fatigue mitigation tailored to the EMS workplace.

Recent research has tested novel approaches to fatigue risk mitigation.[11-15] Our own research has used mobile phone text messaging to identify fatigued EMS clinicians while on duty and then immediately (in real time) provide suggested changes in behavior that may lessen fatigue and reduce odds of a negative outcome.[11-14] These pilot randomized trials leveraged a text message platform to collect EMS clinician shift schedules and automatically send text message assessments at the start, during, and at the end of scheduled shifts to identify high levels of fatigue, sleepiness, or difficulty with concentration. When detected, the platform automatically responded with a tailored strategy message selected from a database of text messages. Strategy messages promoted EMS clinicians adopt a behavioral strategy to address fatigue, sleepiness, or difficulty with concentration.[13,14] Each message was developed by investigators and linked to previous evidence.[13,14] Recent trials testing these strategy messages showed that EMS clinicians reported reduced levels of situational fatigue and sleepiness at the end of extended shifts (i.e., 12-hour shifts).[11,12]

Use of a text message platform and "real-time" assessment approach to fatigue is informed by the principles of Ecological Momentary Assessment (EMA)[16,17] and recent evidence that shows mobile health (mHealth)-based interventions with text messaging as effective for behavior change.[18,19] Key principles of EMA-based data collection include repetitive assessments in rapid sequence to detect changes in health practices or behaviors that are not easily detected with cross-sectional surveys.[16,20,21] Repetitive assessments can act like frequent reminders and impact behaviors in ways that alternative approaches have not, especially for behaviors challenged by long-term adherence.[22-25] As described above, recent pilot trial data are positive[11,12] and imply the potential for high impact for behaviors challenged by adherence. Poor sleep and fatigue among EMS clinicians are widely reported,[1,7,26] difficult to address, and potentially poorly responsive to interventions designed for other occupational groups. Repetitive assessment and real-time intervention of situational fatigue could lead to positive changes in behavior and longer-term effects on sleep health and fatigue for EMS clinicians.

In this study, we sought to build on our pilot intervention,[11-14] and test its effectiveness using a nationwide cluster-randomized trial design. Our primary outcome of interest was fatigue; secondary outcomes included sleep quality, inter-shift recovery, and other indicators of sleep health such as daytime sleepiness.

Design and methods

Study design and setting

We used a cluster-randomized, parallel-arm, attention control (AC) trial design with U.S.-based nationwide recruitment of EMS agencies (clusters) and frontline EMS clinician shift workers.[27] All clusters were randomized to either the intervention (INT) or AC condition. Goal enrollment was 100 geographically and operationally diverse EMS agency clusters (including Alaska and Hawaii) with 15 frontline EMS clinician shift workers per cluster. This research study was approved by the University of Pittsburgh Institutional Review Board (STUDY19040354). The protocol was registered with clinicaltrials.gov on June 29, 2020 (ID# NCT04456764). First enrollment and consent occurred on December 8, 2020.

Eligibility

Criteria for eligibility were informed by the study team's experience with the targeted population and prior studies showing that active, regular shift workers may benefit from the intervention. Eligibility criteria were created to avoid enrollment of volunteers or "casual" personnel as they may not work regularly and not need or benefit from the intervention. Criteria were also based on goal enrollment, described in detail in the "Power calculation" section and based on our prior trial showing attrition at 15% and data showing personnel turnover within agencies at approximately 10% annually.[12,28] Agencies were eligible if (1) they employed 20 paid (full-time or part-time) EMS clinician shift workers; (2) employees worked in shifts; (3) EMS clinician duties included emergent or nonemergent patient care, operating ambulances, and lifting/moving patients and EMS equipment; and (4) policies and procedures did not limit use of personal cell/smartphones with exception of while driving or when performing standard duties. Within a cluster, all EMS clinicians were eligible unless their role was primarily administrative, were < 18 years of age, or did not work at least one shift per week.

Recruitment and enrollment of EMS agency clusters

We recruited all types of EMS agencies with a study-designated website and recruitment video. Agencies merged with fire departments were eligible. In the United States, approximately 19,000 EMS operations respond to 9-1-1 dispatches, with many others performing nonemergent transports.[29] The size and type of U.S.-based EMS operations vary considerably between communities. Oversight and governance of EMS operations also vary, with county-level governance in some states and local governance in others. "Fire-based EMS" personnel perform both EMS and firefighter duties, but the requirement of fulfilling such duties also varies.[30] Most EMS clinicians, including those at fire-based operations, work 12-hour and 24-hour shifts.[3,31] For our purposes, we recruited all types of EMS operations and enrolled agencies who met criteria for eligibility.

Recruitment and enrollment of individual EMS clinicians

Within agencies, study flyers were circulated and directed individuals to the study webpage. Study coordinators screened and enrolled eligible individuals. Total remuneration over the study period was $100 U.S. for monthly survey completion and $100 for smartphone data fees. Novelty items such as coffee mugs and challenge coins were distributed monthly.

