

BMJ Open Examining self-reported and biological stress and near misses among Emergency Medicine residents: a single-centre cross-sectional assessment in the USA

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ABSTRACT

Objectives To examine the relationship between perceived and biological stress and near misses among Emergency Medicine residents.

Design Self-rated stress and stress biomarkers were assessed in residents in Emergency Medicine before and after a day shift. The supervising physicians and residents reported numbers of near misses.

Setting The study took place in the Emergency Department of a large trauma 1 centre, located in Detroit, USA.

Participants Residents in Emergency Medicine volunteered to participate. The sample consisted of 32 residents, with complete data on 28 subjects. Residents' supervising physicians assessed the clinical performance of each resident.

Primary and secondary outcome

measures Participants' preshift and postshift stress, biological stress (salivary cortisol, plasma interleukin-6, tumour necrosis factor- α (TNF- α) and high-sensitivity C-reactive protein), residents' and supervisors' reports of near misses, number of critically ill and patients with trauma seen during the shift.

Results Residents' self-reported stress increased from an average preshift level of 2.79 of 10 (SD 1.81) to a postshift level of 5.82 (2.13) ($p < 0.001$). Residents cared for an average of 2.32 (1.52) critically ill patients and 0.68 (1.06) patients with trauma. Residents reported a total of 7 near misses, compared with 11 reported by the supervising physicians. After controlling for baseline work-related exhaustion, residents that cared for more patients with trauma and had higher levels of TNF- α reported a higher frequency of near misses ($R^2 = 0.72$; $p = 0.001$). Residents' preshift ratings of how stressful they expected the shift to be were related to the supervising physicians' ratings of residents' near misses during the shift.

Conclusion Residents' own ratings of near misses were associated with residents' TNF- α , a biomarker of systemic inflammation and the number of patients with trauma seen during the shift. In contrast, supervisor reports on residents' near misses were related only to the residents' preshift expectations of how stressful the shift would be.

Strengths and limitations of this study

- No data were collected on those residents who chose not to respond to study invitations, or who initially agreed to take part and then were unable to attend. Therefore, it is not known whether potential differences between participants and non-participants were important.
- Results are based on one emergency medicine department in North America. Results need to be reproduced in different settings and also comparing with biological data collected from residents when they are not working in order to control for normal circadian variations.
- Near misses as an outcome is a novel way to determine performance of medical learners. However, more knowledge is needed about possible differences in rating an event as a near-miss between residents and supervisors. Further research is needed as to how near misses relate to adverse medical events, including errors.
- The study demonstrated that it is feasible to collect both self-reports and biological data from residents during active duty in a busy Emergency Department setting.

INTRODUCTION

Physician stress has been associated with adverse medical outcomes in a number of studies.^{1 2} Importantly, physician stress impacts negatively on patient-perceived quality of care and purportedly increases the risks for adverse medical events.³⁻⁷ However, previous studies lack rigour in that they fail to use biological markers of stress and do not consider how sick or injured the patients are, which might be indicators of objective stressor load. Furthermore, no study has linked objective measures of cognitive load and physiological stress to provider-independent measures of adverse outcomes.^{8 9} Studies

looking at the impact of physicians' working conditions on patient safety predominantly focus on either working hours or patient satisfaction.^{10–13} A randomised trial of enhanced working conditions for physicians reported improvement in burn-out and job satisfaction in the intervention, when compared with the control group, with no discernible effects on independently charted clinical performance.⁸ Since acute and chronic stress is associated with changes in neurocognitive and psychophysiological systems with implications for cerebral functioning and medical decision-making, there is a need for more detailed studies designed to investigate whether, and by which biological mechanisms, physician stress impacts patient safety.^{14–16}

Physician stress is increasingly recognised as an overlooked yet important indicator of the quality and safety of patient care.^{1 17–21} Physicians working under acute care conditions, for example, in Emergency Departments (EDs), face a combination of cognitive load, interruptions, communication challenges and time-urgency conditions that are reported to increase the risk of adverse medical events.^{22–31} Of special interest is whether stressor-induced biological processes, such as activation of the hypothalamic–pituitary–adrenal axis and inflammation, contribute to cognitive deficits in physicians.^{16 32 33} Consistent with this hypothesis, Rauchenzauner *et al* demonstrated a positive association between provider on-call duties and inflammatory and cardiac autonomic processes implicated in cardiovascular disease processes, although the impact of professional performance was not determined.³⁴

