

Shift Schedule Change From 24/48 to 1/3/2/3 Improves Markers of Stress and Quality of Life in Career Firefighters

Matthew J. McAllister, PhD, M. Hunter Martaindale, PhD, Andrea Womble, MPA, Nathan Sutton, MS, and Stephanie Uriegas, MS

Objective: This study seeks to better understand the impact of schedule change on physiological and self-report measures of stress and quality of life among career firefighters. **Methods:** This study examined the impact of a schedule change from 24/48 to a 24-hour on/72-hour off, 48-hour on/72-hour off (i.e., 1/3/2/3) shift rotation on markers of stress among career firefighters over a 7-month period. Physiological measures such as salivary biomarkers (cortisol, testosterone, testosterone-to-cortisol ratio, interleukin-6) and blood pressure as well as self-reported survey instruments for occupational stress and job satisfaction were assessed throughout the study. **Results:** By the end of the study, participants demonstrated significantly lower salivary cortisol concentrations, improved quality of life, and better sleep quality. **Conclusions:** These findings suggest that transitioning to a 1/3/2/3 schedule may reduce physiological stress and improve quality of life among career firefighters.

Keywords: cortisol, inflammation, interleukin-6, cytokine, sleep quality, shift work

Firefighters face a range of stressors, including intense physical exertion, environmental hazards (e.g., heat, smoke, chemical exposure), psychological strain, and shift work.¹ These stressors activate the sympathoadrenal (SA) and hypothalamic pituitary adrenal (HPA) axes, leading to increased concentrations of stress hormones such as epinephrine, norepinephrine, and cortisol. These hormones facilitate increases in heart rate, respiratory rate, and blood pressure.² Although acute activation of these systems supports physical and cognitive performance,^{3,4} chronic activation of the SA and HPA axes may elevate cardiovascular strain, promote inflammation, and increase oxidative stress, all of which elevate the risk for developing cardiovascular disease (CVD).⁵⁻⁷ Notably, CVD accounts for approximately 51%–54% of firefighter line-of-duty deaths.⁸⁻¹¹ Major agencies, including the National Fire Protection Agency, US Fire Administration, and the Federal Emergency Management Agency, identify “stress/overexertion” as leading contributors of CVD among firefighters.⁸⁻¹²

Despite recognition of firefighting as a high-stress occupation, longitudinal research examining the effects of occupational stressors

LEARNING OUTCOMES

- Our study investigated the impact of a schedule change from 24/48 to a 1/3/2/3 shift rotation on physiological and psychosocial markers of stress among career firefighters over a 7-month period.
- The shift change resulted in significantly lower salivary cortisol concentrations, and improved quality of life and sleep quality.
- These findings suggest that transitioning from a 24/48 to a 1/3/2/3 shift schedule may reduce physiological stress and improve quality of life among career firefighters.

on biomarkers of stress and inflammation remains limited. Most existing studies rely on self-report surveys in an attempt to quantify stress among firefighters.¹³⁻¹⁵ Although several studies have examined the impact of occupational stressors on biomarkers of stress, inflammation and oxidative stress, most of those trials have been aimed at studying acute responses.¹⁶⁻²⁰ Even though cortisol has been frequently studied in relation to posttraumatic stress disorder, sleep deprivation, and shift work among firefighters,²¹ findings have been inconsistent.²² Therefore, additional biomarkers such as testosterone, the testosterone:cortisol (T:C) ratio, and inflammatory markers like interleukin-6 (IL-6) may provide a more compressive assessment of stress and cardiometabolic health.²³⁻²⁵ Monitoring these biomarkers can also yield insights into recovery and physical performance, which are both critical for firefighter readiness.²⁶⁻²⁸

Shift work, which requires firefighters to work extended hours including overnight, rotating, or irregular hours, is a significant source of occupational stress. The typical 24/48 schedule requires recovery from sleep deprivation while managing responsibilities during the 48-hour off-duty period. Although firefighters face stressors on duty, this type of shift work also poses as an additional stressor because being away from home/family for a day or more at a time can present additional challenges and personal stressors. Extended shifts, such as a 48/96 schedule, may provide more consecutive off-duty days, potentially improving

From the Metabolic & Applied Physiology Laboratory, Department of Health & Human Performance, Texas State University, San Marcos, Texas (M.J.M., N.S., S.U.); ALERRT Center, Texas State University, San Marcos, Texas, (M.J.M., M.H.M.); and Hays County ESD No.5, Kyle, Texas (A.W.).

