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COVID-19; emergency department; heart rate variability; pandemic; stress; visual analog scale

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Key points:
Does the appearance of a new pandemic induce more stress than a daily job among emergency health care workers?
Findings:
Emergency health care workers had higher stress levels between the 2 waves of the pandemic, considered the "control" period. But this period also had a higher level of daily admission.
Meaning:
Overcrowding of an emergency department induces more stress than a new pandemic. Taking care of our health care workers should be a priority for all politics.

Influence of COVID-19 on Stress at Work During the First Wave of the Pandemic Among Emergency Health Care Workers

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Abstract

Objectives: For more than 2 years, coronavirus disease (COVID-19) has forced worldwide health care systems to adapt their daily practice. These adaptations add to the already stressful demands of providing timely medical care in an overcrowded health care system. Specifically, the COVID-19 pandemic added stress to an already overwhelmed emergency and critical care health care workers (HCWs) on the front lines during the first wave of the pandemic.

This study assessed comparative subjective and objective stress among frontline HCWs using a visual analog scale and biometric data, specifically heart rate variability (HRV).

Methods: This is a prospective, observational study using surveys and heart rate monitoring among HCWs who work in 3 frontline health care units (emergency department, mobile intensive care unit, and intensive care unit) in the University Hospital of Clermont-Ferrand, France. Two sessions were performed: 1 during the first wave of the pandemic (April 10 to May 10, 2020) and 1 after the first wave of the pandemic (June 10 to July 15, 2020).

The primary outcome is the difference in stress levels between the 2 time points. Secondary objectives were the impact of overcrowding, sociodemographics, and other variables on stress levels. We also assessed the correlation between subjective and objective stress levels.

Results: Among 199 HCWs, 98 participated in biometric monitoring, 84 had biometric and survey data, and 12 with only biometric data. Subjective stress was higher during the second time point compared to the first (4.39 ± 2.11 vs 3.16 ± 2.34, $P = 0.23$). There were higher objective stress levels with a decrease in HRV between the first and the second time points. Furthermore, we found higher patient volumes as a source of stress during the second time point. We did not find any significant correlation between subjective and objective stress levels.

Conclusion: HCWs had higher stress levels between the 2 waves of the pandemic. Overcrowding in the emergency department is associated with higher stress levels. We did not find any correlation between subjective and objective stress among intensive care and emergency HCWs during the first wave of the pandemic.

For more than 2 years, the coronavirus disease (COVID-19) pandemic impacted an already overwhelmed health care system. The local epidemic quickly became a global pandemic that caused worldwide governments to adapt.[1] During the first pandemic wave (from April 10 to May 10, 2020), no vaccine was available, with some areas being more overwhelmed than others.[2,3] Health care workers (HCWs), especially emergency and intensive care HCWs, were on the front lines managing patients affected by this novel disease.[4] Occupational stress leads to burnout and impacts individual morbidity and mortality.[5] Emergency HCWs are particularly at risk for stress and burnout because of the complex interaction between life-threatening emergencies, emergency department (ED) overcrowding, vicarious trauma,[6–8] lack of sleep, unhealthy diet,[9] and accumulated fatigue.[10,11] Frontline workers were more likely to experience burnout, posttraumatic stress disorders, and poor sleep quality.[12–16] Furthermore, HCWs, especially those on the front lines, reported high rates of depression, anxiety, and insomnia compared to the general public.[17]

The Karasek Job-demand scale or the Perceived Stress Scale is a validated tool that assesses subjective stress at work.[18] However, because of its length and complexity, the time commitment for completion makes this test impractical in the clinical setting. The Visual Analog Scale (VAS) was initially developed to assess pain.[19] It has also been used and validated to evaluate stress.[20] VAS is attractive because it is simple to implement, easy to understand, and time efficient. Currently, VAS is the most common tool used by occupational physicians to assess stress among workers.[20,21] In addition, stress can be objectively evaluated using biomarkers[22,23(p8),24–26] such as heart-rate variability (HRV).[27] Measuring HRV is noninvasive, easy to use, reproducible, and measurable over more extended periods (over 24 hours).[28] Linked to the autonomous nervous system, HRV reflects the cardiovascular response to regulatory impulses affecting heart rhythm.[29] Stress among HCWs has been widely studied with the overwhelming observation that this pandemic induced stress, burnout, and posttraumatic stress disorder.[30–32] Given the dearth of information on stress response during the first wave of the pandemic, we conducted a study among emergency and intensive care unit HCWs. The main objective was to assess the impact of COVID-19 on the subjective and objective stress levels at work. Secondary objectives were to assess the correlation between subjective stress, using VAS, and objective stress, using HRV among HCWs.

Methods

Study Design

We performed a prospective, observational study between April 10 and July 15, 2020, in 3 departments of the University Hospital of Clermont-Ferrand, France: ED, mobile intensive care unit, and intensive care unit (ICU). The study was divided into 2 sessions: the first one during the first wave of the COVID-19 pandemic (April 10 to May 10, 2020) and the second one during the interval between the first wave and the second wave (June 10 to July 15, 2022). We defined this second time point as "control," considering operationally, clinical practice tended to return to pre-COVID practices. The inclusion criteria were all HCWs (physicians, nurses, and nurse's aides) who volunteered to participate in the study. Exclusion criteria included pregnancy, refusal to participate, and being a trainee. At the beginning of each shift, 1 investigator installed a portable monitor belt that measures heart rate (HR) and HRV. Study volunteers were asked to wear the belt for the duration of the shift. Furthermore, a survey was created by 3 investigators (MC, FD, and J-BB-M) regarding stress assessment and the necessity to study the impact of COVID-19 on stress among emergency and ICU HCWs. Completion of the survey took approximately 3 minutes and was divided into 3 parts: (1) sociodemographics—age, sex, height, weight, body mass index (BMI), profession, seniority, physical activity, and tobacco; (2) the 13 VAS questions—stress of caring for a COVID-19 patient, stress at work, stress at home, fatigue, sleep quality, anxiety, mood, burnout, job control, job demand, leadership support, support from colleagues, and job satisfaction (this part was answered at the beginning and end of the shift); and (3) patient acuity and demographics—number of patients personally cared for by the study participants, including life-threatening emergencies and the number of procedures deemed high-risk for COVID-19 exposure[33] (endotracheal intubation, thoracostomy, nasogastric aspiration, and nasopharyngeal swabbing of patients under investigation for COVID-19), number of admissions in the ED, and number of COVID-19-related admissions by shift.