CURRENT STUDY

If there were a causal link between physician stress and patient outcomes, it would have important public health implications, particularly in times when physicians are under increasing pressure to see greater numbers of patients coupled with the introduction of new electronic medical records.³⁵ In this study, we explored the relationship between self-reported and biological indicators of physician stress and self-reported and independent measures of near misses, defined at the participating hospital as 'any process variation that did not reach the patient, employee or visitor, but for which a recurrence carries a significant chance of a serious adverse event'. Near misses are more common and thus provide more power and a more reliable marker of the overall safety in contrast to adverse medical events. The latter is defined by the Institute for Healthcare Improvement as 'unintended physical injury resulting from or contributed to by medical care (including the absence of indicated medical treatment), that requires additional monitoring, treatment or hospitalisation, or that results in death'.

We studied residents in Emergency Medicine since this is a speciality with high levels of stress and burn-out.³⁶ The stressful nature of graduate medical training has been well documented.^{37–41} In addition to learning important

clinical skills, residents also acquire lifelong and often career-defining professional behaviours and practice habits that affect their professional behaviour and ultimately patient care.

We hypothesised that after taking hours of preceding rest, baseline work-related exhaustion and level of physical fitness into account, self-reported and biological stress would relate to number of self-reported and supervisor-reported near misses during the shift. We furthermore posited that objective measures of cognitive load, operationally defined as numbers of critically ill and patients with trauma (also referred to as patient acuity) seen during a shift would relate to near misses. The overall aim was to determine whether self-rated or biologically assessed stress in residents related to frequency of near misses. The study aim was achieved.

MATERIALS AND METHODS

Participants and clinical setting

The study was conducted in the ED at the Detroit Medical Centre (DMC), Michigan, USA, a level 1 trauma centre. The ED represents a 'safety net' for the underserved urban Detroit population and it is home to the Michigan's largest Emergency Medicine residency training programme. The project secured strong support from the ED department's leadership, physicians, residents and staff. Information about the project was distributed to all Emergency Medicine residents. The total number of eligible first, second and third year residents was 42 of which 26 were men. Of these, 34 (81%) consented to participate in the study. However, due to scheduling difficulties, only 32 actually participated, with 28 providing complete data. We have no biological or self-report data on the eight residents who chose not to volunteer for the study. The resident's programme director was not involved in recruitment or data collection. Information about the study was provided to resident participants by a senior Emergency Medicine physician who did not practice on a regular basis in the ED.

The study design and reporting followed the STROBE guidelines.

Data collection

Questionnaire data

The following were assessed at baseline, at a time separate from the actual preshift to postshift assessment: Frequency of exercise in the preceding month was measured using a 5-item self-report question ranging from 1 (never, mostly idle) to 5 (regularly 2–3 times a week). Work-related exhaustion was measured using a 3-item subscale from the Quality Work Competence survey.^{42 43} The participant was asked to report how often they felt 'emotionally drained after work,' 'worn out after work' and 'tired when I think about work' on a zero (never) to five (daily) Likert-type scale. Responses were summed to a total score and converted to a percentage. Higher scores indicate higher work-related exhaustion.

Shift-related assessments

Shift-related assessments included the following measures: energy was assessed both preshift and postshift using a validated 1-item visual analogue scale.^{44–46} The participant was asked to respond to ‘how is your energy level right now’ on a scale ranging from a low of 0 to a high of 10. Self-reported stress levels were determined both preshift and postshift with a single validated item where participants responded to ‘how stressed are you right now’ on a 0 (not at all) to 10 (very stressed) scale.⁴⁷ Participants were also asked to predict how stressful they expected their shift to be at the preshift assessment and how stressful the shift actually was at the postshift assessment using the same 0 to 10-point scale.

Biological samples (blood and saliva)

Biological samples (blood and saliva) were collected immediately before the start of the shift (around 7 am) and postshift (around 4 pm).