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Conflicts of Interest: One of the coauthors, Andy Womble, is currently a graduate student at Texas State University but also employed by HCESD#5. However, the authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a conflict of interest. Please note that HCESD#5 did not (at any point) anticipate any financial benefit from this study whatsoever, regardless of the outcome. Moreover, this was a preplanned shift change intervention (24/48 to 24/72, 48/72), and the funder did not advise or influence the methodology or interpretation of the primary data (salivary biomarkers, blood pressure, and survey data).

Data Availability: Data may be shared upon reasonable request to the corresponding author. Participants did not provide note consent to make data publicly available.

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Address correspondence to: Matthew J. McAllister, PhD, Metabolic & Applied Physiology Lab, Texas State University, San Marcos, TX 78666 (mjm445@txstate.edu).

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stress management and quality of life.²⁹ Watkins et al³⁰ found that firefighters (both married and single) viewed the 24/48 schedule negatively and expressed interest in extended shift length such as a 48/96 (on/off) schedule. Additionally, Garrett et al³¹ analyzed markers of fitness among a large sample of firefighters ($n=1995$) and reported that firefighters working a 48/96 schedule demonstrated superior body composition and fitness compared to those following quickly rotating shifts.

Direct comparisons suggest important tradeoffs. Billings and Focht²⁹ found no statistical difference in sleep quality between 24/48 and 48/96 schedules, although both were superior to rotating shifts. Bowles et al presented new findings regarding the 1/3/2/3 at the June 2025 SLEEP conference.^{32,1} The 1/3/2/3 schedule resulted in lower sleep duration; however, firefighters reported improved subjective sleep satisfaction perhaps due to enhanced work-life balance and recovery opportunities. Taken together, these findings highlight that different shift schedules offer both advantages and disadvantages, underscoring the need to examine not only objective health outcomes but also perceived sleep quality, well-being, and job satisfaction. To our knowledge, no studies, to date, have investigated the physiological or psychological impacts of transitioning from a 24/48 to a 1/3/2/3 schedule. The present study aimed to fill this gap by evaluating changes in salivary markers of stress and inflammation, occupational stress, and job satisfaction following a shift schedule change among career firefighters.

METHODS

Subjects and Experimental Design

This quasi-experimental study involved 26 full-time, career firefighters from the Hays County ESD No. 5 (HCESD#5) in Kyle, Texas. In September 2024, HCESD#5 transitioned from a 24/48 (24 hours on/48 hours off) to a 24/72, 48/72 (24 or 48 hours on/72 hours off) schedule (the 24/72, 48/72 is also known as a 1/3/2/3 schedule). The fire department involved in this study covers 76 square miles and serves an estimated population of 100,000, including both the City of Kyle (TX) and its extraterritorial jurisdiction. The department employs 52 career firefighters and 13 administrative personnel. It is a career fire department with no volunteer staff. During the study period, the department operated three fire stations with four frontline apparatus responding to calls; this has since expanded to four stations, still with four frontline units in service. Annual call volume increased over the past 3 years, with 5925 calls in 2022, 6494 in 2023, and 6974 in 2024. The department's shift start time was 9:00 AM. However, when the 1/3/2/3 schedule was adopted on September 16, 2024, the start time shifted to 8:00 AM.

To assess the effects of this change, measurements of physiological stress—specifically salivary biomarkers and blood pressure—were collected monthly beginning in September 2024 (pre-shift change) and continuing for 6 months post-change (October 2024 through March 2025), resulting in seven total data collection sessions. Self-reported occupational stress and job satisfaction were assessed via survey at five time points: September, October, and November 2024, and January and March 2025.

For consistency, participants were instructed to arrive at each session having fasted for at least 4 hours. All data collection took place between 7:30 AM and 11:00 AM on the subjects' first scheduled workday following their off-duty period. Prior to participation, all firefighters were briefed on the study's purpose and procedures, completed a health history questionnaire, and provided written informed consent. Study procedures were approved by the Texas State University Institutional Review Board (IRB No. 9732) in accordance with the Declaration of Helsinki.

Experimental Procedures

Data collection occurred at HCESD#5 Station 1 on three separate days each month to accommodate all rotating shift crews. Upon arrival, subjects were asked to sit quietly (~10 minutes) and rinse their mouths with water to prepare for saliva collection and to help

standardize resting blood pressure measurements. Blood pressure was measured first, followed by saliva collection and the completion of the occupational stress and satisfaction survey.

Resting Blood Pressure

Resting blood pressure was assessed using an automated wrist monitor (Omron, Kyoto, Japan). Subjects remained seated with their arm supported at heart level, palm facing up. Two readings were taken during each session, with a third measurement obtained if the first two readings differed by more than 10%. The average of the readings was used for analysis. Blood pressure was assessed at all seven data collection sessions.