Intervention

The intervention used the SleepTrackTXT platform and mobile phone text messages to identify high levels of fatigue and intervene in real time with a tailored response designed to promote adoption of fatigue mitigation strategies.[11-14] The repeated text message queries assess state-level (situational variability) in fatigue and fatigue-related symptoms, not trait-level status (see Supplementary File Appendix A).[32] The time interval for text message queries followed the same protocol used in earlier pilot trials with fatigue, sleepiness, and difficulty with concentration status assessed at the start, every 4 hours during, and at the end of scheduled shifts.[11-14] Participants documented shift schedules on a secure study-specific website, which in turn dictated when messages were distributed. Response options were anchored from 0 "Not at all" to 5 "Very much." Like in prior trials,[11-14] participant responses of 4 or 5 were considered "high" and resulted in an immediate automated response with a tailored fatigue mitigation text message. Tailored messages were pulled from a database of messages developed by investigators. Each tailored text message was linked to one of eight domains that comprise the Sleep, Fatigue, and Alertness Behavior (SFAB) survey (see Supplementary File Appendix A).[33] The SFAB is a 50-item tool designed to identify deficits in EMS clinician beliefs and behaviors concerning sleep, fatigue, and alertness behaviors during shift work.[33] The eight domains that comprise the SFAB include attitudes, perceived norms, self-efficacy, knowledge, salience/importance, intention, habits, and environmental constraints and are based on the Integrative Model of Behavioral Prediction (IMBP).[33] The IMBP is a comprehensive framework combining elements of the Theory of Reasoned Action and Theory of Planned Behavior to assist with behavioral prediction.[33] By repeatedly intervening on momentary fatigue with tailored messages linked to behavior, our intent was to influence overall fatigue levels reflected in the past month's ratings.

Attention control

Participants randomized to the AC condition received text message assessments and responses at the same intervals as INT participants. However, the content of all text messages focused on teamwork rather than fatigue or sleep. We chose teamwork as the focus of the AC communication because like fatigue, teamwork is a common concern for EMS clinicians and it is associated with safety outcomes.[31,34-36] Teamwork in the EMS setting has not been shown to impact fatigue and sleep. The AC participants were queried about the quality of teamwork with partners and rated teamwork quality on a 0-5 scale with 0 as "poor teamwork" and 5 as "great teamwork." Responses 0-2 were considered low and resulted in a randomly selected real-time, automated response linked to domains of the EMT-TEAMWORK survey tool.[34] See Supplementary Appendix B for details.

Data collection protocol

Participants received a unique access code and instructions to download and install a mobile app (SaFTiE) developed specifically for this study primarily for purposes of collecting monthly survey data. Participants were directed to the survey component of the mobile app to complete baseline surveys measuring sleep quality via the Pittsburgh Sleep Quality Index (PSQI)[37]; fatigue via the Chalder Fatigue Questionnaire (CFQ)[38]; safety culture via the EMS Safety Attitudes Questionnaire (EMS-SAQ)[39]; satisfaction with work schedule via the Schedule Attitudes Survey (SAS)[40]; acute fatigue, chronic fatigue, and inter-shift recovery via the Occupational Fatigue Exhaustion/Recovery (OFER) scale[41]; beliefs, habits, and behaviors related to fatigue via the Sleep Fatigue and Alertness Behavior (SFAB) instrument[33]; sleep health via the Regularity, Satisfaction, Alertness, Timing, Efficiency, Duration (RU-SATED) instrument[42]; and daytime sleepiness with the Epworth Sleepiness Scale (ESS).[43] All instruments were administered at baseline, at 3 months, and at 6-month follow-up. The PSQI, CFQ, teamwork domain of the EMS-SAQ, RU-SATED, and the ESS were administered monthly. For 1 week each month, participants were asked to visit a secure study website, document their shift schedule for the next 7 days, and when prompted, answer text message queries. See Supplementary Appendix C for details and features of the SaFTiE mobile app.

Outcomes

Multiple measures of sleep and fatigue were included. We defined fatigue as "*…a subjective, unpleasant symptom which incorporates total body feelings ranging from tiredness to exhaustion…*"[44] Sleepiness is referred to the propensity or inclination to fall asleep.[45] While fatigue can manifest in response to multiple factors and possibly be resolved when factors are removed, sleepiness is primarily influenced by circadian rhythms and duration of prior wakefulness.[45,46] The two are strongly related but widely believed to measure different constructs.[45]

Our primary outcome was fatigue as measured monthly by the CFQ; a score ≥4 (range of 0-11) indicated mental and physical fatigue.[38] Secondary outcomes were sleep quality (via the PSQI), chronic fatigue, acute fatigue, and inter-shift recovery assessed by the OFER. We used the CFQ, PSQI, and OFER to assess fatigue and fatigue-related status during the previous month.[32] Scores on the PSQI ≥6 indicate poor sleep quality.[37] A PSQI score decrease ≥3 is considered clinically meaningful and associated with a reduction in signs and symptoms of poor sleep.[47] Chronic fatigue, acute fatigue, and inter-shift recovery were measured with the OFER, with scores ranging from 0-100; higher scores for chronic and acute fatigue domains indicate higher fatigue levels, whereas higher scores on inter-shift recovery indicate greater or improved ability to recover between shifts.[41] Data from the ESS and RU-SATED instruments were examined as recommended.[42,43] For ESS, a decrease ≥2 is considered clinically meaningful and associated with a reduction in signs and symptoms of daytime sleepiness that can impact activities of everyday life.[48]

