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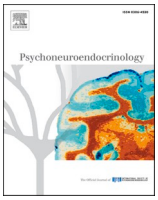

Investigating the influence of shift work rosters on stress measured as cortisol in hair during the SARS-CoV-2 pandemic

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ABSTRACT

The COVID-19 pandemic has increased the workload and has affected physical and mental health of many employees. Hair cortisol concentration (HCC) has proven useful as a marker for retrospective assessment of stress in epidemiological studies and was measured here in non-healthcare night-shift workers with standard shifts (8-h shifts) and extended shifts (12-h shifts) before and during the first wave of the COVID-19 pandemic in Germany. Results showed a twofold increase in HCC among shift workers during the first wave of the COVID-19 pandemic compared with previous measurements. Subjectively reported measures of psychosomatic stress were not found to be reliable predictors of HCC. No statistically significant HCC differences were found between rosters. Working 12-h shifts does not appear to be an additional stressor in the already demanding COVID-19 pandemic.

1. Introduction

The current severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic is one of the biggest health problems the world has faced in the last decade. The related coronavirus disease-2019 (COVID-19) poses serious risks to both physical and mental health. Additionally, for many employee's workload and the average investment in work in terms of time and effort increased during the COVID-19 pandemic. This is true for frontline key-workers in the healthcare sector, but also for employees in other industries or the general population (Gaspar et al., 2021; Shkoler et al., 2021). Negative psychosocial consequences of COVID-19 were evident early in the pandemic and up to 30% of the general population reported psychological distress in the first months of the pandemic (Bendau et al., 2021).

Over time, the COVID-19 pandemic evolved from an acute stress situation characterized by fear of the unknown virus to a chronic stress situation caused by lockdowns, contact restrictions, and limited social activities (Pfeifer et al., 2021). During acute stress, cortisol, a steroid hormone and an end product of the hypothalamic-pituitary-adrenal axis, increases and is supposed to remain elevated during chronic stress (Russell and Lightman, 2019). Due to its passive storage in hair, measurement of hair cortisol concentration (HCC) can be used to retrospectively determine systemic cortisol exposure over a period of several weeks to months (Russell et al., 2012). According to a meta-analysis, long-term stress increased HCC by 22%, especially if chronic stress is still present at the time of measurement (Stalder et al., 2017). HCC has been studied to some extent in shift workers, but with divergent results (Janssens et al., 2017; Manenschijn et al., 2011; Zhang et al., 2020). Other factors associated with HCC elevation are male gender, higher body mass index, prevalent diabetes, and to some extend higher age (Stalder et al., 2017).

A first work from Slovakia that examined HCC in shift workers during the COVID-19 pandemic reported higher HCC in hair segments of healthcare workers in early summer 2020, which was attributed to the first wave of the COVID-19 pandemic, compared to hair segments attributable to a period just before the pandemic outbreak (Rajcani et al., 2021b). However, the impact of specific shift characteristics (*e.g.*, extended 12-h shifts) in combination with the increased potential of stress due to the pandemic has not been studied yet. Here, we investigated the long-term psychological stress in non-healthcare shift workers with standard working hours (8-h shifts) and extended working hours (12-h shifts) before and shortly after the first wave of the COVID-19 pandemic in Germany to answer the following question: Does the pandemic act as an additional stressor for 12-h shift workers? We

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hypothesized that HCC from the period corresponding to the COVID-19 pandemic would be higher compared to HCC reflecting an earlier period with possibly even higher HCC among men working in a potentially more stressful shift system with extended work hours (Caruso, 2014).

2. Methods

2.1. Study population and design

The study population consists of 100 shift workers of a German manufacturing company with rotating shift systems. Participants worked 42 h per week in either rapidly rotating 8-h morning, evening, and night shifts, each with two equal shifts in a row, or 12-h shifts, with one week consisting of only day shifts followed by one week of only night shifts. A hair sample was collected from all participants in summer 2020 (August 20 to September 4, 2020) covering the end of the first wave of COVID-19 and the slow emergence of the second wave of COVID-19 in Germany. At least one additional hair sample per participant was collected in spring 2018 and/or spring 2019. Due to the small number of female participants (n = 4), the analysis was restricted to men. One employee with a diagnosis of depression was also excluded. Two further HCC measurements from participants who were treated with glucocorticoids at the time of hair collection were omitted. However, HCC measurements from these men at later time points were used. The remaining study population (n = 95) comprised 38 men working 8-h shifts and 57 men working 12-h shifts with a total of 243 HCC measurements. Sociodemographic characteristics, medication intake, and chronic diseases, were assessed by questionnaire. The change in job stress and work pressure was assessed in 2019 and 2020 using the following question: "How have stress and work pressure changed? Have they increased, stayed the same, or decreased?". Body height and weight as well as glycated hemoglobin (HbA1c) were measured. All participants provided written informed consent. The study was approved by the Ethics Committee of the Ruhr University Bochum, Germany (Reg. No. 17-6205). Further details with respect to study population and roster have been described elsewhere (Casjens et al., 2022).