Data Collection

All data from questionnaires were manually extracted in an Excel® sheet. HRV data were downloaded daily using Bioharness Zephyr® software. Analysis from Zephyr was performed with the Kubios® software. All HR records available were analyzed. We deleted incorrect data due to artifacts using the very-low filter on the Kubios® software.[34–37] When available, the questionnaires were linked to the biometric data monitoring with an anonymized number.

The following biometric parameters were collected: time-domain measurement—RR interval (interval between every heartbeat), the standard deviation of the regular sinus beats (SDNN), HR mean, root mean square of successive differences between normal (RMSSD), percentage of adjacent NN intervals that differ from each other by more than 50 milliseconds (pNN50), HRV triangular index (HTI), Triangular Interpolation of the NN interval histogram (TINN), the standard deviation of heart rate (STDHR) and frequency-domain measurements to separate HRV into its component, very low frequency (VLF), low frequency (LF), and high frequency (HF) rhythms that operate within different frequency ranges.[38]

Data Analysis

Categorical data were expressed as a number of subjects and associated percentages, and continuous data as mean ± standard deviation or median [25th; 75th percentile] according to the statistical distribution. Characteristics of the participants were compared according to the 2 sessions, using the chi-squared test or Fisher's exact test for categorical variables and the Student's t-test or Mann-Whitney test (if the assumptions of the t-test were not met) for quantitative ones. Normality was verified by the Shapiro-Wilk test and/or histogram, and homoscedasticity by the Fisher-Snedecor test. Factors associated with subjective stress were studied using linear mixed models, considering the participant as a random effect, to account for the repeated measurements per participant. Objective stress was compared according to the 2 sessions using linear mixed models, considering the session a fixed effect and the participant a random effect. If necessary, a logarithmic transformation of the dependent variable was made to achieve normality. Correlations between subjective and objective stress at work (VAS and HRV, respectively) were assessed with Spearman's correlation coefficients (noted ρ). These coefficients were interpreted as follows (absolute value): ≥ 0.70 (strong correlation), 0.50-0.69 (moderate correlation), 0.30-0.49 (low correlation), 0.00-0.29 (no or negligible correlation).[39] Statistical analysis was performed using the Stata software (version 15; StataCorp, College Station, TX, USA). All tests were 2-sided, with an alpha level set at 0.05. No correction for multiple testing was applied in the analysis of secondary outcomes or subgroup analysis.[40] Findings from these analyses were interpreted as exploratory.

Ethics

A French Ethics committee (Comité de Protection des Personnes Sud-Est VI, University hospital of Clermont-Ferrand) approved

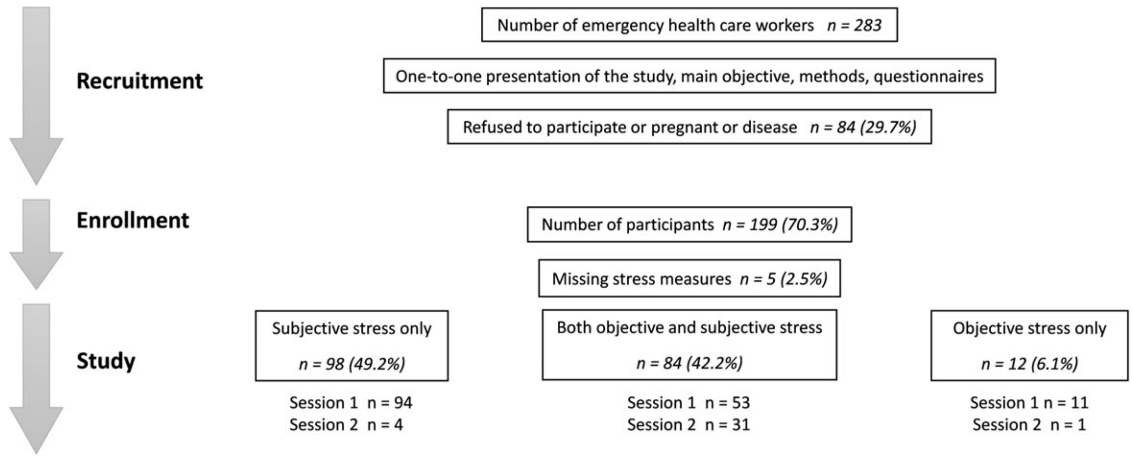

Figure 1. Flowchart of the study.

this study protocol in April 2020 (reference 2020/CE15), and the protocol was registered in ClinicalTrials (NCT04954105).

