The Characterization of the Toll of Caring for Coronavirus Disease 2019 on ICU Nursing Staff

OBJECTIVES: Coronavirus disease 2019 pandemic exercised a significant demand on healthcare workers. We aimed to characterize the toll of caring for coronavirus disease 2019 patients by registered nurses.

DESIGN: An observational study of two registered nurses cohorts.

SETTING: ICUs in a large academic center.

SUBJECTS: Thirty-nine ICU registered nurses assigned to coronavirus disease 2019 versus noncoronavirus disease 2019 patients.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: Skin temperature (t [°C]), galvanic skin stress response (GalvStress), blood pulse wave, energy expenditure (Energy [cal]), number of steps (hr⁻¹), heart rate (min⁻¹), and respiratory rate (min⁻¹) were collected using biosensors during the shift. National Aeronautics and Space Administration Task Loading Index measured the subjective perception of an assignment load. Elevated skin temperatures during coronavirus disease 2019 shifts were recorded (Δt_COVID vs t_non-COVID = +1.3 [°C]; 95% CI, 0.1–2.5). Registered nurses staffing coronavirus disease patients self-reported elevated effort (ΔEffort_COVID vs Effort_non-COVID = +28.6; 95% CI, 13.3–43.9) concomitant with higher energy expenditure (ΔEnergy_COVID vs Energy_non-COVID = +21.5 [cal/s]; 95% CI, 4.2–38.7). Galvanic skin stress responses were more frequent among coronavirus disease registered nurse (ΔGalStress_COVID vs GalvStress_non-COVID = +10.7 [burst/hr]; 95% CI, 2.6–18.7) and correlated with self-reported increased mental burden (ΔTLXMental_COVID vs ΔTLXMental_non-COVID = +15.3; 95% CI, 1.0–29.6).

CONCLUSIONS: There are indications that registered nurses providing care for coronavirus disease 2019 in the ICU reported increased thermal discomfort coinciding with elevated energy expenditure and a more pronounced self-perception of effort, stress, and mental demand.

KEY WORDS: coronavirus disease 2019; critical care; mental demand; National Aeronautics and Space Administration Task Loading Index; registered nurses; stress

The sheer number of cases, infectiousness, and complexity of coronavirus disease 2019 (COVID-19) exposed critical care providers to fatigue, discomfort, and traumatic stress (1). Yet, the precise characterization of the degree and nature of burden needs to be elucidated (2). Here, we quantified the burden of caring for COVID-19 patients by registered nurses (RNs) using biosensors and a Task Loading Index (TLX) survey (3).
METHODS

Biosensors registered skin temperature (t [°C]), galvanic skin stress response (GalvStress), blood pulse wave, energy expenditure (Energy [cal]), number of steps (hr^{-1}), heart rate (min^{-1}), and respiratory rate (min^{-1}) (4). At the end of each shift, RNs completed the National Aeronautics and Space Administration TLX survey to assess the subjective self-assessment of effort, frustration, self-performance satisfaction, and perception of mental, physical, and temporal demand (3). Additionally, we collected some demographic information. Data were acquired in a standardized fashion (Supplement Material 1 http://links.lww.com/CCX/A564). Three-hundred sixty hours of biosensor data were obtained from RNs caring for COVID-19 patients and 264 hours from RNs treating non-COVID patients.

Descriptive statistics demonstrated means (X), median (Me), sd, and interquartile ranges. Bivariable comparisons of ΔX with 95% CIs were used to compare COVID-19 versus non-COVID-19 groups utilizing. Regression included GalvStress with assignment type and assigned bed count. R v3.6.0 (R Core Team, Vienna, Austria) was used for analysis except for p values (Matlab 2019b). Mann-Whitney-Wilcoxon tests were used to calculate significance between studied group. Statistical significance was set at two-sided p value of less than 0.05.

The study was approved by the University of Pennsylvania Institutional Review Board (IRB) (No. 834594).