- ▶ Blood samples (10 mL via venipuncture) were drawn on-site in the ED, placed on ice, and immediately transported to the laboratory. Samples were centrifuged, and plasma was obtained and stored at -80°C for later measurement of the following stress and inflammation markers: interleukin-6 (IL-6), tumour necrosis factor-alpha (TNF- α), and high-sensitivity C-reactive protein (hs-CRP) using routine, commercially available human ELISA kits.^{48 49}
- ▶ Saliva (approximately 1 mL, collected by passive drooling) was placed on ice, immediately transported to the lab and stored at -80°C for later assessment of cortisol and dehydroepiandrosterone-sulfate (DHEA-s)—the latter being an indicator of biological resilience^{50 51}—by standard, commercially available human ELISA kits. The ratio of salivary cortisol to DHEA-s is a valid biological measure of stress.^{52–54}

Patient acuity

At the postshift assessment, residents were asked to report how many critically ill and patients with trauma they cared for during the shift using a 11-point Likert-type scale (from 0 to 10 or greater). The combination of these two measures were used as an indicator of stressor (cognitive) load. Near misses: Both residents and supervising physicians reported the perceived number of near misses that occurred during the shift (none, one, more than one). DMC has clearly defined what is a near-miss. Residents and attendings are strongly encouraged to self-report all known or perceived near misses and errors. However, there is no established mechanism of validating the total number of near misses, and in this study, there was no systematic way near misses were reported or used in quality development processes.

The selected shift to be assessed for each consenting participant represented the first day of a day shift in a cycle of shifts. This was done to limit residual effects from prior shifts, to minimise the scheduling variation between the residents and to account for the diurnal patterns in cortisol secretion.

Institutional review

The study was approved by Wayne State University Institutional Review Board and the DMC Research Office. All participating residents and supervising attendants provided their informed consent to participate in the study.

Statistical analysis

Statistical analysis was done using IBM SPSS statistics, V.23. Differences in baseline and preshift variables between men and women were tested using independent t-tests for continuous data and χ^2 tests for dichotomous data. Associations among variables were tested using Pearson's correlations. Preshift and postshift changes in continuous variables were analysed using paired t-tests. Hierarchical linear regression was used to assess the percentage of variance accounted for in resident and supervising physician reports of near misses, respectively. At the first step, exercise, work-related exhaustion, preshift energy and stress, expectations of shift stressfulness and preshift levels of TNF- α were used to predict near misses. At the second step, the number of critically ill and patients with trauma treated during the shift were entered into the model. Statistical significance was set at a two-sided p value of <0.05 .

Figure 1 depicts the theoretical model that guided our study design and analysis.

RESULTS

Primary outcomes

Demographics and baseline physiological assessment

The final study sample consisted of 28 healthy adults between 26 and 35 years of age (mean=29.4, SD=2.3). Haemodynamics (heart rate, systolic and diastolic pressures) and serum lipid concentrations were within the normal range (table 1). The majority of participants in the final study was male (71.4%). They were either in their second (60.7%) or third (39.3%) year of residency. Slightly over half of the participants (55.2%) reported having rested between 4 and 8 hours prior to the start of the shift, with 37.9% having rested over 8 hours, and only 6.9% reporting less than 4 hours of rest. Although the official shift duration was 8–12 hours, data revealed that the actual shift length ranged from 8 to 10 hours (mean=8.84, SD=0.69). Hours of preshift rest did not relate to shift-related reports of near misses. However, there was an inverse relationship between hours of rest and postshift stress ($r=-0.39$; $p<0.05$).

Exercise, energy and work-related exhaustion

Approximately half of the participants reported exercising once weekly or less (46.4%). On a scale of 1 (never) to 5 (2–3 times a week), the average exercise score was 3.71 (SD=1.05). Men and women did not differ in terms of exercise frequency or preshift energy (data not shown). In terms of work-related exhaustion (graded on a scale of 0–100), assessed at baseline, residents reported an average score of 62.50 (SD=21.22). Men were less likely