Results

Characteristics of the Population

From April 10 to July 15, 2020, we included 199/283 volunteer participants for 192 records, 182 (94.8%) of whom responded to the survey questions regarding stress at work (subjective stress), and 96 (50.0%) participants provided HR data entries (objective stress). The flowchart is shown in Figure 1. We had a total of 98 (51.0%) subjective stress responders: 94 (95.9%) during the first session and 4 (4.1%) during the second session. We also had 12 (6.3%) responders provide objective biometric data entry without their subjective stress data: 11 (91.7%) during the first session and 1 (8.3%) during the second session. We had 84 (43.8%) responders provide both subjective and objective stress data: 53 (63.1%) during the first session and 31 (36.9%) during the second time session.

The participants' demographics were mostly female (61.5%), with a mean age of 33.7 ± 7.9 years old and a mean BMI of 23.0 ± 3.3 kg/m[2]; 49 (25.5%) were smokers, and 95/190 (50.0%) had a physical activity superior to the World Health Organization recommendations (≥ 2.5 hours per week). Of the study respondents, 93 (48.4%) were physicians, 76 (39.6%) were nurses, 13 (6.8%) were ambulance drivers, and 10 (5.2%) were nurse's aides. Of the patient demographics/acuity survey respondents, 52/141 (36.9%) faced life-threatening emergencies, and 28/141 (19.9%) high-risk COVID-19 transmission procedures. The characteristics of participants were similar between the 2 sessions (Table 1). However, there was a significant difference in the median number of patient volumes per day, the median number of COVID-19 patients, the work location, and the number of patients per worker (see Table 1).

Main Objective: Impact of COVID-19 on Stress

Subjective stress

The mean stress level at work was 3.40 ± 2.34, without any difference between the 2 sessions (3.16 ± 2.34 vs 4.39 ± 2.11, $P = 0.23$). No difference was found according to sex, job, and physical activity. However, a higher stress level was found among smokers ($P = 0.03$) and participants who had a life-threatening emergency during their shift ($P = 0.006$) (Table 2). Furthermore, at the beginning of the shift, a moderate correlation (0.52) was observed between the stress of taking care of a COVID-19 patient and anxiety, and a low correlation between stress at home (0.35), tiredness (0.37), burnout (0.40), and job demand (0.38) (Table 3).

Objective stress

We found no significant difference between the 2 sessions in all frequency-domain measurements (Figure 2). However, during the second session, time-domain measurements, TINN and PNN50, were significantly lower compared to the first session signaling higher stress levels, respectively, 760 ms versus 630 ms for TINN and 31.5% versus 20.6% for PNN50. In addition, SDNN and HR were lower during the second session but not statistically significant (122.9 ms vs 99.5 ms, $P = 0.06$ for SDNN, and 98.0/min vs 93.3/min, $P = 0.08$ for HR, respectively) (see Figure 2).

Secondary Objective: Correlation Between Objective and Subjective Stress

We did not find any correlation between objective and subjective stress except for time-domain measurements, RR (-0.23, $P = 0.04$) and HTI (-0.28, $P = 0.01$), considering as low Spearman's correlation coefficients. However, no other domain was significant: −0.14 for SDNN, 0.17 for HR, −0.15 for STDHR, −0.12 for RMSSD, −0.06 for PNN50, and −0.06 for TINN. Regarding frequency domain measurements, no correlation was significant: −0.17 for VLF, −0.10 for LF and HT, and 0.13 for LF/HF. No linear measurement was significant: −0.13 for SD1 and −0.16 for SD2 (Supplementary Table).

Discussion

We found moderate stress levels among emergency HCWs during the first wave and the control period of the novel pandemic in a low-incidence place. Interestingly, our data show that the novel pandemic did not increase the stress levels of emergency HCWs beyond the expected daily stress. Furthermore, we did not find a strong relationship between subjective (VAS) and objective (HRV) data. Prior literature supports this observation.[41]

Period of Measurement

We performed the first session during the first wave of the pandemic in France from April 10 to May 7, 2020. At that time,

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Table 1. Characteristics of the population

	Total (n = 192)	Session 1 (n = 156)	Session 2 (n = 36)	*P*-value
Age (years)	33.7 ± 7.9	34.0 ± 8.2	32.4 ± 6.9	0.25
Female sex	118 (61.5)	98 (62.8)	20 (55.6)	0.42
Body mass index (kg/m^2)	23.0 ± 3.3	23.1 ± 3.4	22.8 ± 2.9	0.64
Tobacco	49 (25.5)	37 (23.7)	12 (33.3)	0.23
Physical activity ≥ 2.5 hours per week	95/190 (50.0)	74/154 (48.1)	21/36 (58.3)	0.27
VAS of stress at work (/10)	3.40 ± 2.34	3.16 ± 2.34	4.39 ± 2.11	0.23
Job				0.08
Ambulance driver	13 (6.8)	13 (8.3)	0 (0.0)	
Nurse’s aide	10 (5.2)	10 (6.4)	0 (0.0)	
Nurse	76 (39.6)	62 (39.7)	14 (38.9)	
Physician	93 (48.4)	71 (45.5)	22 (61.1)	
Workplace				< 0.001
Urgent care	6 (3.1)	2 (1.3)	2 (5.6)	
Triage	6 (3.1)	4 (2.6)	4 (11.1)	
Trauma room	21 (10.9)	15 (9.6)	6 (16.7)	
Emergency department	48 (25.0)	28 (17.9)	20 (55.6)	
COVID-19 unit	66 (34.4)	62 (39.7)	4 (11.1)	
Mobile intensive care unit	45 (23.4)	45 (28.8)	0 (0.0)	
Number of patients per day	97 [91; 106]	96 [91; 104]	138 [102; 152]	< 0.001
Number of COVID-19 patients per day	19 [3; 23]	22 [19; 23]	0 [0; 3]	< 0.001
Number of patients per worker per day	7 [5; 15]	6 [4; 14]	15 [7; 20]	< 0.001
Life-threatening emergencies	52/141 (36.9)	42/106 (39.6)	10/35 (28.6)	0.24
High-risk actions	28/141 (19.9)	22/106 (20.8)	6/35 (17.1)	0.64