Power calculation

Preliminary data guided the sample size calculation for this study,[11,12] which was performed with PASS 2024 software (Kaysville, Utah: NCSS, LLC). Our original power calculation required enrollment of 36 EMS operations (clusters) with an average of 30 individual participants per cluster for 82% power to detect at least a 15% absolute reduction in work-related fatigue (intracluster correlation coefficient = 0.07), assuming 50% fatigued in the AC group.[5,9,12] Goal enrollment was inflated to 45 clinicians per EMS agency with turnover estimated at 10%-15%[28] and 15% 6-month attrition. Recruitment began during the COVID-19 pandemic, leading to concerns about enrollment. We twice re-evaluated sample size during the first 2 years ultimately determining that 100 total EMS agencies (clusters) and 5 individual participants per cluster completing the 6-month protocol provided 85.8% power to detect an absolute difference in fatigue of 15% between the INT and AC conditions.

Randomization, allocation concealment, and implementation

We randomized agency clusters using a minimization/imbalance procedure with two factors[49] based on type of EMS agency (fire-based, hospital/third service, or air-ground combination/other) and agency size (20-49 frontline employees, 50-99 frontline employees, or 100+ frontline employees). The randomization was carried out by the lead statistician (CGP) and a co-investigator (MDW) using SAS 9.4 (Cary, NC). Team members responsible for enrollment were not informed of assignment probabilities. Randomization assignment was sent via email from the study statistician (or co-investigator) to the study coordinator who contacted each EMS agency (e.g., the Chief/Director), provided guidance on enrollment procedures, and asked EMS personnel to disseminate information to their agency clinicians.

Blinding

The interventions were not blinded to participants, but participants were blinded to the outcomes of interest.

Statistical analyses

Our primary analysis followed the intent-to-treat principle.[50] We used descriptive statistics to assess differences in baseline characteristics by randomization assignment. Dichotomized outcomes were compared between groups over time using generalized linear mixed models with a logit link, random individual and agency effects, and fixed effects for agency size and type, randomization group, time, and the group*time interaction. CFQ scores between groups were compared with a linear mixed model with the same random and fixed effects. Time was treated as a categorical factor (0-6 months). For our primary outcome, fatigue measured by the CFQ, we calculated the standardized effect size within each group. For secondary measures with the PSQI and ESS, we examined the proportion of participants that experienced a clinically meaningful improvement from baseline.[47,48] Secondary analyses of fatigue and sleep quality dichotomized these measures using established thresholds for severe fatigue (CFQ responses ≥4) and poor sleep quality (PSQI responses ≥6).[37,38] We examined the proportion who started with poor sleep quality and no longer met that threshold on their last submitted survey. All analyses were performed using SAS version 9.4 (Cary, NC).

Ethics

The study protocol was approved by the University of Pittsburgh Institutional Review Board (IRB# STUDY19040354) and registered with ClinicalTrials.gov on June 29, 2020 (NCT04456764). All individuals were informed and consented prior to participation. First enrollment occurred on December 8, 2020, and follow-up of the last individual enrolled concluded on December 11, 2023.

Results

We screened 145 EMS agency clusters, excluded 37 as ineligible, and confirmed 108 as eligible (Fig. 1). The most common reason for exclusion was no response from an agency administrator during follow-up screening-related communication. Fifty-four EMS agencies were randomized to the INT group and 54 to the AC group. The most common agency type was Fire-based (37.0%) and the most represented region was the Midwest at 34.3% (Table 1). Nearly two-thirds (61.1%) of enrolled agencies employed < 100 full-time and part-time employees and most (60.2%) reported < 10,000 dispatches during calendar year 2019. Most agencies (71.3%) reported no formal fatigue risk management program.

In total, 708 individuals enrolled, with 385 randomized to the INT group and 323 to the AC group (Fig. 1). Participants in both groups were similar to those in previous studies of EMS clinicians. Most were male (> 60%), between the ages of 35 and 40, reported full-time employment, and worked long-duration shifts (12-24 hours in duration; Table 2). At 6-month follow-up, 319 (82.9%) in the INT group and 272 (84.2%) in the AC group remained as active participants (Supplementary Fig. 1). Participants completed 78.4% (3584) of 4571 monthly surveys. The overall response rates for monthly surveys were similar for the INT group and the AC group (79.0% vs. 77.7%, respectively). Among active participants at 6-month follow-up, 291 (91.2%) in the INT group and 252 (92.6%) in the AC group partially or fully completed most monthly surveys, including the 6-month survey. The mean number of cumulative text message prompts and queries by group is shown in Supplementary Fig. 1. Response rates for text message queries were 84% for INT group participants and 77% for AC group participants.

Primary outcomes: Intent-to-treat analysis

The proportion of participants who reported fatigue decreased over time in both groups (Fig. 2), and groups did not differ at 6 months (OR = 1.33, 95% CI 0.69, 2.56; AC = referent group; Supplementary Table 2). In addition, the mean CFQ fatigue score and corresponding effect sizes did not differ over time (all p's > .05; Supplementary Tables 1 and 2).