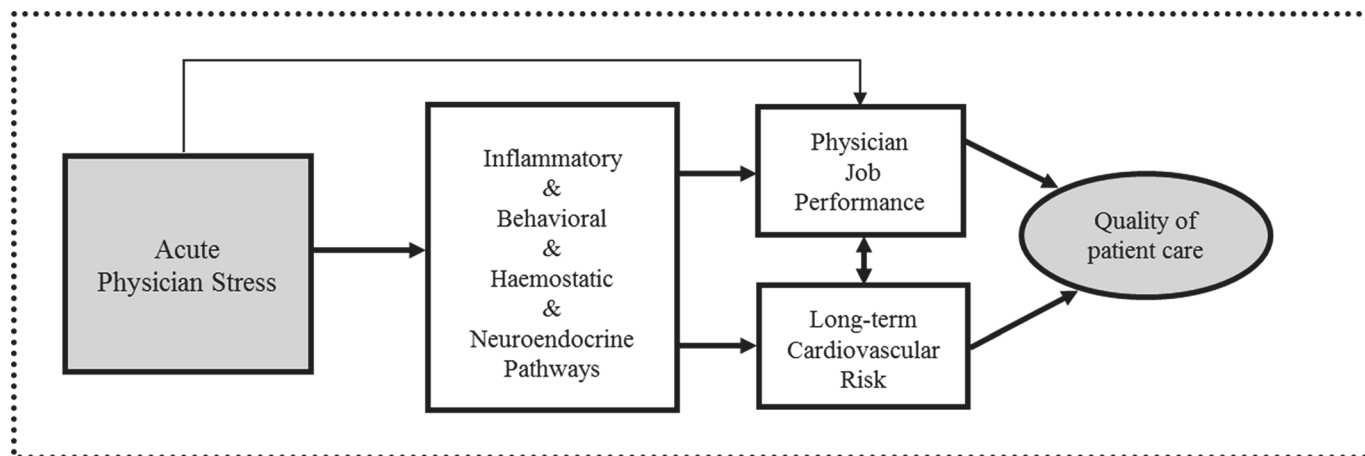


Figure 1 Conceptual model linking physician stress and its impact on stress biomarkers to physician performance and quality of care.

to report work-related exhaustion in the baseline assessment (mean=57.50, SD=21.61) than women (mean=75, SD=21.61; $p<0.05$). Residents' energy levels did not change over the course of the shift (preshift mean=5.61, SD=1.87; postshift mean=5.50, SD=1.84; $p=n.s.$).

Stress and inflammatory biomarkers

Residents' self-reported stress increased significantly during the shift, from an average of 2.79 (SD=1.81) before the shift to 5.82 (SD=2.13) after the shift ($p<0.001$). Their scoring of how stressful the shift actually was did not differ (mean=6.39, SD=2.39) from their preshift expectation of how stressful the shift would be (mean=5.75, SD=1.69, $p=n.s.$). Men and women did not differ with regard to self-reported stress at the baseline assessment (data not shown).

Male and female residents did not differ in preshift levels of any biomarker (data not reported). Correlations between concentration of preshift biomarker and residents' self-reported preshift stress revealed positive associations between self-rated stress and both IL-6 levels

($r=0.45$, $p<0.05$) and cortisol ($r=0.44$, $p<0.05$). In contrast, there were no correlations between plasma biomarker concentrations and preshift expectations of how stressful the shift would be (data not shown). The only bivariate correlations between preshift biomarkers of stress and postshift reports of near misses was between IL-6 ($r=0.37$, $p<0.05$) and TNF- α (0.67, $p<0.001$). Due to the limited sample size, we only entered TNF- α into the subsequent regression model since it depicted the strongest association with near misses.

Shift experience and performance near misses

Residents reported caring for 0–8 critically ill patients (mean=2.32; SD=1.52) and 0–4 patients with trauma (mean=0.68; SD=1.06) during their shift. Seven residents and 11 supervising physicians reported the occurrence of a near miss during the shift. There was no significant agreement between the reported number of near misses between residents and supervising physicians ($p=n.s.$). Specifically, the supervisors identified 17 residents that they rated as having no near misses during the shift. However, 4 of these 17 residents reported having experienced a near-miss. Moreover, among the 11 residents reported by the supervising physicians as having a near-miss, only three concurred with the residents' assessment.

Predicting near misses

In predicting residents' self-report of near misses (table 2), work-related exhaustion, assessed at baseline, and TNF- α were both significant ($p<0.01$). In the final model, after controlling for work-related exhaustion, preshift TNF- α remained significant ($p<0.01$). In addition, the number of patients with trauma cared for during the shift significantly predicted residents' rating of near misses. The final model accounted for 71.6% of the total variance in residents' self-reported near misses ($p=0.001$). Sex did not enter the equation.