Saliva Collection and Analysis

Saliva samples (~1.0 mL) were collected via passive drool method at each session. Subjects rinsed their mouth with filtered water 10 minutes before providing the sample. Samples were immediately placed on ice in a portable cooler (Fisher Scientific, Hampton, NH) and transported within 1 hour to the Metabolic and Applied Physiology Laboratory at Texas State University, where they were stored at -80°C. Prior to analysis, samples were thawed and centrifuged at 1500g for 15 minutes. Cortisol, testosterone, and interleukin-6 (IL-6) concentrations were analyzed using commercially available assay kits following the manufacturer's instructions (Salimetrics, State College, PA). Absorbance data (in duplicates) were collected using a colorimetric plate reader (BioTek, Winoosky, VT).

Occupational Stress and Satisfaction Survey

The Occupational Stress and Satisfaction (OSS) Survey consisted of 27 items adapted from multiple validated instruments. Thirteen items were drawn from the European Quality of Life Questionnaire (EQL³³), five items from the Staff Satisfaction Index and Happy Career Scale (SSI-HCS³⁴), and five items from the Sleep Quality Scale (SQS³⁵). Four additional items assessed exposure to traumatic events at work or in personal life and, if yes, how many events. The SSI-HCS items were previously validated in a firefighter sample, whereas the others were previously utilized within the general population.³⁴ A copy of the OSS is provided in Appendix A (<http://links.lww.com/JOM/C311>).

The EQL items were divided into two factors. Items 1 through 7 asked subjects to respond based on their position on the day each survey was conducted (EQL1). Items 8 through 13 asked subjects to respond based on how they felt over the previous week (EQL2). Subsequent confirmatory factor analyses (CFAs) were conducted to verify if the individual scale items aligned to create each composite latent variable (EQL1, EQL2, SSI-HCS, and SQS; see Appendix A (<http://links.lww.com/JOM/C311>) for items and item loadings for each latent variable). For EQL1, all seven items loaded on the quality-of-life questions related to how the subjects felt on the day of testing. One item (eql_9) was removed from EQL2 due to poor factor loading. All five SSI-HCS items loaded on a single factor representing job satisfaction. For SQS, all five items loaded on a single construct; however, sqs_1 and sqs_2 loadings were only slightly higher than the widely recognized cutoff of 0.3. Removal of these two items resulted in a more parsimonious, better-fitting model (AIC was 2335.33 with all items present and 1338.45 after removal of the two aforementioned items).

After completing the CFAs, each scale was used to create a composite variable by summing all responses and dividing by the number

TABLE 1. Subject Descriptive Characteristics

Height (cm)	Weight (kg)	Age (yr)	Experience (yr)	BMI (kg/m ²)
180.1 ± 5.4	90.6 ± 11.4	29.0 ± 7.9	6.5 ± 7.0	27.9 ± 3.6

Data are shown as mean ± SD.
BMI, body mass index.

¹These findings were presented at a scientific conference and should be regarded as preliminary results until a peer-reviewed publication is available.