Secondary outcomes: Intent-to-treat analysis

Both the INT and AC groups reported improved sleep quality scores on the PSQI, with lower scores for each month of the study period compared with baseline (Supplementary Fig. 3). More participants in the INT group vs. the AC group experienced a clinically meaningful improvement in sleep quality from baseline to 2-month follow-up (27% vs. 17%, p = .02); however, all other comparisons were not statistically significant (Supplementary Table 3). Supplementary Fig. 4 shows that 22% of the INT group participants vs. 15% of AC group participants changed from poor sleep quality at baseline to not having poor sleep quality at 6 months (p = .10).

The secondary outcome, daytime sleepiness, decreased over the 6-month study period for INT participants, whereas AC group participants experienced an inconsistent response over time (Supplementary Tables 5 and 6; adjusted model with interaction group*time p = .04). A larger proportion of participants in the INT group experienced a clinically meaningful decrease of ≥2 points in daytime sleepiness at 6 months compared with baseline (Fig. 3; 45% vs. 35%, respectively, p = .04). A significant group*time interaction effect was detected, with the largest difference observed at 2 months (adjusted mean difference = −0.58 (95% CI −1.09, −0.07; Supplementary Table 5). No other differences detected for additional secondary outcomes of OFER, RU-SATED, and EMS-SAQ (see Supplementary Tables 4, 7, 8 and Fig. 5).

Discussion

The intervention reduced daytime sleepiness but not fatigue. We demonstrated that text message assessments followed by immediate intervention are engaging, effective for sleep health-related outcomes, and scalable on a nationwide level for targeting EMS clinician shift workers. Behavioral interventions that target poor sleep health,