Data are presented as a number of subjects (percentages), mean ± standard deviation, or median [25th; 75th percentile]. VAS, visual analog scale. Session 1: during the first wave of the pandemic (April 10 to May 10, 2020); session 2: the time interval after the first wave of the pandemic (June 10 to July 15, 2020).

scientists did not know much about the virus, its contagiousness, and its transmissibility.[42] Since a diagnosis using polymerase chain reaction was not readily available compared to today, we used chest tomography as a surrogate for diagnosing COVID-19.[43]

Furthermore, no vaccine was available during the time of the study. Emergency and ICU HCWs treated and cared for possible or known COVID-19 patients with only personal protective equipment (PPE), adding to moral distress. The French Auvergne region was relatively protected from high volumes of COVID-19 admissions during the first pandemic wave following the French Government declaring lockdown on March 17, 2020. For example, the average daily entries at the Clermont-Ferrand ED are 160 patients per day. On March 18, 2020, the patient volume was 60 patients only.[2,3] Additionally, all non-urgent surgery and medical hospitalization were canceled. These new constraints decreased overcrowding during the first lockdown,[2,3] and the French Auvergne region took care of patients transferred from other locations.[39] This situation was not anticipated at the time we began the study. We anticipated the ED to be overwhelmed, similar to other EDs,[44] and expected a higher stress level in the first session than in the second session. However, our study showed that the control period was more stressful than the pandemic’s first wave, based on objective stress data using HRV. The main explanation we found is overcrowding, with the number of patients in the ED being significantly higher in the second period, aggravated by the lack of beds available to admit patients. Similar to pre-pandemic observations, overcrowding significantly impacts increasing stress among nurses and physicians.[45]

Subjective Stress

During more than 24 months, COVID-19 and its impact on emergency HCWs have been studied. We hypothesize that the pandemic increased the stress levels of HCWs. The best performing concept to assess stress is the job-demand-control model created and validated by Karasek in 1981.[18] The Job Content Questionnaire is derived from Karasek’s model and has been developed and validated in several languages.[18] Studies have highlighted its psychometrics properties, especially in a French population of 24 486 workers.[46] However, this tool is difficult to use daily in the population of HCWs because of its length (18 items) and complexity. Similarly, studies show that the participation rate decreases with the length of the questionnaires and decreases in attention and concentration.[47] The VAS was developed to assess occupational stress.[20,21] It is a suitable tool for clinical activity and has good psychometric characteristics.[48,49]

Heart Rate Variability

However, when people are less able to cope with stressors or if the duration of stress is too long or often repeated, the autonomic nervous system activity is reduced or unbalanced, inducing anxiety and depression.[50] Baseline HR and HRV are measures of stress highlighting a sympathetic shift in sympathovagal balance and reduced complexity of the cardiac signal.[51] Although we did not find any statistically significant baseline HRV between the 2 sessions, we were able to find a tendency. Second session HRV seems to be lower than firsts. We hypothesize that our sample size is not strong enough. However, we will not be able to perform such

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Table 2. Factors associated with subjective stress at work measured by a visual analog scale

	Total			Session 1			Session 2		
	n	Mean ± SD or ρ	*P*-value	n	Mean ± SD or ρ	*P*-value	n	Mean ± SD or ρ	*P*-value
Age (years)	182	−0.01	0.85	147	−0.01	0.92	35	0.03	0.85
Sex			0.38			0.69			0.20
Female	112	3.67 ± 2.37		92	3.42 ± 2.28		20	4.80 ± 2.47	
Male	70	2.97 ± 2.25		55	2.74 ± 2.39		15	3.83 ± 1.40	
Body mass index (kg/m^2)	182	0.00	0.99	147	0.00	1.00	35	−0.02	0.91
Tobacco			0.03			0.27			0.03
No	136	3.13 ± 2.29		113	2.97 ± 2.30		23	3.87 ± 2.11	
Yes	46	4.21 ± 2.34		34	3.79 ± 2.38		12	5.38 ± 1.81	
Physical activity			0.70			0.54			0.83
< 2.5 hours per week	92	3.15 ± 2.21		78	2.96 ± 2.21		14	4.21 ± 1.93	
≥ 2.5 hours per week	88	3.69 ± 2.46		67	3.43 ± 2.48		21	4.50 ± 2.26	
Job			0.19			0.69			0.002
Paramedic	96	3.59 ± 2.67		82	3.26 ± 2.61		14	5.57 ± 2.15	
Physician	86	3.18 ± 1.90		65	3.05 ± 1.95		21	3.60 ± 1.71	
Number of patients per day	124	0.04	0.64	89	0.01	0.93	35	0.025	0.89
Number of possible COVID-19 patients	124	−0.01	0.27	89	−0.10	0.34	35	0.183	0.29
Number of patients per worker per day	142	0.12	0.15	107	0.22	0.02	35	−0.24	0.17
Life-threatening emergencies			0.006			0.07			0.008
No	89	3.54 ± 2.30		64	3.37 ± 2.44		25	4.00 ± 1.89	
Yes	52	4.32 ± 2.26		42	4.07 ± 2.18		10	5.35 ± 2.43	
High-risk aerosolizing procedures			0.07			0.03			0.46
No	113	3.58 ± 2.26		84	3.34 ± 2.26		29	2.28 ± 2.14	
Yes	28	4.84 ± 2.29		22	4.82 ± 2.39		6	4.92 ± 2.06	

n, Number of observations; rho (ρ), Spearman's correlation coefficient; SD, standard deviation. Spearman's correlation coefficients were interpreted as follows (absolute value): ≥ 0.70 (strong correlation), 0.50-0.69 (moderate correlation), 0.30-0.49 (low correlation), 0.00-0.29 (no or negligible correlation). Session 1: during the first wave of the pandemic (April 10 to May 10, 2020); session 2: after the first wave of the pandemic (June 10 to July 15, 2020).