In predicting attending physicians' reported number of near misses observed among the residents (table 3), the only significant predictor was residents' self-reported expectations of how stressful the shift would be. However,

Table 1 Demographics and baseline physiological assessment

Male, n (%)	21/32 (65.6)
Smoker, n (%)	1/32 (3.1)
Treatment for hypertension, n (%)	1/32 (3.1)
Age, years, mean (SD)	29.3 (2.3)
Body mass index (BMI) (SD)	24.7 (3)
Systolic blood pressure, mm Hg, mean (SD)	127 (12)
Diastolic blood pressure, mm Hg, mean (SD)	75 (5)
Heart rate beats, per min, mean (SD)	76 (13)
Total cholesterol, mg/dL, mean (SD)	175 (33)
LDL, mg/dL, mean (SD)	117 (27)
HDL, mg/dL, mean (SD)	58 (15)
Triglycerides, mg/dL, mean (SD)	115 (49)

HDL, high-density lipoprotein; LDL, low-density lipoprotein.

Table 2 Summary of hierarchical regression analysis for variables predicting residents' self-reports of near misses (n=28)

Variable	Step 1			Step 2		
	β †	SE β	β ‡	β †	SE β	β ‡
Exercise	0.151	0.087	0.296	0.129	0.076	0.253
Preshift energy	-0.007	0.048	-0.024	0.021	0.043	0.073
Preshift stress	0.037	0.054	0.125	0.068	0.048	0.232
Expectation of stressfulness of shift	0.035	0.054	0.110	0.035	0.047	0.111
Work-related exhaustion	-0.010	0.004	-0.381*	-0.009	0.004	-0.371*
TNF- α	0.002	0	0.638***	0.002	0.001	0.612**
Critically ill patients				0.010	0.068	0.028
Patients with trauma				0.195	0.068	0.386*
R ²	0.583			0.716		
F for change in R ²	4.884**			4.466*		

*p<0.05; **p<0.01; ***p<0.001.

†Unstandardised beta.

‡Standardised beta.

TNF- α , tumour necrosis factor-alpha.

the final model, including exercise habits, preshift stress and energy, work-related exhaustion at baseline, number of critical ill patients and patients with trauma managed during the shift, and residents' expectations of how stressful the upcoming shift would be, was not significant (p=n.s.). Sex did not enter the equation.

DISCUSSION

This study explored the relationships between self-rated and biological measures of stress in Emergency Medicine residents and near misses (both self-reported and supervisor reported) during a day shift in a high-volume urban ED of a level 1 trauma centre. As expected, residents reported increased stress during the shift. Residents'

own ratings of near-misses were associated with residents' general levels of work-related exhaustion, TNF- α , a biomarker of systemic inflammation and the number of patients with trauma seen during the shift. In contrast, supervisor-derived data on residents' near misses was only related to residents' preshift expectations of how stressful the shift would be.

Although limited in scope, this pilot study suggests that both self-rated stress and independent indicators of stress or cognitive load (ie, number of patients with trauma cared for during the shift) are related to the risk of near misses. Furthermore, there is an apparent association between plasma levels of at least one inflammatory stress biomarker and self-reported near misses.

Table 3 Summary of hierarchical regression analysis for variables predicting attending physicians' report of residents' near misses (n=28)

Variable	Step 1			Step 2		
	β †	SE β	β ‡	β †	SE β	β ‡
Exercise	-0.229	0.135	-0.347	-0.210	0.132	-0.318
Preshift energy	-0.130	0.074	-0.351	-0.134	0.074	-0.361
Preshift stress	-0.019	0.084	-0.051	0.001	0.084	0.002
Expectation of stressfulness of shift	0.179	0.083	0.436*	0.172	0.081	0.419*
Work-related exhaustion	-0.011	0.007	-0.329	-0.012	0.007	-0.368
TNF- α	0	0.001	0.096	0.002	0.001	0.445
Critically ill patients				-0.210	0.119	-0.458
Patients with trauma				0.086	0.119	0.131
R ²	0.637			0.701		
F for change in R ²	2.392			1.600		

*p<0.05.

†Unstandardised beta.

‡Standardised beta.

TNF- α , tumour necrosis factor-alpha.