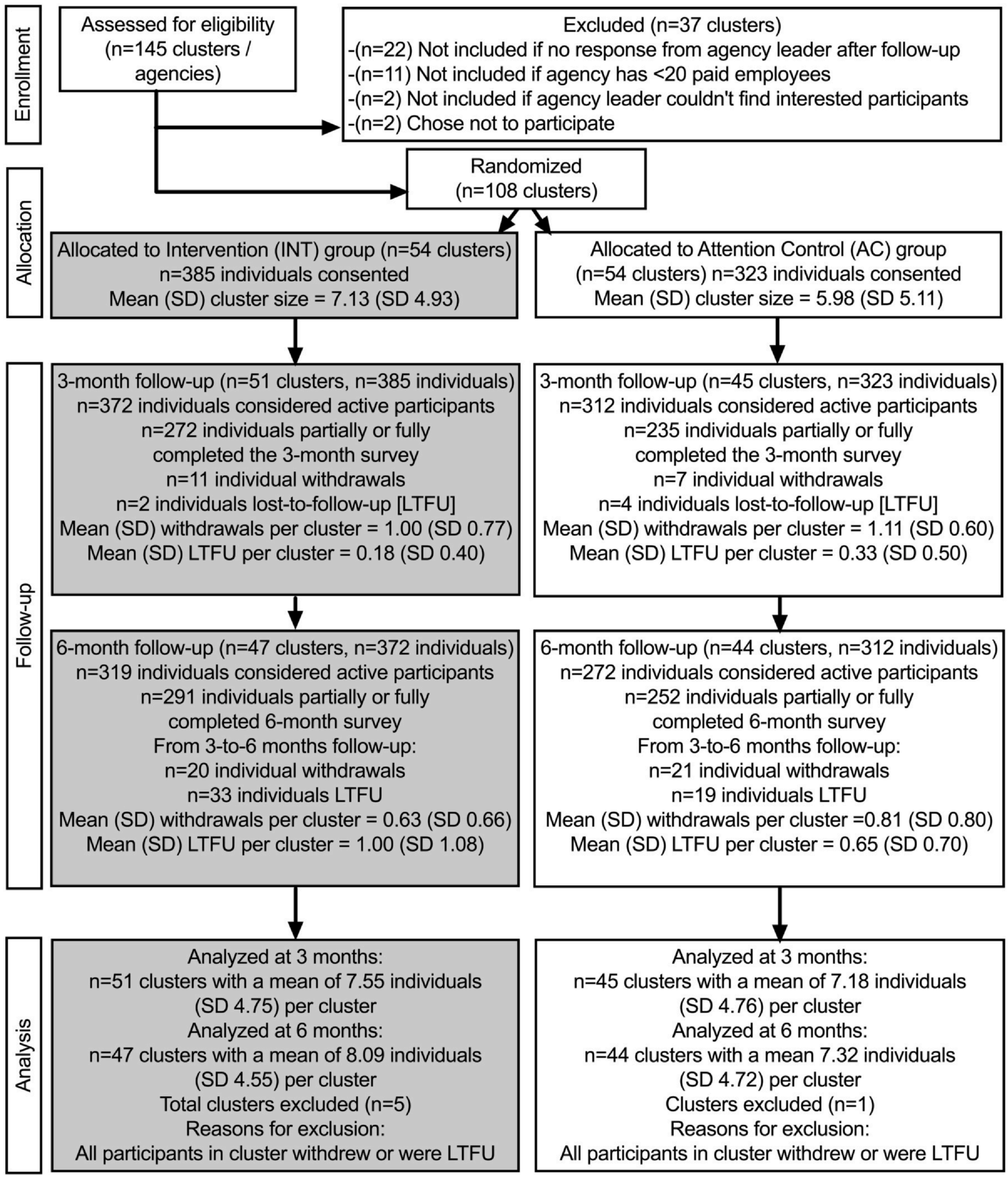

Fig. 1. CONSORT flow diagram for clusters and individual participants. n = 685 enrolled participants attempted the baseline survey (INT n = 369, AC n = 316). Three-month active participants—individuals who answered texts for at least 2 out of the first 3 months of their enrollment in the study, regardless if they completed the surveys or not. Six-month active participants—individuals who answered texts for at least 2 out of the last 3 months of their enrollment in the study, regardless if they completed the surveys or not. AC, attention control group; LTFU, lost to follow-up; SD, standard deviation

sleep debt, and presleep rest could plausibly enhance the effectiveness of real-time text message-based interventions on-shift, such as those tested in this study.

While we did not identify an intervention effect on fatigue reported during the previous month, other studies targeting diverse health behaviors have also failed to find significant effects on fatigue.[51] Workplace fatigue is a complex phenomenon affected by many employer and individual-level factors.[52] Furthermore, wide variability in EMS agency safety culture, shift scheduling, job duties, and patient-related workload could impact fatigue.[1,53] EMS clinicians also show substantial interindividual variability, with many (up to 80% of EMS clinicians in some locations) working multiple jobs and irregular shift schedules.[6] This variability may have been captured in our situational/state-level text message assessments, which is the focus of a subsequent paper from this research study. Our ability to capture this variability and its contribution to "past month fatigue" was limited given our design, which limited shift-level assessments to 1 week per month. Our ability to assess the impact of the cumulative number of shifts per month on our fatigue outcome was likely affected.

Prior studies have assessed the impact of bright light, napping, exercise, and other behavioral interventions.[54] Some studies have tested modifications to shift schedules and also shown mixed or limited impact on sleep and fatigue outcomes.[55] Other studies have tested sleep health education tailored for shift workers and showed

Table 1
Agency (cluster) demographics by study group

Variable	Total agencies (N = 108) N (%)	INT group (N = 54) N (%)	AC group (N = 54) N (%)
Agency type			
Fire-based	40 (37.0%)	19 (35.2%)	21 (38.9%)
Third service	29 (26.9%)	17 (31.5%)	12 (22.2%)
Air/ground combination	4 (3.7%)	3 (5.6%)	1 (1.9%)
Hospital-based	23 (12.0%)	5 (9.3%)	8 (14.8%)
Private	10 (9.3%)	2 (3.7%)	8 (14.8%)
Nonprofit	9 (8.3%)	6 (11.1%)	3 (5.6%)
Other	3 (2.8%)	2 (3.7%)	1 (1.9%)
Census region			
Midwest	37 (34.3%)	17 (31.5%)	20 (37.0%)
Northeast	27 (25.0%)	12 (22.2%)	15 (27.8%)
South	27 (25.0%)	17 (31.5%)	10 (18.5%)
West	17 (15.7%)	8 (14.8%)	9 (16.7%)
Paid employees (full-time and part-time)			
Smaller (< 100)	66 (61.1%)	33 (61.1%)	33 (61.1%)
Larger (≥100)	42 (38.9%)	21 (38.9%)	21 (38.9%)
Total dispatch CY 2019			
< 10,000	65 (60.2%)	32 (59.3%)	32 (59.3%)
10,000-19,999	17 (15.7%)	9 (16.7%)	8 (14.8%)
20,000-49,999	18 (16.7%)	7 (13.0%)	11 (20.4%)
50,000+	9 (7.4%)	5 (9.3%)	3 (5.6%)
No data	1 (0.9%)	1 (1.9%)	0 (0%)
Total transports CY 2019			
< 10,000	64 (59.3%)	32 (59.3%)	32 (59.3%)
10,000-19,999	17 (15.7%)	9 (16.7%)	8 (14.8%)
20,000-49,999	18 (16.7%)	7 (13.0%)	11 (20.4%)
50,000+	8 (7.4%)	5 (9.3%)	3 (5.6%)
No data	1 (0.9%)	1 (1.9%)	0 (0%)
Formal Fatigue Program			
Yes	31 (28.7%)	19 (35.2%)	12 (22.2%)
No	77 (71.3%)	35 (64.8%)	42 (77.8%)

Abbreviations: AC, attention control; CY, calendar year; INT, intervention.
Group comparison p-values: agency type p = .27; census region p = .48; paid employees (full-time and part-time) p = 1.00; total dispatch CY 2019 p = .69; total transports CY 2019 p = .53; Formal Fatigue Program p = .14.