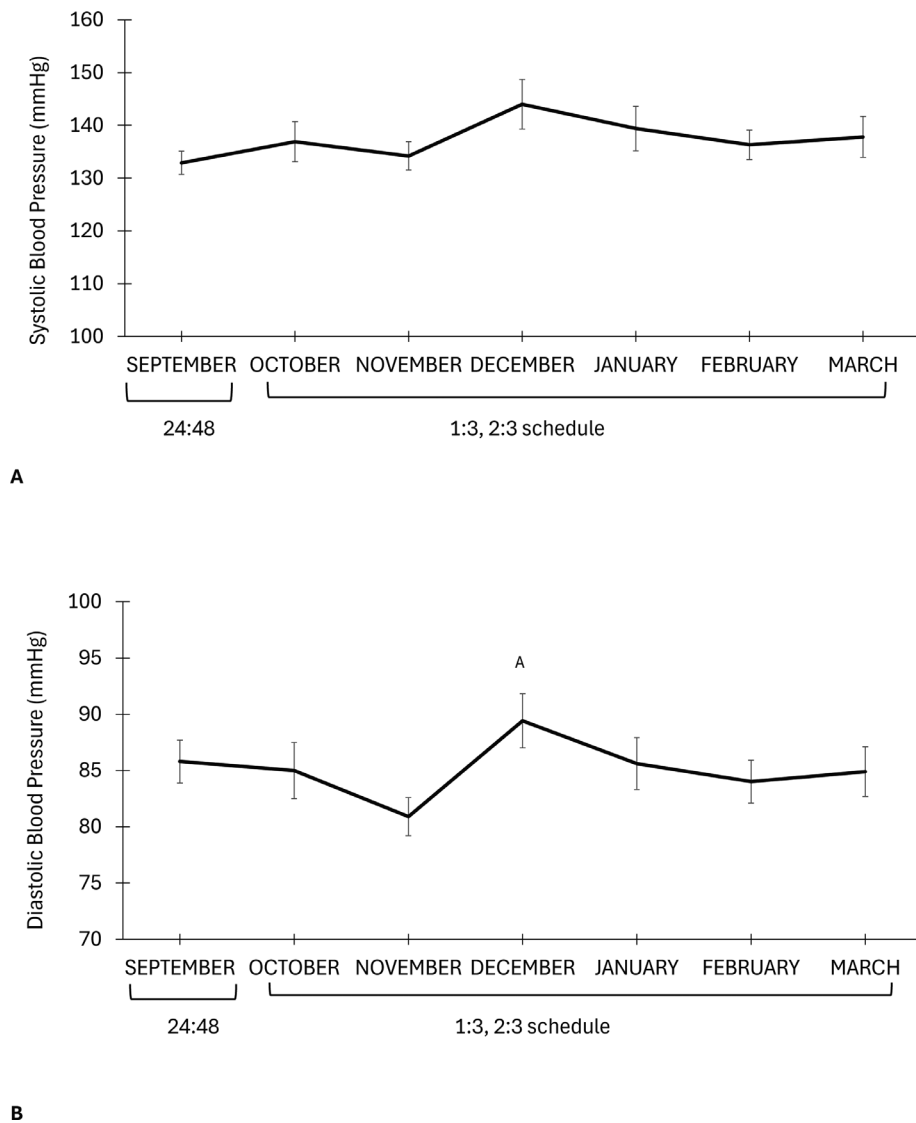


FIGURE 1. Changes in systolic blood pressure (A) and diastolic blood pressure (B) across time. “A” = significant increase compared to November ($P=0.01$). Note, due to variations in firefighters present for blood pressure measures, the observations varied each time point and are provided: $N=26, 15, 23, 18, 22, 22, 19$.

of items for EQL1, EQL2, SSI-HCS, and SQS. This allowed for an average score for each of the four constructs at each time point. Internal consistency (Cronbach's alpha) for each scale is reported with the CFA tables (Appendix B, <http://links.lww.com/JOM/C312>).

The OSS was administered at five time points: September, October, and November 2024, and January and March 2025.

Statistical Analysis

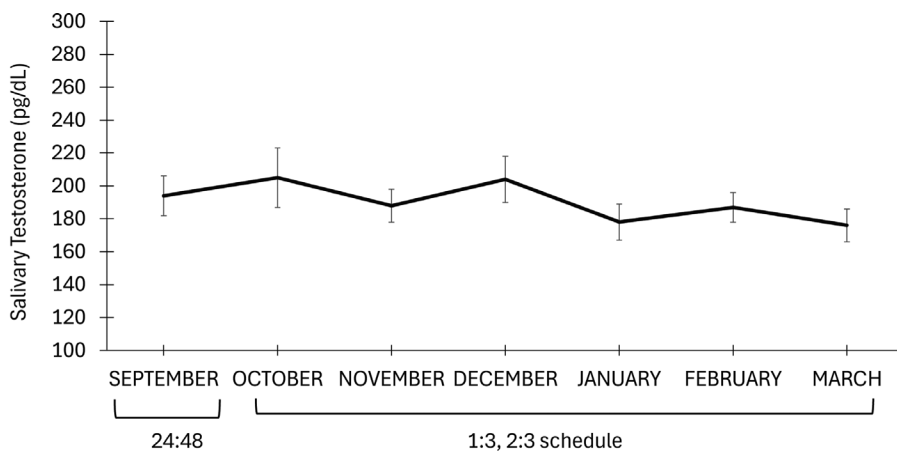
All statistical procedures were conducted using SAS version 9.4 (SAS Institute, Cary, NC). One-way repeated-measures analysis of variance (ANOVAs) were used to assess changes over time in salivary cortisol, testosterone, T:C ratio, IL-6, systolic blood pressure, diastolic blood pressure, and the survey-derived measures of occupational stress and satisfaction. When significant main effects were observed, Tukey's post hoc tests were used to examine pairwise differences. Outliers were identified using the Robustreg procedure and excluded from analysis if their standardized residuals exceeded ± 3.0 .