RESULTS

The average participants’ age was 35.3 ± 7.23 years. Average time from graduation and of ICU experience were 9.4 ± 4.98 and 4.3 ± 4.59, respectively (yr). No difference in Acute Physiology and Chronic Health Evaluation (APACHE) II admission score between COVID and non-COVID-19 patient was seen (APACHE COVID-19 = 36.0 ± 12.58 vs APACHE non-COVID-19 = 34.3 ± 11.14; p = 0.62) in the studied ICUs.

COVID-19 RNs self-reported elevated effort (ΔXTLXEffort = 28.6; 95% CI, 13.3–43.9) concomitant with biosensor registering increased energy expenditure (ΔXEnergy = 21.5; 95% CI, 4.2–38.7 [cal/s]) (Table 1 and Supplemental Digital Content 2, http://links.lww.com/CCX/A565). A significant increase in skin temperature during COVID-19 shifts was demonstrated (ΔtCOVID vs tnon-COVID = +1.3°C; 95% CI, 0.1–2.5). Phasic galvanic skin responses indicating the emergence of stress response were more frequent in COVID-19 RNs (ΔGalStressCOVID vs GalvStressnon-COVID = +10.7; 95% CI, 2.6–18.7) (Supplement Material 3, http://links.lww.com/CCX/A566). Significant correlations of biosensor registered indices of stress (GalvStress) with TLX self-reported effort (r^2 = 0.5; p < 0.001) and mental demand (r^2 = 0.18; p = 0.04) was observed. Additionally, GalStress correlated with energy expenditure (r^2 = 0.4; p = 0.01) (Supplemental Digital Content 2, http://links.lww.com/CCX/A565). RNs caring for COVID-19 patients reported increased mental burden as well (ΔXTLMental = +15.3; 95% CI, 1.0–29.6).

DISCUSSION

Increased self-perception of mental burden and effort concomitant with biosensors registering increased energy expenditure tend to be more prevalent among RNs taking care of COVID-19 patients. The increased energy expenditure and perception of effort may be linked to overheating registered as elevation in skin temperature, most likely secondary to wearing personal protective equipment (PPE). No difference in RN steps was registered between the two cohorts, underscoring PPE as a cause of increased energy expenditure. This is consistent with COVID-19–specific hospital policy limiting the movement of RN in/out ICU rooms and recommending PPE (5). Increased mental demand could be related to a novelty of the COVID-19 pandemic during the study itself (1, 4). It correlated with several indices, including galvanic stress responses. This perceived demand was not high enough to trigger profound physiologic changes like respiratory rate or skin blood flow changes (4–6).

Study limitations include reliance on a single hospital, pilot nature of the data, and presence of unaccountable confounders. Although we controlled for some clinical characteristics using APACHE, other clinical measurements would be more accurate, but the IRB protocol excluded their collection. Also, we do not monitor the activity of the RNs specifically while wearing the sensors, but all our participants were provided with detailed instructions and in-service. The study did not account for the effect of gender and socioeconomical background as we did not collect this information per IRB regulation (7). Finally, the effect of stress depends on several individual psychologic traits, especially coping strategies and resilience (8).
### TABLE 1. Differences in Provider Stress Metrics Between Coronavirus Disease 2019 and Standard ICU Shifts