Table 3. Correlation between work and personal environment (at the beginning and end of the shift) and subjective stress at work (measured by a visual analog scale)

	Beginning of the shift			End of the shift		
	n	ρ	*P*-value	n	ρ	*P*-value
Care of possible COVID-19 patient	182	0.52	< 0.001	181	0.51	< 0.001
Stress at home	182	0.35	< 0.001	181	0.38	< 0.001
Tiredness	182	0.37	< 0.001	181	0.51	< 0.001
Sleep quality	182	−0.07	0.36	181	−0.07	0.38
Anxiety	182	0.52	< 0.001	182	0.59	< 0.001
Mood	182	0.04	0.63	180	−0.04	0.56
Burnout	182	0.40	< 0.001	181	0.38	< 0.001
Job control	180	0.07	0.36	180	0.11	0.16
Job demand	181	0.38	< 0.001	181	0.40	< 0.001
Leadership support	182	−0.03	0.73	182	0.01	0.85
Co-workers' support	182	0.04	0.59	182	0.01	0.87
Personal job satisfaction	182	0.01	0.94	182	−0.10	0.17

n, Number of observations; rho (ρ), Spearman's correlation coefficient. Spearman's correlation coefficients were interpreted as follows (absolute value): ≥ 0.70 (strong correlation), 0.50-0.69 (moderate correlation), 0.30-0.49 (low correlation), 0.00-0.29 (no or negligible correlation). All data were assessed using a visual analog scale.

study before decades. Indeed, the first wave of the COVID-19 pandemic was the first worldwide pandemic since the Spanish flu in the early 20th century. No HCWs have already lived this type of pandemic. To perform the exact same study with a stronger sample, we need a long-term wash-out period to study new HCWs free of the COVID-19 virus. We can only hypothesize on our results and therefore on tendencies. One of the main differences between the 2 periods was the number of daily consults, which is

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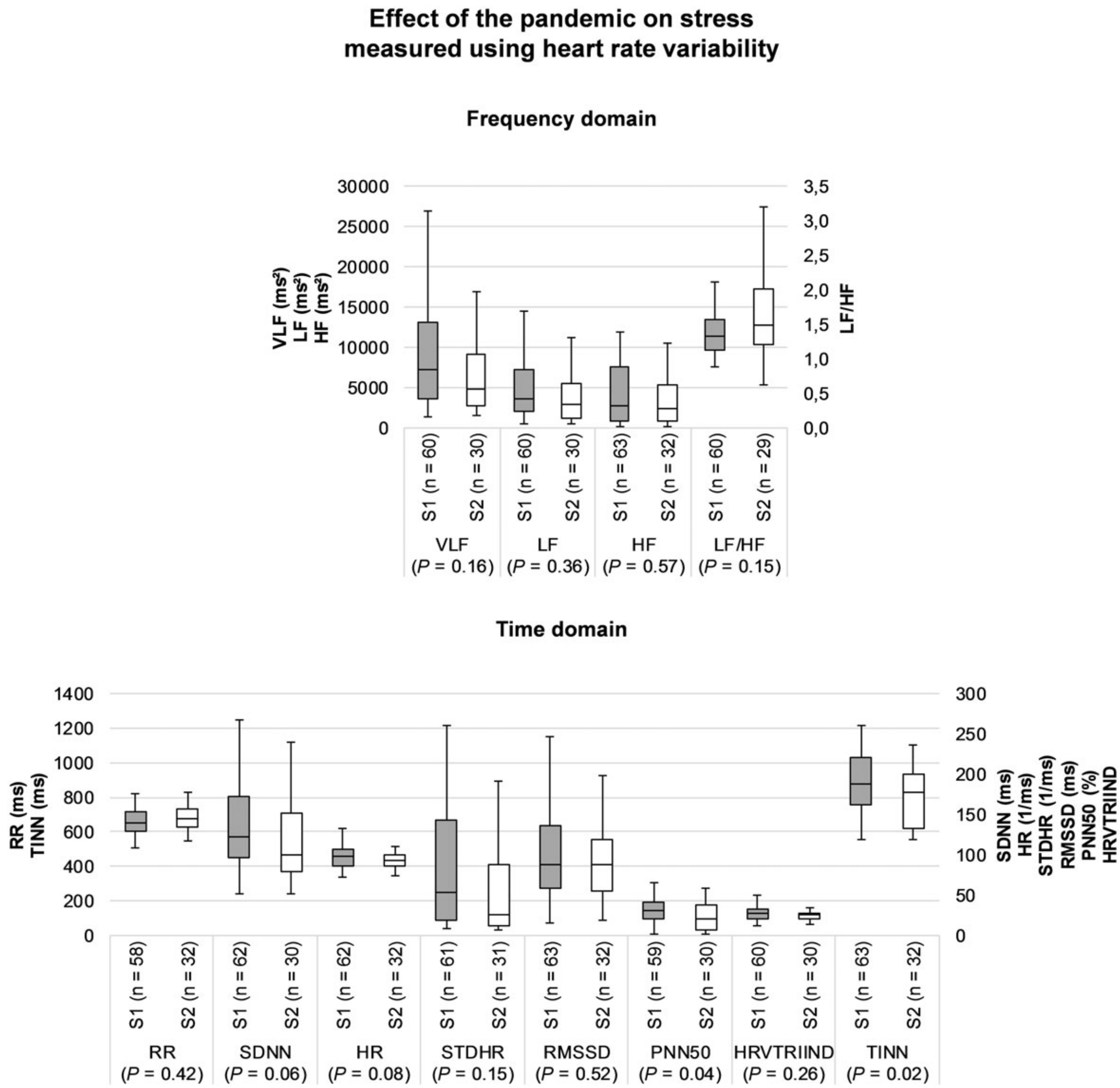

Figure 2. Comparison of heart rate variability.

known to be stressful.[52] However, we had a lot of cofounding factors that could decrease its impact.