RESULTS

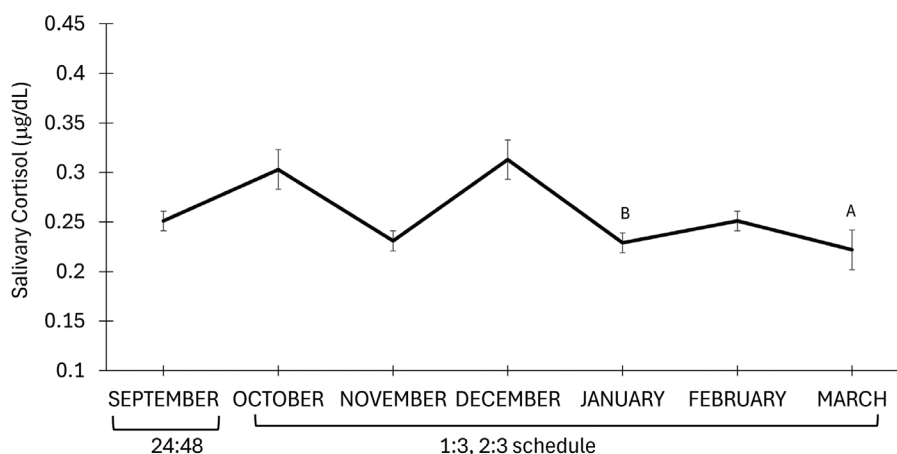
A total of 26 firefighters ($n=26$) completed the 7-month study. However, participation varied slightly across sessions due to scheduling conflicts and operational demands, with an average of 21 ± 3 firefighters participating each month. Participant demographic data are provided in Table 1. Salivary biomarker data were excluded from analysis for any subject who had not fasted for at least 4 hours prior to testing.

Blood Pressure

Systolic blood pressure did not change significantly over the study period, although the effect approached statistical significance ($F=2.14, P=0.05$). Diastolic blood pressure changed significantly over time ($F=2.27, P=0.04$), with a notable increase from November to December ($P=0.01$). However, diastolic blood pressure at baseline (September) did not differ significantly from any subsequent month. Blood pressure results are presented in Figure 1.



A



B

FIGURE 2. Changes in salivary testosterone (A) and cortisol (B) concentrations across time. “A” = significant decrease in cortisol concentrations from December 2024 to March 2025 ($P=0.04$). “B” = reduction in concentrations December to January that approached significance ($P=0.05$). Note, due to variations in firefighters present, outliers detected or usable samples for saliva measures, the observations varied each time point and are provided: $N=22, 14, 20, 16, 20, 20, 17$.

TABLE 2. T:C Ratio and IL-6 Data

	September	October	November	December	January	February	March
T:C ratio	0.09±0.03	0.07±0.03	0.08±0.03	0.07±0.02	0.08±0.03	0.07±0.02	0.07±0.03
IL-6	15.2±10.0	11.6±6.4	8.5±6.9	10.2±6.8	7.4±4.6	7.3±5.8	12.1±8.9

Data are shown as mean ± SD.

IL-6, salivary interleukin-6; T:C ratio, salivary testosterone:cortisol ratio.

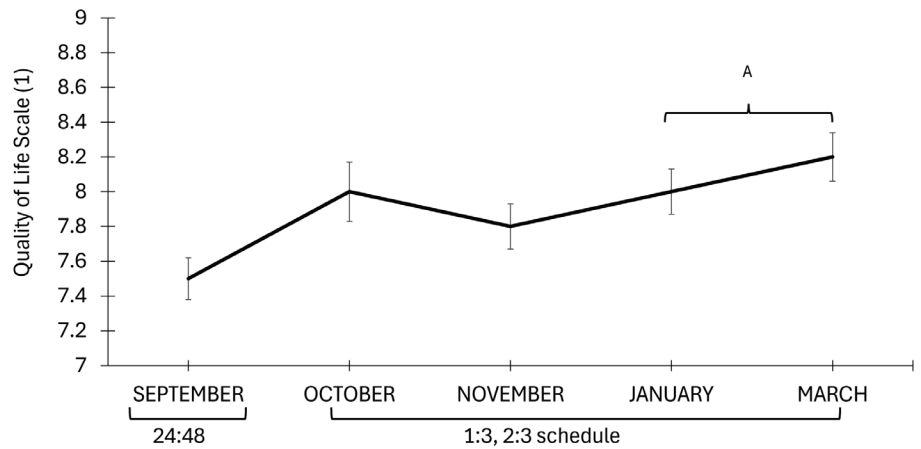
Saliva Markers

Salivary testosterone concentrations showed significant variability among participants ($F=8.27, P<0.001$) but did not change over time ($F=1.67, P=0.14$). Cortisol concentrations also varied significantly among the participants ($F=5.17, P<0.001$) and demonstrated a significant reduction over time ($F=3.13, P=0.007$). Post hoc analysis revealed a significant decrease in cortisol concentrations from December 2024 to March 2025 (29%, $P=0.04$). A similar reduction from December to January approached significance (26%, $P=0.05$). Mean testosterone and cortisol concentrations are shown in Figure 2.