| Stress Measure                  | Statistical Analyses | Coronavirus Disease 2019 Shift | Standard ICU Shift | Difference (95% CI) | p     |
|--------------------------------|----------------------|--------------------------------|--------------------|--------------------|-------|
|                                | n                    | 24                             | 15                 |                    |       |
| Effort                         | Mean (sd)            | 76.3 (18.8)                    | 47.7 (17.5)        | 28.6 (13.3–43.9)   | < 0.001|
|                                | Median (IQR)         | 80 (70–90)                     | 50 (35–58)         |                    |       |
| Frustration                    | Mean (sd)            | 56.3 (27.4)                    | 48.7 (25.2)        | 7.6 (–10.1 to 25.3)| 0.34  |
|                                | Median (IQR)         | 60 (39–71)                     | 50 (28–68)         |                    |       |
| Mental demand                  | Mean (sd)            | 69.0 (20.8)                    | 53.7 (19.7)        | 15.3 (1.0–29.6)    | 0.02  |
|                                | Median (IQR)         | 75 (64–80)                     | 50 (43–68)         |                    |       |
| Performance                    | Mean (sd)            | 16.7 (12.7)                    | 15.7 (9.8)         | 1.0 (–6.7 to 8.7)  | 0.66  |
|                                | Median (IQR)         | 15 (10–20)                     | 20 (10–23)         |                    |       |
| Physical demand                | Mean (sd)            | 65.6 (17.6)                    | 57.3 (18.1)        | 8.3 (–3.7 to 20.3) | 0.22  |
|                                | Median (IQR)         | 70 (54–80)                     | 45 (40–75)         |                    |       |
| Temporal demand                | Mean (sd)            | 55.4 (25.4)                    | 47.0 (18.2)        | 8.4 (–6.9 to 23.7) | 0.26  |
|                                | Median (IQR)         | 60 (40–71)                     | 50 (30–65)         |                    |       |
| Biometrics during shift        | n                    | 9                              | 11                 |                    |       |
| Blood pulse wave               | Mean (sd)            | 3.01 (0.58)                    | 2.91 (0.75)        | 0.10 (–0.52 to 0.73)| 0.46  |
|                                | Median (IQR)         | 2.77 (2.65–3.36)               | 2.65 (2.50–2.98)   |                    |       |
| Energy expenditure (cal/s)     | Mean (sd)            | 52.2 (19.8)                    | 30.7 (9.7)         | 21.5 (4.2–38.7)    | 0.01  |
|                                | Median (IQR)         | 52.7 (36.5–61.7)               | 27.7 (25.3–31.2)   |                    |       |
| Galvanic skin response (peaks/hr) | Mean (sd)         | 12.6 (8.9)                    | 2.0 (2.1)          | 10.7 (2.6–18.7)    | 0.03  |
|                                | Median (IQR)         | 14.5 (6.3–18.9)               | 1.1 (0.5–3.0)      |                    |       |
| Heart rate (min⁻¹)             | Mean (sd)            | 89 (15)                       | 82 (16)            | 7.3 (–7.8 to 22.5) | 0.33  |
|                                | Median (IQR)         | 89 (77–100)                   | 81 (72–89)         |                    |       |
| Respiratory rate (min⁻¹)       | Mean (sd)            | 21 (4.2)                      | 19 (3.9)           | 1.6 (–2.2 to 5.4)  | 0.55  |
|                                | Median (IQR)         | 20 (17.5–21.6)                | 19 (18.1–20.1)     |                    |       |
| Skin conductance (µS)          | Mean (sd)            | 1.01 (0.87)                   | 0.29 (0.16)        | 0.72 (0.04–1.41)   | 0.10  |
|                                | Median (IQR)         | 0.94 (0.29–1.48)              | 0.22 (0.17–0.41)   |                    |       |
| Skin temperature (°C)          | Mean (sd)            | 34.0 (1.1)                    | 32.8 (1.2)         | 1.3 (0.1–2.5)      | 0.04  |
|                                | Median (IQR)         | 34.0 (33.3–35.0)              | 33.2 (31.7–33.6)   |                    |       |
| Steps (hr)                     | Mean (sd)            | 619 (187)                     | 734 (238)          | −115 (−322 to 92.0)| 0.30  |
|                                | Median (IQR)         | 572 (505–699)                 | 675 (562–809)      |                    |       |