SDNN explores short-term stress, that is, less than 2 hours, whereas PNN50 and TINN explore both acute and long-term stress. SDNN and stress index positively correlate when the stress level is correctly adapted. SDNN increases when stress increases. Our data showed that SDNN levels were lower in the second period, assuming lower stress levels; in the context of long-term stress, it is important to remember that SDNN is the best marker for long-term stress. On the contrary, PNN50 is low during stress exposure, explores short-time variability, and is influenced by both acute and long-term stress.[53,54] We found that PNN50 was lower during the second period highlighting higher stress levels. Lastly, TINN, a well-known HRV parameter to be higher when the stress is lower, is also higher during the first period, signaling lower stress levels during the first period.[51]

Limitations

Our study has some limitations. Our study period covered the first wave of the pandemic, which had comparably less impact in the French Auvergne region, mainly due to early lockdown and public adherence. It may be interesting to perform new measurements during different periods of the COVID-19 pandemic (eg, first wave, second wave, when the vaccine became available, after the third wave), and during "non-COVID-19" and pandemic recovery periods.

Additionally, we used Bioharness Zephyr®, and participants were asked to place the belt themselves after a demonstration, which introduced a lot of artifacts and uninterpretable data. To counter this issue, we used the very-low artifact correction option of Kubios® software. It may be relevant to train participants to use the belt before the beginning of the measurement. Data collection was only obtained during regular business hours and missed those working overnights. Nocturnist schedules may pose unique stressors.

Furthermore, there were some missing data for each variable (not all participants provided both HRV data and the VAS survey). The VAS survey is based on the Karasek model for measuring stress, although it has not been validated. Biometric data obtained were limited to HRV and did not include respiration rates, depth, or amplitude of respiration. Although less studied, evidence for

HRV biomarkers is mostly focused on acute stress. Also, we did not study the impact of COVID-19 on neuroendocrine indexes such as plasmatic cortisol or catecholamine levels. Finally, we recruited a sample of young, healthy participants, which impairs the generalization of our results, although it represents the population of our departments.

Conclusion

COVID-19 alone did not increase stress levels during the first wave of the pandemic. This is likely because the French Auvergne region faced fewer COVID-19 patients during the first wave. We found that a higher volume of patients who daily consult in the ED, active smoking, and exposure to life-threatening emergencies was associated with higher stress levels at work during the COVID-19 pandemic. We also found no significant correlation between subjective and objective stress at work.

Competing interests

The authors have declared that no competing interests exist.

