Developing a Data-Driven Fatigue Management System Dashboard for Paramedic Services

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SUMMARY

Paramedic Fatigue is linked to poor work performance, including increased medical errors, and adverse health outcomes for the paramedic, such as increased accident risk, musculoskeletal disorders, and burnout. Currently, there are no effective and practical risk assessment tools that consider the various fatigue factors attributed to work tasks, work arrangement, and personal demographics. This presentation describes findings from a large prospective cohort fatigue study with a rural paramedic service in Ontario, Canada. Research data informed the development of a Fatigue Management System Dashboard (FMSD) to support a Service's critical decision making for enhancing service efficiency, improving paramedic health and wellbeing, and maintaining patient safety.

KEYWORDS

Field Study, Cohort Longitudinal, Sleep-Related Fatigue, Performance, Health, Paramedic

Introduction

Paramedics experience significant levels of fatigue, which if left without intervention, may not only affect their health and safety but may also endanger the safety of the public they serve. A recent survey study found that 55% of paramedics reported feeling fatigued at work and were twice as likely to be injured, three times more likely to engage in safety-compromising behaviours, and 1.5 times more likely to commit a medical error than paramedics who did not report feeling fatigued (Donnelly et al., 2020). Fatigue is also linked to increased risk of musculoskeletal disorders and burnout (Yung et al., 2021), which may lead to work disability and early exits from the workforce. The impact of fatigue will take a toll on paramedic services, having to deal with significant sick leaves, compensation costs, and a potential labour shortage.

In response, the Canadian Standards Association (CSA) developed Canada's first standard on fatigue risk management for first responders (CSA Z1615:22). Informed by research conducted by the Canadian Institute for Safety, Wellness, and Performance (CISWP), the First Responder Fatigue Risk Management (FRM) Standard uniquely positions fatigue as a multidimensional and multifactorial construct. Fatigue was recognized to be attributed to work task (e.g., workload demands, call volume, call complexity), work arrangement (e.g., shift schedules, paramedic role), and paramedic personal factors (e.g., sex/gender, age, job tenure, chronotype etc.) (Yung et al., 2021; Gevaert et al., 2026).

After the launch of the FRM Standard, a pilot implementation study with a large urban and a large rural paramedic service was conducted in Canada. Although the Standard laid the foundation for the risk management framework, it was quickly realized that there was no paramedic-specific risk assessment tool that considered the various fatigue factors (Yung et al., 2022). This may be problematic, as effective and practical risk assessment tools are integral to the success of any risk management program.

This presentation will describe findings from a large prospective paramedic cohort fatigue study that enabled the development of a Fatigue Management System Dashboard (FMSD), a risk assessment tool for sleep-related fatigue. This presentation will also discuss the evidence-informed FMSD and its application by paramedic services for their critical decision-making.

Methodology

Collaborating with a large rural paramedic service in Ontario, Canada, we recruited 18 primary and advanced care paramedics for a 1-year prospective cohort study. Data were collected at three time periods, four months apart. Participants wore a wrist-mounted ActiGraph device to monitor sleep quality and duration, for 28 days each collection period. Participants completed a sleep diary log and a demographic survey, which provided personal factor information (e.g., age, sex, BMI, job tenure). For each participant, we gathered their administrative data, which provided work arrangement information (e.g., shift schedule, paramedic role). We analysed their ambulance call report (ACR) data, which documented daily events including workload factors (e.g., call volume, call complexity, number of clinical procedures per call, total call time, transfer of care wait time, total drive time, and number of procedures per shift). From ActiGraph data, we defined a "fatigue case" as a sleep event that met the following criteria: (1) $\leq$ 85% sleep efficiency, and (2) $\geq$ 6 average awakenings per night, and (3) >5 minutes average awakening length.