Table 2
Individual participant demographics by study group

Variable	INT group (N = 369) N (%)	AC group (N = 316) N (%)
Sex		
Male	230 (62.3%)	210 (66.5%)
Female	138 (37.4%)	105 (33.2%)
Unknown	1 (0.3%)	1 (0.2%)
Certification/license		
EMT-Basic	105 (28.5%)	112 (35.4%)
Paramedic	239 (64.8%)	185 (58.5%)
Nurse	16 (4.3%)	15 (4.7%)
Other	9 (2.4%)	4 (1.3%)
Where do most work as EMS clinician		
Air-medical-based EMS	27 (7.3%)	28 (8.9%)
Combination ground/air EMS	15 (4.1%)	9 (2.8%)
Ground-based EMS	326 (88.3%)	279 (88.3%)
Other	1 (0.3%)	0 (0.0%)
Work multiple jobs		
Yes	197 (53.4%)	162 (51.3%)
No	172 (46.6%)	154 (48.7%)
Employment status		
Full-time	314 (85.1%)	278 (88.0%)
Part-time	54 (14.6%)	38 (12.0%)
Volunteer	1 (0.3%)	0 (0.0%)
Type of shift commonly worked		
48-h	31 (8.4%)	37 (11.7%)
24-h	204 (55.3%)	162 (51.3%)
12-h	117 (31.7%)	80 (25.3%)
8-h	6 (1.6%)	11 (3.5%)
Other	11 (3.0%)	26 (8.2%)
Health		
Excellent	68 (18.4%)	71 (22.5%)
Good	245 (66.4%)	199 (63.0%)
Fair	53 (14.4%)	44 (13.9%)
Poor	3 (0.8%)	2 (0.6%)
Race		
American Indian/Alaskan Native	1 (0.3%)	0 (0.0%)
Asian	5 (1.4%)	1 (0.3%)
Black or African American	8 (2.2%)	4 (1.3%)
White	337 (91.3%)	299 (94.6%)
More than one race	14 (3.8%)	8 (2.5%)
Unknown	0 (0.0%)	2 (0.6%)
I prefer not to answer	4 (1.1%)	2 (0.6%)
Ethnicity		
Hispanic or Latino	24 (6.5%)	12 (3.8%)
Not Hispanic or Latino	337 (91.3%)	296 (93.7%)
I prefer not to answer	5 (1.4%)	5 (1.6%)
Young children at home		
Yes	167 (45.3%)	141 (44.6%)
No	201 (54.5%)	175 (55.4%)
I prefer not to answer	1 (0.3%)	0 (0.0%)
Conditions		
Adrenal disease	1 (0.3%)	1 (0.3%)
Cardiovascular disease	11 (3.0%)	8 (2.5%)
Chronic kidney disease	4 (1.1%)	1 (0.3%)
Myocardial infarction	3 (0.8%)	2 (0.6%)
Stroke/TIA	2 (0.5%)	2 (0.6%)
Organ transplantation	2 (0.5%)	1 (0.3%)
Cancer	11 (3.0%)	4 (1.3%)
Hematologic disease	4 (1.1%)	5 (1.6%)
Liver disease	1 (0.3%)	4 (1.3%)
Rheumatologic disease	7 (1.9%)	4 (1.3%)
Thyroid disease	21 (5.7%)	13 (4.1%)
Hypertension	80 (21.7%)	53 (16.8%)
None	255 (69.1%)	233 (73.7%)
I prefer not to answer	0 (0.0%)	1 (0.1%)
Patient demographic means (± SD)		
Height (in.)	68.3 (5.6)	69.1 (4.2)
Weight (lbs)	207 (55.6)	208 (53.2)
Years of experience	14.0 (9.8)	12.6 (9.3)
Number of shifts worked last month	11.7 (4.3)	11.3 (4.6)
Alcoholic drinks (per week)	3.4 (6.1)	3.4 (5.6)
Cigarettes (per week)	3.2 (15.6)	2.9 (13.9)
Age (y)	37.7 (10.6)	35.3 (9.8)
Baseline survey means (± SD)		
PSQI	8.8 (3.5)	8.6 (3.7)
% with poor sleep	303 (82.1%)	246 (77.9%)
CFQ	5.3 (2.9)	5.2 (3.2)
% with severe fatigue	260 (70.5%)	219 (69.3%)
ESS	9.0 (4.5)	8.9 (4.4)
SAS	41.2 (24.9)	37.6 (24.3)
OFER—chronic fatigue	35.8 (25.0)	32.7 (24.4)
OFER—acute fatigue	59.8 (23.7)	57.6 (25.1)
OFER—inter-shift recovery	51.4 (25.6)	55.0 (25.1)
EMS-SAQ—teamwork climate	71.1 (22.0)	75.0 (20.4)
EMS-SAQ—safety climate	75.1 (19.9)	78.0 (18.5)
EMS-SAQ—job satisfaction	72.8 (23.4)	77.6 (20.1)

Abbreviations: AC, attention control; CFQ, Chalder Fatigue Questionnaire; EMS, emergency medical services; EMS-SAQ, EMS-Safety Attitudes Questionnaire; EMT, emergency medical technician; ESS, Epworth Sleepiness Scale; in, inches; INT, intervention; lbs, pounds; OFER, Occupational Fatigue Exhaustion/Recovery Scale; PSQI, Pittsburgh Sleep Quality Index; SAS, Schedule Attitudes Survey; TIA, transient ischemic attack.
n = 685 enrolled participants attempted the baseline survey. All group comparisons p > .05, except for Type of shift commonly worked p < .01; Height (in) p = .02; Age (y) p < .02; OFER—Inter-shift recovery p = .04; EMS-SAQ Teamwork climate p = .01; EMS-SAQ—Safety climate p = .04; EMS-SAQ Job satisfaction p = .01.