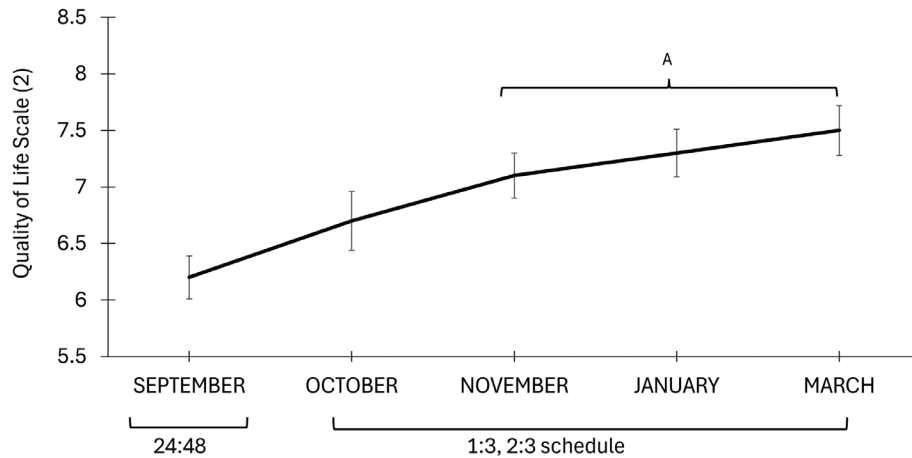
No significant changes were observed for the T:C ratio ($F=1.39, P=0.22$) or for IL-6; however, the main effect for IL-6 changes over time approached significance ($F=2.2, P=0.05$). Mean T:C ratio and IL-6 data are shown in Table 2.

Survey Data

Both quality-of-life scales (EQL1 and EQL2) showed significant improvements over time (EQL1: $F=4.2, P=0.03$; EQL2: $F=5.7, P<0.001$). Post hoc analysis showed that EQL1 scores increased significantly in January and March 2025 compared to baseline ($P<0.05$). EQL2 scores



A



B

FIGURE 3. Changes in European Quality of Life Scale 1 (A) and European Quality of Life Scale 2 (B). (A) “A” = significant increase in quality of life in January and March 2025 compared to baseline ($P < 0.05$). (B) “A” = increased quality of life in November 2024, January, and March 2025 compared to baseline ($P < 0.05$). Note, due to variations in firefighters present for testing, the observations varied at each time point and are provided: $N = 26, 16, 24, 23, 21$.

increased significantly in November 2024, January, and March 2025 compared to baseline ($P < 0.05$). Quality-of-life results are shown in Figure 3.

No significant changes were observed for job satisfaction ($F = 1.82, P = 0.13$). Self-reported sleep quality improved significantly over time ($F = 10.4, P < 0.001$), with higher scores beginning in October 2024 (compared to baseline in September) that persisted through March 2025 ($P < 0.05$). Job satisfaction and sleep quality results are shown in Figure 4.

Call Data

As a secondary, descriptive analysis, call data were reviewed to account for variations in operational workload that might influence stress outcomes. Call volume remained relatively stable throughout the study period. These data are provided in Table 3.

DISCUSSION

The primary findings from this study suggest that transitioning from a 24/48 to a 1/3/2/3 shift schedule led to measurable benefits for

the participating firefighters. Specifically, the shift change was associated with significant reductions in salivary cortisol concentrations, along with improvements in quality of life (by two indexes) and sleep quality by the end of the 7-month observation period. Although diastolic blood pressure increased briefly from November to December, this change was not different from baseline. Additionally, no significant changes were found for testosterone, IL-6, or systolic blood pressure. Taken together, these findings suggest that extending consecutive off-duty days may reduce physiological stress and improve subjective well-being among career firefighters.