After linking fatigue factor data to actigraphy on a per shift basis (n=259 workday observations), we performed univariate logistic regression models to examine the unadjusted association between independent variables and the odds of experiencing a poor sleep episode. Multivariable associations were then used to estimate adjusted associations between predictors. These models, guided by the CSA Z1615:22 conceptual framework, evaluated predictors grouped as: personal, work arrangement, and workload-related factors. The initial models was an intercept-only (null) model, which provided a reference framework for subsequent models. Personal factors were fit first to account for individual differences. Work arrangement factors were then added to adjust for scheduling-related influences. Workload variables were then evaluated one at a time to determine their independent contribution. McFadden's pseudo-R^2 was calculated as a measure of overall model performance and Akaike's Information Criterion (AIC) compared model fit across sequential models. The final overall model fit was evaluated using the Hosmer-Lemeshow goodness-of-fit test.

The FMSD was developed based on candidate features identified from the multivariable logistic regression modelling. Data from the large rural paramedic service were aggregated with additional prospective study data from several other services in Canada into a single training and evaluation dataset (n = 1,227 observations). We compared several candidate machine learning models using a primary train-test split of 80-20 at the participant-level and evaluated model performance.

Preliminary Findings

We found statistically significant associations between adverse sleep-related fatigue and personal (sex and age), work arrangement (paramedic role), and workload (call complexity) factors (Malik et al., 2026). After adjusting for all other covariates, female paramedics had lower odds of experiencing sleep-related fatigue compared to their male counterparts (OR = 0.26, p = 0.002), while increasing paramedic age was a protective factor (OR = 0.82, p < 0.001). Paramedic's role demonstrated a strong association with fatigue; ambulance drivers exhibited higher odds of experiencing fatigue compared to the patient compartment attendant (OR = 5.35, p = 0.039). There was a clear dose-response relationship between call complexity (number of clinical interventions performed per call) and fatigue (OR = 1.22, p = 0.012).

These research findings confirmed that the three factor categories should be included in the preliminary FMSD. Random Forest was selected as the primary machine learning model, having

produced the strongest single split held out performance (Test ROC AUC 0.722, Balanced Accuracy 0.705) and the highest mean Test AUC across 50 repeats (0.602), while maintaining group aware evaluation and class imbalance handling. This employed machine learning model will enable future analysis of emerging datasets, once they were made available from our current ongoing paramedic-fatigue studies.

After model build and training, a graphical interface was designed to allow paramedic management to input paramedic factor data on a per shift basis and output a daily sleep-related fatigue risk score (Figure 1). Data entered for each paramedic for each shift will generate a fatigue risk estimate, which can be displayed as a historical record (Figure 2).

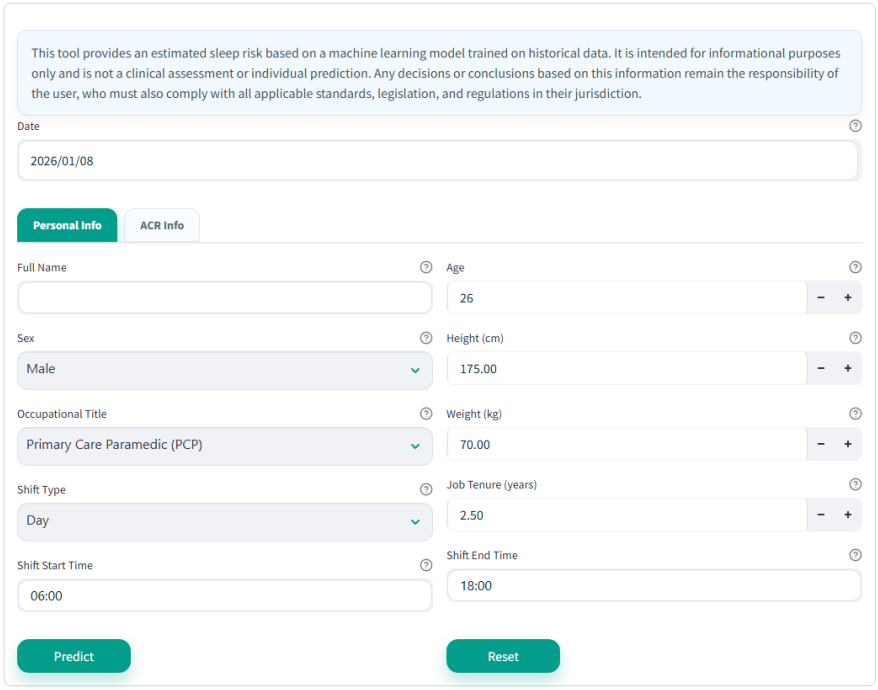

Figure 1: Example graphical user interface of FMSD input page where paramedic services can insert personal, work arrangement, and workload information, organised in two tabs: Personal Information and ACR (Ambulance Call Report) Info.