2.2. Determination of cortisol concentration in hair

A minimum of 10 mg of hair was collected from a posterior vertex position, where the hair growth rate is most uniform and the intra-individual variability of HCC is lowest (Sauvé et al., 2007). Hair samples were stored in a dry, dark place until shipment and HCC determination at the Biopsychology Laboratory of the Technical University Dresden, Germany. Hair samples were washed and HCC determined using a commercially available immunoassay with chemiluminescence detection (CLIA, IBL-Hamburg, Germany) on the 3 cm section of hair closest to the scalp according to the protocol (Davenport et al., 2006). Due to the known average hair growth of about 1 cm per month the last three months before sampling were analyzed (Wennig, 2000).

2.3. Statistics

Boxplots with median and interquartile range (IQR) and whiskers representing the 2.5th and 97.5th percentile were used to show the distribution of HCC between rosters and measurement time points. Differences between groups were tested with Wilcoxon signed-rank tests or Fisher's exact tests. Due to the skewed distribution of HCC, logarithmic transformed HCC was modeled with linear mixed regression models accounting for multiple measurement per participant. The effect of COVID-19 pandemic and roster on HCC was modeled using both standard no interaction and joint effects models, each adjusted for age (per 10 years) and body mass index (BMI) [kg/m^2]. Results were presented as exp(β) with 95% confidence intervals (95% CI) and p values. Statistical analyses were undertaken using SAS software, version 9.4 (SAS Institute Inc., Cary, NC, USA). Graphs were prepared with GraphPad Prism, version 9 (GraphPad Software, La Jolla, California, USA).

3. Results

At the time of the first COVID-19 wave, the age of shift workers (mean ± standard deviation) was 47,3 ± 10.3 years. They worked 23.8 ± 11.6 years in shift work and their BMI was 28,6 ± 4,2 kg/m^2. Twenty-seven men (28,4%) were obese (20 men with BMI between 30 and 34.9 kg/m^2, six men with BMI between 35 and 39.9 kg/m^2, and one man with BMI ≥ 40 kg/m^2). Four men (4.2%) suffered from diabetes mellitus or had an abnormal HbA1c value (≥ 6.5%). Every other shift worker had completed an apprenticeship (53%), 22% had a master craftsman's degree, 6% had a technical college or university degree, and 19% did not provide any information on their vocational training. Job stress and work pressure were reported to be increased by 58 men (61%), unchanged by 29 men (30.5%), and decreased by seven men (7.4%) compared to pre-pandemic periods. Men from different rosters did not differ according to BMI ($p_{Wilcoxon}$=0.264), vocational training (p_{Fisher} =0.377) or job stress and work pressure (p_{Fisher}=0.237). However, 12-h shift workers were younger (47.3 *vs.* 50.9 years, $p_{Wilcoxon}$=0.001) and did less years of shift work (22.1 *vs.* 26.7 years, $p_{Wilcoxon}$=0013) than 8-h shift workers.

Median HCC and IQR were 3.48 pg/mg (2.69–4.58) in 2018, 2.73 pg/mg (1.71–4.28) in 2019, and 8.01 pg/mg (4.57–13.19) in 2020, respectively. Fig. 1 depicts the increased HCC during the first wave of the COVID-19 pandemic compared to pre-pandemic times (p < 0.001). This was true for shift workers with and without extended shifts. Median HCC of 12-h shift workers were slightly higher at all times (2018: 3.54 *vs.* 3.43 pg/mg, $p_{Wilcoxon}$=0.349; 2019: 2.78 *vs.* 2.28 pg/mg, $p_{Wilcoxon}$=0.474; 2020: 8.59 *vs.* 6.36 pg/mg, $p_{Wilcoxon}$=0.421), but not statistically significant. Additionally, HCC was similar in men with different perceived work stress and work pressure during the first corona wave (increased stress 7.72 pg/mg (4.57–13.90), unchanged 6.71 pg/mg (4.36–11.43), decreased 8.04 pg/mg (4.85–11.26), p = 0.922) and before (2018: p = 0.439, 2019: p = 0.597).

Regression models revealed a twofold increase of HCC in shift workers during the first COVID-19 wave compared to earlier measurements (exp(β)= 2.38, 95% CI 2.06–2.76, Table 1). By contrast, roster did not show an additional impact on HCC. Furthermore, we did not observe a statistically significant interaction between the impact of the pandemic and roster on HCC (data not shown, p = 0.833). In further regression models, we also found no statistically significant effect of subjectively reported increased job stress and work pressure or psychosomatic distress on HCC (job stress: p = 0.202, general fatigue: p = 0.626, physical fatigue: p = 0.494, emotional exhaustion: p = 0.596, data not

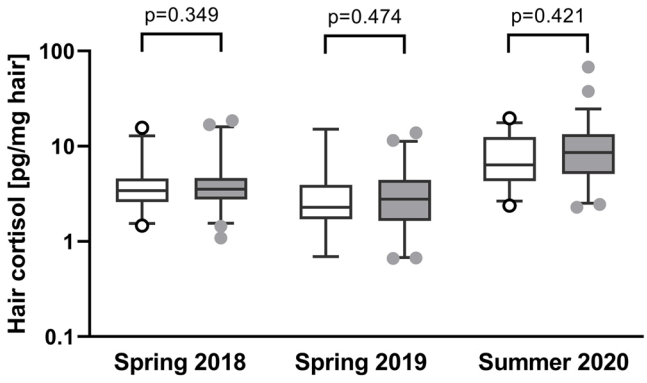

Fig. 1. Distribution of hair cortisol concentrations among shift workers at three measurement time points. Bars show medians with 95% confidence intervals, with white bars representing 8-h shift workers and gray bars representing 12-h shift workers.