References

1. **Gebru AA, Birhanu T, Wendimu E, *et al.*** Global burden of COVID-19: situational analyis and review. *Hum Antibodies.* 2021;29(2):139-148. doi: 10.3233/HAB-200420
2. **Bouillon-Minois JB, Schmidt J, Dutheil F.** SARS-CoV-2 pandemic and emergency medicine: the worst is yet to come. *Am J Emerg Med.* 2021;42:246-247. doi: 10.1016/j.ajem.2020.06.014
3. **Bouillon-Minois JB, Raconnat J, Clinchamps M, *et al.*** Emergency department and overcrowding during COVID-19 outbreak; a Letter to Editor. *Arch Acad Emerg Med.* 2021;9(1):e28. doi: 10.22037/aaem.v9i1.1167
4. **Nguyen LH, Drew DA, Graham MS, *et al.*** Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. *Lancet Public Health.* 2020;5(9):e475-e483. doi: 10.1016/S2468-2667(20)30164-X
5. **Kivimaki M, Leino-Arjas P, Luukkonen R, *et al.*** Work stress and risk of cardiovascular mortality: prospective cohort study of industrial employees. *BMJ.* 2002;325(7369):857.
6. **Roden-Foreman JW, Bennett MM, Rainey EE, *et al.*** Secondary traumatic stress in emergency medicine clinicians. *Cogn Behav Ther.* 2017;46(6): 522-532. doi: 10.1080/16506073.2017.1315612
7. **Nydoo P, Pillay BJ, Naicker T, Moodley J.** The second victim phenomenon in health care: a literature review. *Scand J Public Health.* 2020;48(6):629-637. doi: 10.1177/1403494819855506
8. **Stehman CR, Testo Z, Gershaw RS, Kellogg AR. Burnout**, drop out, suicide: physician loss in emergency medicine, Part I. *West J Emerg Med.* 2019;20(3):485-494. doi: 10.5811/westjem.2019.4.40970
9. **Bouillon-Minois JB, Thivel D, Croizier C, *et al.*** The negative impact of night shifts on diet in emergency healthcare workers. *Nutrients.* 2022; 14(4):829. doi: 10.3390/nu14040829
10. **Moukarzel A, Michelet P, Durand AC, *et al.*** Burnout syndrome among emergency department staff: prevalence and associated factors. *Biomed Res Int.* 2019;2019:6462472. doi: 10.1155/2019/6462472
11. **Durand AC, Bompard C, Sportiello J, *et al.*** Stress and burnout among professionals working in the emergency department in a French university hospital: prevalence and associated factors. *Work.* 2019;63(1):57-67. doi: 10.3233/WOR-192908
12. **Shanafelt T, Ripp J, Trockel M.** Understanding and addressing sources of anxiety among health care professionals during the COVID-19 pandemic. *JAMA.* 2020;323(21):2133-2134. doi: 10.1001/jama.2020.5893
13. **Shanafelt TD, West CP, Sinsky C, *et al.*** Changes in burnout and satisfaction with work-life integration in physicians and the general US working population between 2011 and 2020. *Mayo Clin Proc.* 2022; 97(3):491-506. doi: 10.1016/j.mayocp.2021.11.021
14. **Prasad K, McLoughlin C, Stillman M, *et al.*** Prevalence and correlates of stress and burnout among U.S. healthcare workers during the COVID-19 pandemic: a national cross-sectional survey study. *EClinMed.* 2021;35:100879. doi: 10.1016/j.eclinm.2021.100879
15. **Sinsky CA, Brown RL, Stillman MJ, Linzer M.** COVID-related stress and work intentions in a sample of US health care workers. *Mayo Clin Proc Innov Qual Outcomes.* 2021;5(6):1165-1173. doi: 10.1016/j.mayocpiqo.2021.08.007
16. **Yin Q, Sun Z, Liu T, *et al.*** Posttraumatic stress symptoms of health care workers during the corona virus disease 2019. *Clin Psychol Psychother.* 2020;27(3):384-395. doi: 10.1002/cpp.2477
17. **Zhang X, Zhao K, Zhang G, *et al.*** Occupational stress and mental health: a comparison between frontline medical staff and non-frontline medical staff during the 2019 novel coronavirus disease outbreak. *Front Psychiatry.* 2020;11:555703. doi: 10.3389/fpsyt.2020.555703
18. **Karasek R, Brisson C, Kawakami N, *et al.*** The Job Content Questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. *J Occup Health Psychol.* 1998;3(4):322-355.
19. **Heller GZ, Manuguerra M, Chow R.** How to analyze the Visual Analogue Scale: myths, truths and clinical relevance. *Scand J Pain.* 2016;13:67-75. doi: 10.1016/j.sjpain.2016.06.012
20. **Lesage FX, Berjot S, Deschamps F.** Clinical stress assessment using a visual analogue scale. *Occup Med (Lond).* 2012;62(8):600-605. doi: 10.1093/occmed/kqs140
21. **Dutheil F, Pereira B, Moustafa F, *et al.*** At-risk and intervention thresholds of occupational stress using a visual analogue scale. *PLoS One.* 2017;12(6):e0178948. doi: 10.1371/journal.pone.0178948
22. **Wong DL.** Epinephrine biosynthesis: hormonal and neural control during stress. *Cell Mol Neurobiol.* 2006;26(4-6):891-900. doi: 10.1007/s10571-006-9056-6
23. **Dutheil F, Trousselard M, Perrier C, *et al.*** Urinary interleukin-8 is a biomarker of stress in emergency physicians, especially with advancing age—the JOBSTRESS* randomized trial. *PLoS One.* 2013;8(8):e71658. doi: 10.1371/journal.pone.0071658
24. **Bouillon-Minois JB, Trousselard M, Thivel D, *et al.*** Leptin as a biomarker of stress: a systematic review and meta-analysis. *Nutrients.* 2021;13(10): 3350. doi: 10.3390/nu13103350
25. **Bouillon-Minois JB, Trousselard M, Thivel D, *et al.*** Ghrelin as a biomarker of stress: a systematic review and meta-analysis. *Nutrients.* 2021;13(3):784. doi: 10.3390/nu13030784
26. **Dutheil F, de Saint Vincent S, Pereira B, *et al.*** DHEA as a biomarker of stress: a systematic review and meta-analysis. *Front Psychiatry.* 2021;12:688367. doi: 10.3389/fpsyt.2021.688367
27. **Dutheil F, Boudet G, Perrier C, *et al.*** JOBSTRESS study: comparison of heart rate variability in emergency physicians working a 24-hour shift or a 14-hour night shift—a randomized trial. *Int J Cardiol.* 2012;158(2): 322-325. doi: 10.1016/j.ijcard.2012.04.141
28. **Malik M, Bigger JT, Camm AJ, *et al.*** Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *Circulation.* 1996;93(5):1043-1065.
29. **Kim HG, Cheon EJ, Bai DS, *et al.*** Stress and heart rate variability: a meta-analysis and review of the literature. *Psychiatry Investig.* 2018;15(3): 235-245. doi: 10.30773/pi.2017.08.17
30. **Couarraze S, Delamarre L, Marhar F, *et al.*** The major worldwide stress of healthcare professionals during the first wave of the COVID-19 pandemic—the international COVISTRESS survey. *PLoS One.* 2021; 16(10):e0257840. doi: 10.1371/journal.pone.0257840
31. **Douplat M, Termoz A, Subtil F, *et al.*** Changes over time in anxiety, depression, and stress symptoms among healthcare workers in French emergency departments during the first COVID-19 outbreak. *J Affect Disord.* 2022;316:194-200. doi: 10.1016/j.jad.2022.08.028
32. **Guillen-Burgos F, Gomez-Ureche J, Renowitzky C, *et al.*** Prevalence and associated factors of mental health outcomes among healthcare workers in northern Colombia: a cross-sectional and multi-centre study. *J Affect