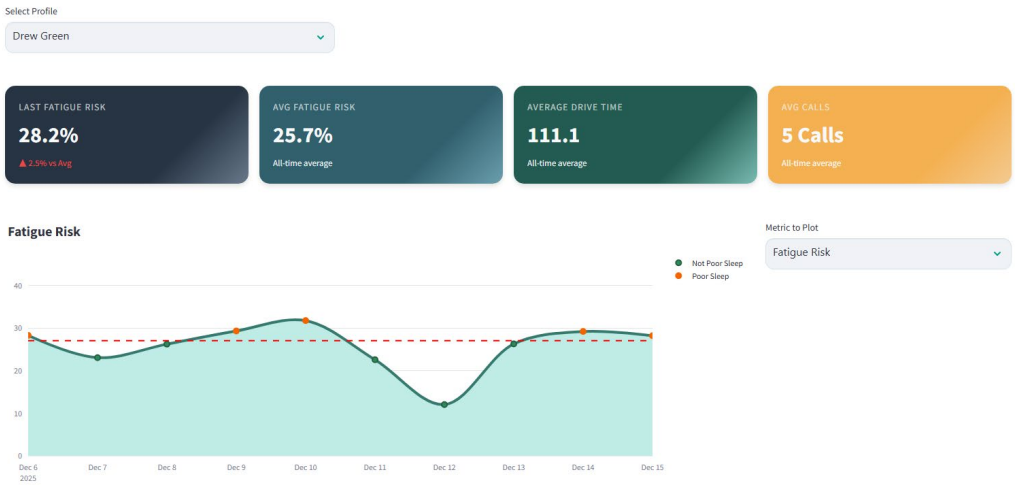

Figure 2: Example graphical user interface of FMSD output page where historical trends and key performance metrics are displayed.

Key Takeaways

Findings from this research will help Services forecast probable adverse sleep-related fatigue events through a Fatigue Management System Dashboard (FMSD) and support their critical decision making. The FMSD was based on robust predictive models, informed by longitudinal paramedic fatigue research findings with a large urban and rural paramedic service. As fatigue studies are ongoing with other Ontario paramedic services, emerging data will further improve the precision and accuracy of the FMSD. Future FMSD will also consider the physical, cognitive, and emotional workload demands of clinical interventions and work tasks that were assessed from direct measurement. Ultimately, this novel tool, based on daily workloads, will provide real-time, data-driven insights to enhance service efficiency, paramedic health and wellbeing, and patient safety.

References

Donnelly, E.A., Bradford, P., Davis, M., …., & Chandra Pichika, S. (2020). What influences safety in paramedicine? Understanding the impact of stress and fatigue on safety outcomes. Journal of the American College of Emergency Physicians Open, 1(4), 460-473.

Gevaert, V., Yung, M., Howard-Azzeh, M., Driezen, P., Cunsolo, A., Du, B., & Yazdani, A. (2026). Applying a fatigue risk management framework in paramedicine: A multidimensional assessment. Submitted.

Malik, A., Gevaert, V., Driezen, P., Cunsolo, A., Howard-Azzeh, M., Somasundram, K.G., Yazdani, A., & Yung, M. (2026). Beyond shift schedules: On the job workload and poor sleep episodes among paramedics in a large rural paramedic service. Submitted.

Yung, M., Du, B., Gruber, J., & Yazdani, A. (2021). Developing a Canadian fatigue risk management standard for first responders: Defining the scope. Safety Science, 134, 105044.

Yung, M., Du, B., Gruber, J., Hackney, A., & Yazdani, A. (2022). Fatigue measures and risk assessment tools for first responder fatigue risk management: A scoping review with considerations of the multidimensionality of fatigue. Safety Science, 154, 105839.