Beyond these observed patterns, the structure of the 1/3/2/3 schedule itself offers plausible mechanisms for the physiological and psychological improvements reported. Unlike the 24/48 model, which limits off-duty recovery to a single full day between shifts, the 1/3/2/3 rotation provided repeated blocks of 72 consecutive hours off-duty. These extended recovery windows may allow firefighters to adequately recover before beginning their next shift. From an operational perspective, longer off-duty blocks also reduce the frequency

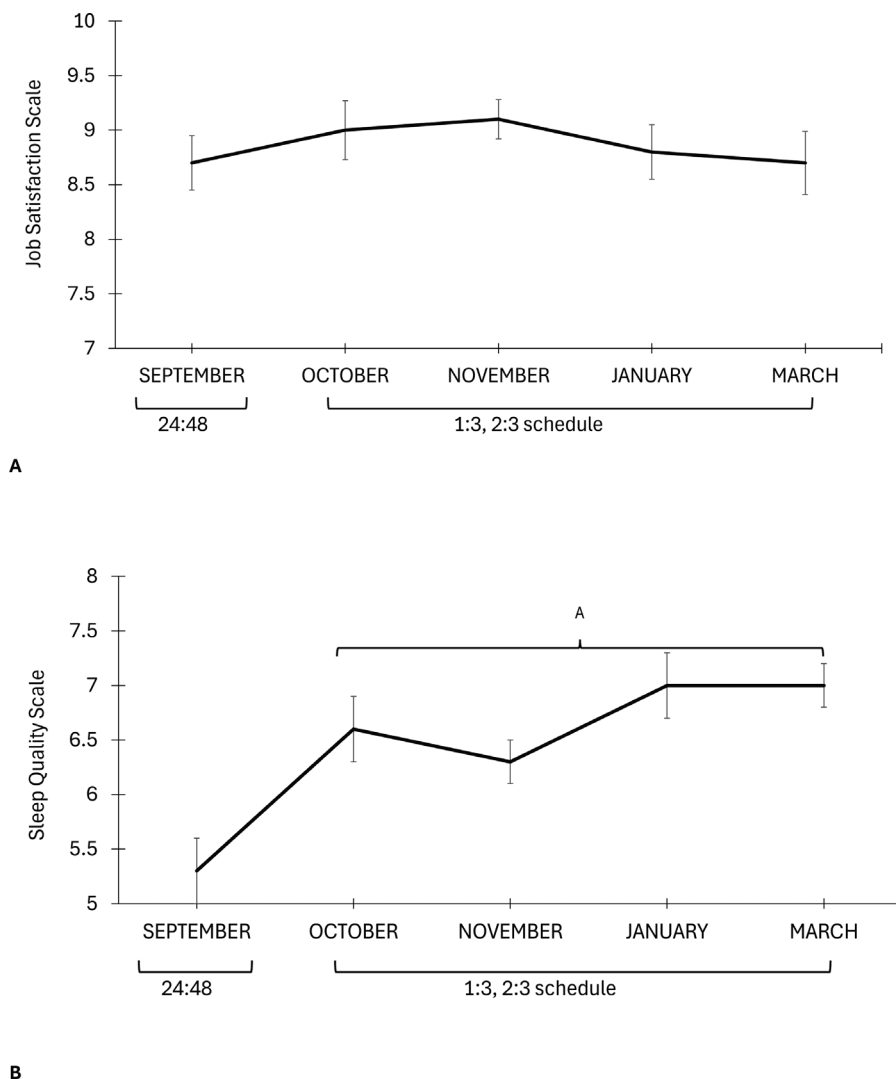


FIGURE 4. Changes in job satisfaction (A) and sleep quality (B) across time. (B) “A” = significant increase in sleep quality in October 2024 (compared to baseline in September) that persisted through March 2025 ($P < 0.05$). Note, due to variations in firefighters present for testing, the observations varied at each time point and are provided: $N = 26, 16, 24, 23, 21$.

TABLE 3. Call Data for Kyle Fire Department

	September	October	November	December	January	February	March
Fire	13	10	13	5	17	9	20
Explosion	0	2	1	0	0	0	0
EMS	365	373	329	349	369	342	369
HAZMAT	7	11	6	10	11	9	10
Service call	25	18	23	25	18	26	33
Series (other)	136	120	140	117	123	104	107
False alarm	32	39	44	34	56	33	26
Special incident	1	3	0	0	0	0	1
Total	579	576	556	540	594	523	566

EMS, emergency medical services; HAZMAT, hazardous materials.

of rapid transitions between home and work roles, which may otherwise contribute to chronic stress and impaired sleep quality. Together, these structural differences suggest that the 1/3/2/3 rotation may better support recovery between shifts, which in turn could explain reductions in cortisol concentrations and improvements in perceived quality of life.