Stress-induced increases in TNF- α , an indicator of neuroinflammation, have been reported to be associated with worse cognitive functioning.⁵⁵ Importantly, these findings hold true after controlling for residents' work-related exhaustion (which is a measure of the provider's overall exhaustion assessed at baseline, and independent from the shift). Work-related exhaustion is partly the result from sustained stress and might adversely impact occurrence of near misses.¹ Interestingly, and in support of our hypothesis, residents' anticipation that the upcoming shift would be stressful was a predictor of near misses observed by the supervising attending physician. This finding suggests that stress, at some level, may influence the occurrence of near misses. A major concern in determining actual clinical performance among residents evaluated in this study, at least within the framework of near misses, is the lack of agreement between residents and supervising attendings. Lack of consensus between the medical learner and the instructor has numerous implications in terms of studying the relationship between stress and medical performance. It might be that residents have a different threshold for reporting what is a near-miss. It might also be due to the fact that an experienced physician is better at identifying processes and actions that are near misses than residents. At DMC, there is no formal process by which residents and supervisor attendants discuss whether or not either party perceived a near-miss had occurred during the shift. Although residents, as well as supervising attendants, are encouraged to report near misses, there is no formal mechanisms in place that guarantees that will happen.

There is concern that long working hours might adversely impact residents' clinical performance by limiting the amount of time available for rest.^{10 56–58} In this study, residents' reported hours of preshift rest did not relate to shift-related reports of near misses. However, there was an inverse association between hours of preshift rest and postshift stress. This is in line with other studies on the restorative effects of rest and its contribution to building resilience to stress.^{59–61}

To be externally valid, the current single-site study needs to be reproduced in another setting involving a larger number of residents and supervising physicians. However, this study identifies several key issues, depicted in [figure 1](#), that merit further investigation, including the identification of possible behavioural and biological mechanisms that may play a role in mediating the relationship between professional stressor exposures and near misses, and whether there is a causal relationship between physician stress and adverse patient outcomes. To more definitively address this, it will be important in future studies to incorporate self-rated as well as provider-independent indicators of stressor exposure by including biological stress markers.¹⁹ In terms of study power, using near misses is suggested to be a more relevant outcome since it occurs more frequently. From

a culture of safety point of view, it is also a more relevant outcome to focus on since it is less punitive in nature, and probably encourages a more honest reporting, both by the residents and the supervisor, than using adverse medical events as an outcome.

LIMITATIONS

We acknowledge that our current study is limited in its scope. First, we enrolled only 32 residents at a single site, with complete data obtained for 28 residents. In addition, a control group was not included in the study design. As a result, statistical power is limited and conclusions may be confounded by both type-1 and type-2 errors. The study per se might also have contributed to stress in residents. Second, our independent measure of residents' near misses was based exclusively on the assessments made by supervising physicians. Ideally, the analysis should be expanded to incorporate an in-depth analysis of quality of patient care, including, for example, medical chart review for condition-specific quality indicators, real-time peer-review assessments, patient satisfaction with the care provided by the residents and cost analysis. Third, our biological measures capture some of the effects of stress, but stress was only assessed immediately before and after the shift. Future studies should sample more biomarkers at more frequent intervals throughout the shift, and be expanded to include postshift recovery in order to determine long-term wear and tear.¹⁰ Cortisol is known to have sharp circadian variations and in order to fully control for this, biological data should have also been collected from residents during a day of rest. However, the concentrations of stress biomarkers observed in our residents are in line with those reported in other professionals under stress.^{62 63} Finally, more definitive indices of cognitive load and executive function are required.

Implication for practice

Despite the preliminary nature of this investigation, our results nonetheless reveal that self-rated stress and biomarkers of stress in providers are related to near misses. Future studies should address whether measures of near misses relate to adverse medical events, patient safety and quality of care in the healthcare systems' most critical arena = the ED.

CONCLUSION

We have demonstrated the feasibility of collecting both self-reported and biological indicators of stress from providers to study the relationship between provider stress and clinical performance in a high-volume urban ED. Results suggest a significant relationship between self-rated and biological stressor load and patient outcomes, but results should be confirmed in further, adequately powered studies.

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Contributors BBA: concept and design, acquisition, analysis or interpretation of data, drafting of the manuscript, critical revision of the manuscript for important intellectual content, statistical analysis and administrative, technical or material support. PL: concept and design, acquisition, analysis or interpretation of data, critical revision of the manuscript for important intellectual content and administrative, technical or material support. JA: concept and design, acquisition, analysis or interpretation of data and critical revision of the manuscript for important intellectual content. KB: acquisition, analysis or interpretation of data, critical revision of the manuscript for important intellectual content and statistical analysis. KP: concept and design, acquisition, analysis or interpretation of data, drafting of the manuscript, critical revision of the manuscript for important intellectual content and administrative, technical or material support.

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Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Upon request, and after the requesting researchers have secured relevant institutional review board approval, the de-identified dataset is available in IBM SPSS Statistics, V.23.

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