a positive, yet small effect on sleep 4-8 weeks post exposure.[56] In aggregate, these data reveal that intervening on-shift worker sleep health and fatigue is difficult and no known nonpharmacological

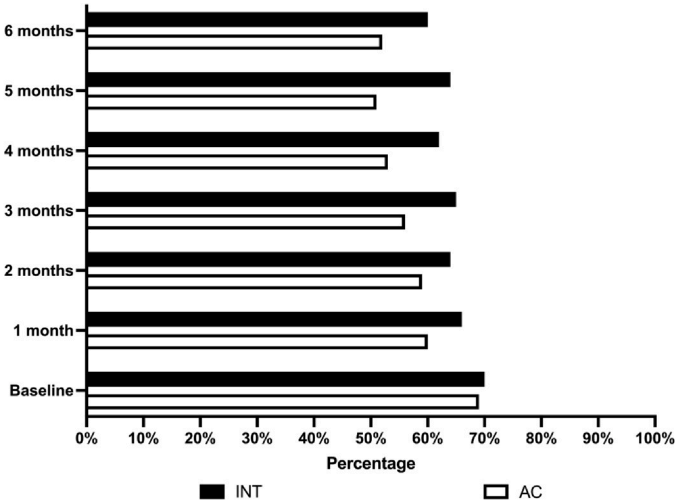

Fig. 2. Proportion of participants fatigued based on CFQ scores each month of the 6-month study period stratified by INT/AC group status. Sample sizes: Baseline INT n = 260 AC n = 219, 1-month INT n = 195 AC n = 147, 2-month INT n = 176 AC n = 130, 3-month INT n = 172 AC n = 122, 4-month INT n = 163 AC n = 115, 5-month INT n = 162 AC n = 105, 6-month INT n = 144 AC n = 107. AC, attention control group; CFQ, Chalder Fatigue Questionnaire; INT, intervention group

intervention has consistently demonstrated a large effect on targeted outcomes.

Motivation for the current trial was based, in part, on prior data showing that mobile health and text message-based interventions are attractive and useful for researchers, clinicians, and workplace wellness directors who seek to improve health through behavior change.[25] While some researchers have targeted shift worker fatigue and sleep,[15] findings have been mixed with some reporting difficulty with enrollment, compliance, and retention with mobile apps.[15,21] Interestingly, no studies, other than our own research,[11-14] have used text messaging as the core tool or vehicle to assess fatigue and sleep indicators and then intervene.[25] This is surprising given the widespread success with text message-based behavior change studies targeting binge drinking, substance use, smoking cessation, dieting, exercise, and disease management-related behaviors.[25] Suffoletto described text message-based interventions as engaging and as “deceptively simple, profoundly impactful,” and powerful through “steady and subtle influence over time.”[25] We saw similar levels of engagement compared with our prior research[11,12] and other studies targeting various health behaviors.[25]

Our mobile app was complementary to our text message platform and not the primary vehicle for intervention delivery. The mobile app was successfully used to obtain monthly outcomes (> 77% response) and collect information related to participation. Comparable efforts,[15] although smaller in scale, report a different experience with low enrollment, low compliance, and high withdrawal. Mobile apps hold promise as a vehicle for fatigue risk management; however, the varied experiences reported in multiple studies deserves additional investigation so that EMS employers and individual EMS clinicians are adequately informed regarding utility.

The intervention tested in this study improved daytime sleepiness compared with the AC group. A similar, but not statistically significant, trend was observed for the PSQI measure of sleep quality. Repeated exposure to brief text message queries about fatigue and sleep (both assessment and intervention messages) could have led to “steady and subtle influence over time” that impacted daytime sleepiness.[25] These repeated queries may have acted as little mental notes or reminders to participants that led many to pay greater attention to their sleep. Notably, participants in the INT group, on average, received a larger number and greater variety of text messages (thus more mental notes or reminders) during the study