Table 1
Factors influencing hair cortisol concentration of shift workers from different rosters assessed with mixed regression models.

			Exp (β)	95% CI[a]		P value
Standard model	Intercept		1.05	0.40	2.76	
	Age (per 10 years)		1.07	0.96	1.20	0.237
	Body mass index [kg/m^2]		1.02	1.00	1.05	0.063
	COVID-19 pandemic	Before pandemic	1			
		During pandemic	2.38	2.06	2.76	< 0.001
	Roster	8-h shifts	1			
		12-h shifts	1.19	0.94	1.50	0.142
Joint effect estimates (95% CI)[b]			8-h shifts		12-h shifts	
	Before pandemic		1		1.18 (0.91–1.52)	
	During pandemic		2.34 (1.87–2.94)		2.84 (2.16–3.72)	

[a] confidence interval.
[b] adjusted by age (per 10 years) and body mass index [kg/m^2].

shown).

4. Discussion

The COVID-19 pandemic constituted a significant influence on HCC in the studied non-healthcare shift workers in Germany. We found statistically significantly higher HCC during the pandemic than before in a group of shift workers with different rosters including night shifts. Differences between rosters were not evident.

The median HCC determined in this study during the first COVID-19 wave in Germany was slightly higher than reported for Slovak nurses at the same time (8.01 pg/mg *vs.* 6.67 pg/mg) although less shift workers reported that overall stress at their workplace had increased during the COVID-19 pandemic (Rajcani et al., 2021b). As reported in a meta-analysis (Stalder et al., 2017) our data also confirm a positive association between HCC and BMI.

We did not find any notably HCC differences between the two shift systems, nor did we observe an interaction between pandemic-related elevated HCC and the putatively more stressful shift system with extended working hours. This is in line with a recent study of petroleum workers in China (Zhang et al., 2020). In this study, higher HCC was found in shift workers than in day workers, but also no differences were found between different rosters with 8-h and 12-h shifts, respectively. Hence, the stress caused by the COVID-19 pandemic might have been so severe that a potential further stressor such as 12-h shifts does not have an additional impact on HCC.

In addition, we did not observe an association between perceived stress and HCC at the beginning of the pandemic. In general, however, the number of studies in this regard is sparse, and the results of both longitudinal and cross-sectional studies are inconsistent (Schaafsma et al., 2021). A follow-up study of Slovenian nurses showed lower HCC during the more severe COVID-19 wave in fall 2021 with more COVID-19 cases and deaths compared to spring 2021, which could be explained by the novelty and uncertainty in the early phase of the pandemic in spring (Rajcani et al., 2021a). Further research is needed regarding to clarify the effects of perceived stress, work-related stressors, and pandemic-related long-term stress on HCC in non-healthcare shift workers, A comparison between shift workers with and without night shifts would also be desirable, as there is evidence that cortisol concentrations are elevated after night shifts (Lim et al., 2020; Zhang et al., 2020).

The following strengths and limitations are associated with the present study. Strengths include that hair samples were collected by trained study nurses. Thus, we assume that the observed differences in HCC are not due to incorrect sampling. Two men had tinted or dyed hair. As this type of hair treatment is negatively related to HCC (Stalder et al., 2017), we repeated the analyses after excluding the corresponding four hair samples (1.6%). Results did not change (data not shown). However, differences in hair washing frequency between participants were not considered, which could also have an impact on HCC (Stalder et al., 2017). In addition, cortisol has a seasonal rhythm that may have contributed to the variability of the data, although this was probably minor because Germany is located in the temperate climate zone (Maimon et al., 2020). Before the pandemic, hair samples were collected in spring (March 20 to April 11, 2018 and April 9 to May 10, 2019) and in the year of the pandemic during late summer (August 20 to September 04, 2020). As HCC can be expected to be seasonally lower in late summer than in spring, the observed pandemic effect on HCC may even have been slightly underestimated. Finally, the limited number of shift workers studied (n = 95) may be the reason why no roster effect was observed.

5. Conclusion

The majority of participating shift workers had elevated HCC attributable to pandemic-related stress compared with the pre-pandemic period. Working 12-h shifts does not appear to represent an additional stressor in the COVID-19 pandemic.

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Contributors

All authors contributed to the study design. AT and FB contributed to the data acquisition. SR concepted the research question. SC performed the data analysis. SC, TBe and SR interpreted the results. SC drafted the manuscript. AT, FB, BB, TBr, TBe, and SR critically reviewed and edited the manuscript. All authors approved the final version of the manuscript for submission.

Declaration of Competing Interest

We declare no conflict of interest.

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