IQR = interquartile range.
Boldface values represent significant p values.
Our study had several strengths. We used FDA-approved biosensors for high data accuracy to measure stress objectively (6). Stress correlated with perception of demand as expected. Energy expenditure correlated with the TLX survey is a well-recognized tool to measure task load (3). For the pilot study, we had a sizeable number of RNs involved logging several work hours, similarly to other studies (6). During planning the subsequent study, we calculated preliminary power analysis suggesting a similar number of individuals will be sufficient to conduct investigation with robust statistical power. Our RNs had similar assignment ratios and APACHE II in COVID-19 and non-COVID-19 group, an essential factor determining load (7, 9). All collections were done over a short period, reducing the time-lag–related variability that was particularly intense during the beginning of the pandemic.

Few had quantitatively monitored the COVID-19–related strain (2, 5, 10). Recognizing and alleviating staff strain is an essential strategy to maintain care quality and well-being after the COVID-19 era (1, 2, 9, 10). This study’s result can be potentially applicable to other providers, but COVID-19 presented with unique stress. Also, while ICU environment-related stress is unique, factors leading to burnout seem to be similar (9).

ACKNOWLEDGMENTS

We gratefully acknowledge the University of Pennsylvania Health System’s nursing staff for their assistance and participation in the study.

Dr. Moon involved in study concept and design, obtaining funding, analysis and interpretation of data, drafting and review of article, and supervision. Mr. Singh involved in study concept and design, and analysis and interpretation of data. Mrs. Chen involved in data collection and recruitment. Ms. Restrepo involved in data collection and article preparation. All authors reviewed the final version of the article and agreed to its publication.

Supported, in part, from an Analytics at Wharton research grant and from the Operations, Information, and Decisions Department of the Wharton School, University of Pennsylvania.

The authors have disclosed that they do not have any potential conflicts of interest.

For information regarding this article, E-mail: klausdanski@gmail.com

The Institutional Review Board approved the study at the University of Pennsylvania (No. 834594). The datasets used and/or analyzed during the current study are available from the corresponding authors on reasonable request.

REFERENCES

1. Poston JT, Patel BK, Davis AM: Management of critically ill adults with COVID-19. JAMA 2020; 323:1839–1841
2. Azoulay E, De Waele J, Ferrer R, et al; ESICM: Symptoms of burnout in intensive care unit specialists facing the COVID-19 outbreak. Ann Intensive Care 2020; 10:110
3. Cao A, Chintamani KK, Pandya AK, et al; NASA TLX: Software for assessing subjective mental workload. Behav Res Methods 2009; 41:113–117
4. Keogh A, Dorn JF, Walsh L, et al: Comparing the usability and acceptability of wearable sensors among older Irish adults in a real-world context: Observational study. JMIR Mhealth Uhealth 2020; 8:e15704
5. Hu D, Kong Y, Li W, et al: Frontline nurses’ burnout, anxiety, depression, and fear statuses and their associated factors during the COVID-19 outbreak in Wuhan, China: A large-scale cross-sectional study. EClinicalMedicine 2020; 24:100424
6. Phitayakorn R, Minehart RD, Plan-Smith MC, et al: Practicality of using galvanic skin response to measure intraoperative physiologic autonomic activation in operating room team members. Surgery 2015; 158:1415–1420
7. Vahedian-Azimi A, Hajesmaeili M, Kangasniemi M, et al: Effects of stress on critical care nurses: A national cross-sectional study. J Intensive Care Med 2019; 34:311–322
8. Burgess L, Irvine F, Wallymahmed A: Personality, stress and coping in intensive care nurses: A descriptive exploratory study. Nurs Crit Care 2010; 15:129–140
9. Keane A, Ducette J, Adler DC: Stress in ICU and non-ICU nurses. Nurs Res 1985; 34:231–236
10. Wu Y, Wang J, Luo C, et al: A comparison of burnout frequency among oncology physicians and nurses working on the front-line and usual wards during the COVID-19 epidemic in Wuhan, China. J Pain Symptom Manage 2020; 60:e60–e65