There are also practical differences in how work demands are distributed within the 1/3/2/3 schedule that may influence well-being. The schedule reduces the total number of shift start-ups each month, which may lessen anticipatory stress, sleep disruption on transition days, and logistical burden on firefighters and their families. The addition of a 48-hour shift within the rotation also concentrates operational

exposure, potentially enabling more predictable periods of workload followed by predictable periods of recovery. These features may enhance perceived control over time away from work, a factor consistently associated with improved occupational health outcomes among shift workers.^{36,37}

Salivary cortisol and testosterone concentrations are useful for monitoring occupational stress, fatigue, and burnout—conditions frequently experienced by shift workers, including firefighters.^{20,22,38–41} Prior research has demonstrated that elevated waking cortisol concentrations are significantly related to psychological well-being among firefighters and law enforcement officers.⁴¹ Although this study did not specifically measure waking cortisol concentrations, the overall reduction in fasted cortisol concentrations by the end of the intervention could potentially explain a mechanism contributing to improvements in quality of life and sleep quality among the present sample.^{40,42–44} It is important to note that, although cortisol and testosterone concentrations are useful at monitoring acute stress response and sleep-related fatigue, chronic hypercortisolemia may also be a contributing factor to chronic health conditions among firefighters.³⁹

The nonsignificant changes in IL-6 observed in this study deserve mention, particularly given the established links between IL-6, sleep quality, and occupational stress in high-risk professions.⁴⁵ Previous research has shown that elevated IL-6 concentrations are predictive of poor sleep quality among shift workers including firefighters.^{46–48} Additionally, IL-6 has been correlated with other stress-related biomarkers such as cortisol in wildland firefighters.⁴⁸ Although the changes in IL-6 in the present study only approached statistical significance (20%–47% reduction from baseline), these findings concurrent with improved sleep quality and lower cortisol concentrations align with previous studies.^{25,47} However, the interpretation of salivary IL-6 should be approached with caution, as oral inflammation may influence measurements.^{49,50}

Because the goal of the study was to examine not only the outcomes but also the adaptation process following the scheduling change, we included multiple measurement periods to track the immediate and longitudinal changes. The results suggest that improvements accumulated gradually rather than appearing all at once, particularly for cortisol and sleep quality, which continued to improve several months after the shift change was initiated.

The survey findings further support the physiological data, with both quality-of-life scales showing significant improvements over time. These results align with prior research suggesting that firefighters perceive extended off-duty schedules as beneficial for managing work-life balance and recovery.³⁰ Although job satisfaction did not significantly change, it is noteworthy that no negative trends were observed. Improvements in sleep quality emerged early in the intervention period and persisted throughout, suggesting that extended recovery periods may help mitigate the cumulative sleep debt commonly experienced in firefighter's shift schedules.

As a secondary analysis, call volume data were examined to account for fluctuations in operational demand that may influence physiological or psychological outcomes. Call volume remained relatively stable across the observation period, including December, when diastolic blood pressure temporarily increased. Therefore, it is possible that the increase in diastolic blood pressure in December may be related to personal stressors, which were not accounted for in the present study. However, this is speculative.

Several limitations of this study should be acknowledged. First, and likely the most salient, the absence of a control group limits the ability to definitively attribute observed changes to the shift schedule change alone. Because all HCESD#5 personnel transitioned to the new schedule, a control group would have required concurrent collection from a comparable department, introducing logistical challenges and potential confounders. Regardless, future studies should expand on the present findings by studying a larger department and including a control group. Second, although efforts were made to standardize testing conditions, unmeasured personal

and occupational stressors may have influenced the results. Third, it is possible that confounding factors such as holiday, vacation, overtime, and shift trades may have impacted results. Fourth, the small sample size and single-department focus limit the generalizability of the findings. To address these limitations, future studies should include larger samples, control groups, and more rigorous control of pretesting conditions to strengthen causal inferences. Fifth, it should be noted that, due to scheduling conflicts, an average of 22 ± 2 firefighters participated each month. This variation in the observation (sample size number) is a limitation that should be acknowledged. Finally, the department implemented two changes simultaneously: the shift schedule and adjusted the shift start time from 9:00 AM to 8:00 AM. This dual modification makes it difficult to determine the extent to which observed improvements were attributable to the schedule structure itself versus potential effects of the earlier start time, which may have influenced sleep time, commuting demands, or other morning routines.

CONCLUSIONS

The findings from this study indicate that shifting from a 24/48 to a 1/3/2/3 schedule may reduce physiological stress and improve both sleep and quality of life among career firefighters. Although the absence of a control group limits the strength of the conclusions, the findings collectively indicate that a significant improvement across multiple outcomes provides preliminary support for the benefits of allowing more consecutive days off-duty.

Although these results are promising, more research is needed to further explore these changes. Future studies should incorporate control groups and explore additional health and performance outcomes to better understand the long-term impacts of the schedule modifications. Nevertheless, the present findings offer practical insights for fire departments considering schedule changes as part of their efforts to support the health, well-being, and operational readiness of their career firefighters.

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