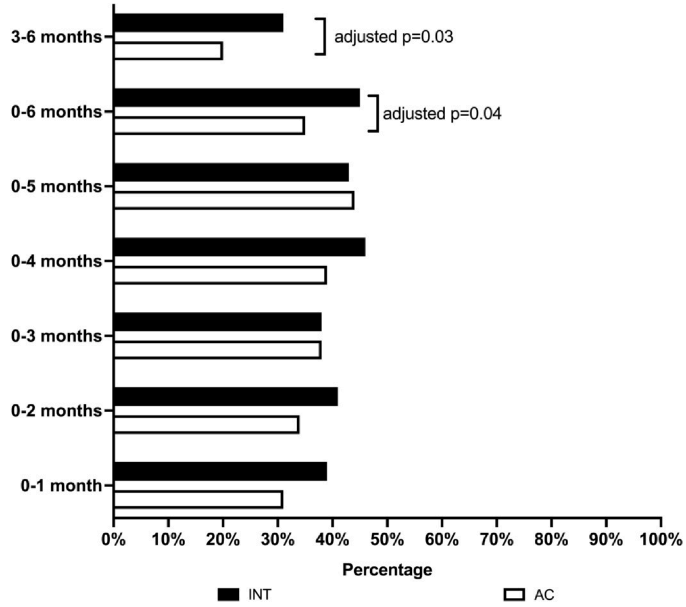

Fig. 3. Proportion of participants experiencing a clinically meaningful change in ESS over time by group status. Sample sizes: 3-6-month INT n = 68/220 AC n = 36/183, 0-6-month INT n = 107/240 AC n = 72/206, 0-5-month INT n = 109/255 AC n = 91/206, 0-4-month INT n = 121/263 AC n = 85/219, 0-3-month INT n = 101/263 AC n = 84/219, 0-2-month INT n = 114/275 AC n = 74/219, 0-1-month INT n = 115/293 AC n = 75/242. AC, attention control group; INT, intervention group

period than did participants in the AC group. This was due, in part, to the INT group’s tailored messages being linked to 8 constructs of the SFAB instrument (see Supplementary File Appendix A[33]) compared with 3 constructs for the AC group. We created what we believed was the maximum variety of text messages on these topics without being overly repetitive. Our approach was intentional and based on guidance regarding use of AC groups in randomized controlled trials.[27]

Greater frequency (dose) of text messages does not automatically translate into greater impact.[25] The number of text messages sent in prior studies varies considerably with some reporting just several messages each week to greater than 12 per day.[25] There is no established consensus on the number of text messages or on how to tailor text messages for studies targeting select health behaviors.[25] Based on our findings, repeated exposure to tailored text messages that are relevant, salient, and motivational appear impactful on daytime sleepiness among EMS clinicians.

Any intervention that reduces sleepiness or fatigue in EMS workers is clinically relevant, given the impact of these symptoms on performance and safety.[9] However, our findings and the findings from prior studies suggest that a hybrid approach—one that includes tailored educational modules and guidance for off-shift behavior available at any time combined with real-time, repeated messaging via a mobile app or text messaging—may have greater clinical impact. Small modifications to our platform, such as changing the frequency or pattern of tailored text messages, should be explored. Additional pilot research testing such modifications would be essential before testing in a larger phase III-type design.

Limitations

Participating EMS/fire agencies and individuals may differ from those who chose not to participate; however, the characteristics of our sample are like those who participated in previous studies.[1] The COVID-19 pandemic impacted our ability to reach goal enrollment and may have impacted burnout and fatigue.[57] We also fell short of 100 total EMS agency clusters with 5 individual participants per cluster completing the 6-month protocol. Recruitment and enrollment were terminated early for grant closeout.

The discovery of moderate (r = 0.39-0.56, $p < .0001$) and consistent month-to-month correlations between our primary measure of fatigue (the CFQ) and daytime sleepiness (as measured by the ESS), supports previous findings of a strong relationship between indicators of fatigue and sleepiness (see Supplementary Table 9).[46] These results raise questions about the sensitivity of our selected measures of fatigue and whether alternative measures may be more sensitive among EMS clinician shift workers.

Conclusions

The real-time assessment and texting tool did not result in lower past month fatigue at the end of the study period when compared with the attention control group. However, the text message assessment followed by immediate intervention was engaging, effective for sleep health-related outcomes like daytime sleepiness, and is scalable.

Author contributions

Authors PDP, CGP, BP, FXG, and DJB conceived of the study, led funding acquisition, and project administration. Authors PDP, SEM, CGP, BP, IWP, FXG, and DJB contributed to methodology, design of the study, and developed the study tools for data acquisition. Authors PDP, BP, IWP, and DJB contributed to computer programming and algorithms. Authors PDP, SEM, MDW, CGP, BP, IWP, LSW, RPT, FXG, and DJB were involved in creating participant materials that included information and materials sent to intervention and control group participants. Authors PDP, SEM, CGP, BP, and IWP led data curation, investigation, and data acquisition. Authors PDP and SEM contributed to validation of participant responses. Authors PDP, SEM, CGP, and CNS contributed to formal analyses and visualization. All authors were involved in reviewing, analysis, and interpretation of the data. All authors agree to the final version of this paper and agree to be accountable for all aspects of this work.

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Use of generative AI and AI-assisted technologies in the writing process

The authors did not use a generative artificial intelligence (AI) tool or service to assist with preparation or editing of this work. The author(s) take full responsibility for the content of this publication.

Data availability

The study protocol and related documents can be accessed on clinicaltrials.gov. Requests for deidentified data must be submitted to the corresponding author. Procedures for accessing data will follow the procedures as outlined by the University of Pittsburgh as part of standard Data Use Agreements

Declaration of conflicts of interest

Author MDW reports consulting fees with the University of Pittsburgh and Fred Hutchinson Cancer Center. Author DJB reports personal fees and grant support from Sleep Number, and personal fees from Synchronicity Pharma and Google Health. The other authors have no conflicts of interests to disclose.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.sleh.2026.02.011.

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