Disord Rep. Published online August 19, 2022:100415. doi: 10.1016/j.jadr.2022.100415
33. **Mick P, Murphy R.** Aerosol-generating otolaryngology procedures and the need for enhanced PPE during the COVID-19 pandemic: a literature review. *J Otolaryngol Head Neck Surg.* 2020;49(1):29. doi: 10.1186/s40463-020-00424-7
34. **Królak A, Wiktorski T, Bjørkavoll-Bergseth MF, Ørn S.** Artifact correction in short-term HRV during strenuous physical exercise. *Sensors (Basel).* 2020;20(21):E6372. doi: 10.3390/s20216372
35. **Dos Santos Ribeiro G, Neves VR, Deresz LF, *et al.*** Can RR intervals editing and selection techniques interfere with the analysis of heart rate variability? *Braz J Phys Ther.* 2018;22(5):383-390. doi: 10.1016/j.bjpt.2018.03.008
36. **Salo MA, Huikuri HV, Seppanen T.** Ectopic beats in heart rate variability analysis: effects of editing on time and frequency domain measures. *Ann Noninvasive Electrocardiol.* 2006;6(1):5-17. doi: 10.1111/j.1542-474X.2001.tb00080.x
37. **Plaza-Florido A, Alcantara JMA, Amaro-Gahete FJ, *et al.*** Cardiovascular risk factors and heart rate variability: impact of the level of the threshold-based artefact correction used to process the heart rate variability signal. *J Med Syst.* 2020;45(1):2. doi: 10.1007/s10916-020-01673-9
38. **Shaffer F, Ginsberg JP.** An overview of heart rate variability metrics and norms. *Front Public Health.* 2017;5:258. doi: 10.3389/fpubh.2017.00258
39. **Hinkle DE, Wiersma W, Jurs SG.** *Applied statistics for the behavioral sciences*. 5th ed. Houghton Mifflin; Hi Marketing (distributor); 2003.
40. **Feise RJ.** Do multiple outcome measures require p-value adjustment? *BMC Med Res Methodol.* 2002;2:8.
41. **Petrowski K, Herhaus B, Schöniger C, *et al.*** Stress load of emergency service: effects on the CAR and HRV of HEMS emergency physicians on different working days (N = 20). *Int Arch Occup Environ Health.* 2019;92(2):155-164. doi: 10.1007/s00420-018-1362-z
42. **Bhagavathula AS, Aldhaleei WA, Rahmani J, *et al.*** Knowledge and perceptions of COVID-19 among health care workers: cross-sectional study. *JMIR Public Health Surveill.* 2020;6(2):e19160. doi: 10.2196/19160
43. **Lv M, Wang M, Yang N, *et al.*** Chest computed tomography for the diagnosis of patients with coronavirus disease 2019 (COVID-19): a rapid review and meta-analysis. *Ann Transl Med.* 2020;8(10):622. doi: 10.21037/atm-20-3311
44. **Azoulay É, Beloucif S, Guidet B, *et al.*** Admission decisions to intensive care units in the context of the major COVID-19 outbreak: local guidance from the COVID-19 Paris-region area. *Crit Care.* 2020;24(1):293. doi: 10.1186/s13054-020-03021-2
45. **Bond K, Ospina MB, Blitz S, *et al.*** Frequency, determinants and impact of overcrowding in emergency departments in Canada: a national survey. *Healthc Q.* 2007;10(4):32-40. doi: 10.12927/hcq.2007.19312
46. **Niedhammer I, Chastang JF, Levy D, *et al.*** Study of the validity of a job-exposure matrix for psychosocial work factors: results from the national French SUMER survey. *Int Arch Occup Environ Health.* 2008;82(1):87-97. doi: 10.1007/s00420-008-0311-7
47. **Aceves-Martins M, Whitehead R, Inchley J, *et al.*** Self-reported weight and predictors of missing responses in youth. *Nutrition.* 2018;53:54-58. doi: 10.1016/j.nut.2018.01.003
48. **Sung YT, Wu JS.** The Visual Analogue Scale for Rating, Ranking and Paired-Comparison (VAS-RRP): a new technique for psychological measurement. *Behav Res Methods.* 2018;50(4):1694-1715. doi: 10.3758/s13428-018-1041-8
49. **Abend R, Dan O, Maoz K, *et al.*** Reliability, validity and sensitivity of a computerized visual analog scale measuring state anxiety. *J Behav Ther Exp Psychiatry.* 2014;45(4):447-453. doi: 10.1016/j.jbtep.2014.06.004
50. **Yoo HH, Yune SJ, Im SJ, *et al.*** Heart rate variability-measured stress and academic achievement in medical students. *Med Princ Pract.* 2021;30(2):193-200. doi: 10.1159/000513781
51. **Orsila R, Virtanen M, Luukkaala T, *et al.*** Perceived mental stress and reactions in heart rate variability—a pilot study among employees of an electronics company. *Int J Occup Saf Ergon.* 2008;14(3):275-283.
52. **Eriksson J, Gellerstedt L, Hillerås P, Craftman ÅG.** Registered nurses' perceptions of safe care in overcrowded emergency departments. *J Clin Nurs.* 2018;27(5-6):e1061-e1067. doi: 10.1111/jocn.14143
53. **Hernando D, Roca S, Sancho J, *et al.*** Validation of the Apple Watch for heart rate variability measurements during relax and mental stress in healthy subjects. *Sensors (Basel).* 2018;18(8):E2619. doi: 10.3390/s18082619
54. **Hernando D, Garatachea N, Almeida R, *et al.*** Validation of heart rate monitor Polar RS800 for heart rate variability analysis during exercise. *J Strength Cond Res.* Published online September 27, 2016. doi: 10.1519/jsc.0000000000001662