atmosphere

MDPI

Article

Examining Work Stress and Air Pollutants Exposure of Home Healthcare Workers

Thomas Gerding [1], Jun Wang [1,*] and Nicholas Newman [1,2,3]

[1] Department of Environmental and Public Health Sciences, College of Medicine, University of Cincinnati, 160 Panzeca Way, Cincinnati, OH 45220, USA; gerdintr@mail.uc.edu (T.G.); newmannc@mail.uc.edu (N.N.)
[2] Department of Pediatrics, Division of General and Community Pediatrics, College of Medicine, University of Cincinnati, Cincinnati, OH 45267, USA
[3] Environmental Health & Lead Clinic, Cincinnati Children's Hospital Medical Center, Cincinnati, OH 45229, USA
* Correspondence: jun.wang@uc.edu; Tel.: +1-513-558-4301

Abstract: Occupational exposures in on-campus healthcare settings have increasingly been investigated, while the sector of home healthcare typically receives less focus. This study explored work stress exposure and air pollution's effects on home healthcare workers through the collection of multiple salivary cortisol samples per day, the completion of stress diaries, and the use of low-cost personal air monitors. This study was designed to identify the physiological responses to various types of stress, as well as the impact of air pollution on the home healthcare workforce. Due to the sample size and duration, the data showed that neither the stress levels recorded in the diaries ($p = 0.754$), nor the air pollution data (with only VOC and PM_1 having Pearson correlation coefficients of >0.25), exhibited a significant association with the cortisol levels. The air sensor data were inconsistent with previously published indoor air pollutant literature. Forty percent of events reported by participants were identified as high stressor (level 6–10) events. One participant in this study accounted for 18% of these high-stress events. The most common emotional responses to these stressor events included feelings of frustration, irritation, anger, and fury, which together comprised 22.4% of the reactions. Future work should include studies with a larger sample size, a more robust air quality monitor, and a longer study duration to improve the power to detect potential associations. Although previous studies have indicated that home healthcare workers experience workplace stress and exposure to multiple air pollutants, this study did not detect a consistent relationship between these exposures and the physiological stress response.

Keywords: occupational stress; salivary cortisol; air quality; healthcare workers; stress diary

Citation: Gerding, T.; Wang, J.; Newman, N. Examining Work Stress and Air Pollutants Exposure of Home Healthcare Workers. *Atmosphere* **2023**, *14*, 1393. https://doi.org/10.3390/atmos14091393

Academic Editor: Elisabete Carolino

Received: 30 July 2023
Revised: 30 August 2023
Accepted: 31 August 2023
Published: 3 September 2023

1. Introduction

Occupational stress, linked to a variety of adverse health outcomes, is associated with an estimated 120,000 deaths annually in the U.S. [1–7]. The World Health Organization (WHO) reports that 83% of U.S. workers experience work-related stress, with over half admitting it impacts their home life [8]. Furthermore, Nelson et al. (2022) established a link between occupational stress and disturbed sleep patterns [9]. Workplace stress has been shown to impact workers' health, absenteeism rates, and earning potential. A Gallup poll revealed that employees who rated their mental health as "fair" or "poor" missed an average of 11.8 workdays per year, contributing to an annual loss of USD 47.6 billion due to reduced productivity. This equates to roughly USD 340 per day of lost work for a full-time worker [10]. The poll also showed higher rates of mental health issues among women compared to men (23% vs. 15%) experiencing workplace stressors, with the majority unable to confirm the presence of easily accessible mental health support services in their workplaces.

Physiological responses to stress involve the activation of the hypothalamic–pituitary–adrenal (HPA) and sympathetic–adrenal–medullary (SAM) axes [11]. Exposures to stressors can trigger fluctuations in hormonal regulations, potentially indicating stress severity. For instance, frontline police officers were found to have higher diurnal cortisol levels than the general population [12]. Deviation from typical diurnal cortisol patterns may imply exposure to stress, with both chronic highs and lows presenting potential health risks [13]. Chronic lows may signal adrenal insufficiency, while chronic highs could indicate Cushing's disease or overexposure to stress [14,15]. Such high levels may alter immune responses or suppress digestive functions [16].

While stress is a significant health concern, environmental exposures, such as ambient air pollution, also have measurable effects on health. For example, asthmatic children showed decreased physical activity and increased sedentary behaviors when exposed to higher air pollution levels [17]. Higher particulate matter (PM) exposure has been linked to increased levels of stress hormones and other health markers, especially particles less than 2.5 microns ($PM_{2.5}$) [11]. Home healthcare workers (HHCWs) tend to experience stressful and precarious work arrangements, typically for low wages in poor working conditions [18–20]. Access to personal resources and job satisfaction have been correlated with reductions in emotional labor and job stress seen by HHCWs [21]. This working population may also be exposed to noticeable levels of air pollutants due to commuting between patients, and also activities within the home, such as VOCs from disinfectants used; tobacco smoke; poor ventilation; and bioaerosols, like mold and pet dander [20,22,23]. Combined, these airborne exposures could have a synergistic effect on poor cardiovascular outcomes and, when combined with chronic cortisol dysfunction, the likelihood of physical and mental disease increases [24,25].

This study aimed to assess the association between occupational stress and salivary cortisol levels among HHCWs and the influence of personal air pollution exposure on cortisol fluctuations. Previous research has utilized cortisol monitoring, yet its use in occupational stress exposure monitoring remains limited [26]. Recent work by the study team followed a general working population for three consecutive working days to determine a relationship between work stress exposure documented through the use of daily stress diaries and salivary cortisol from the provision of multiple saliva samples throughout each workday [27]. The results showed both a relationship in the diurnal trends of the highest average levels in the morning and tapering off throughout the day as well as statistically significant correlations between exposure to stressors from the diaries and increases in cortisol following these events. The authors of the present study hoped to build off this literature and expand in terms of relating changes in cortisol with exposures to ambient airborne pollutants through the use of personal air quality monitors.

2. Materials and Methods

2.1. Saliva Sampling and Analysis

Twelve participants were recruited for this University of Cincinnati Institutional Review Board-approved study (protocol #2022-0782) through convenience sampling via phone and email directed at local home healthcare agencies. The study team previously positively validated the study methodology using a general working population consisting of fifteen individuals over the course of three days each, with a total of 135 samples [27]. In this work, typical diurnal trends were documented as well as increases in cortisol levels following documented exposures to stress through work stress diaries [27]. For this reason, the recruitment of twelve participants followed for at least a four-day work week would yield 144 total samples. In this study, we wished to examine the feasibility of taking these measurements in a different occupational group. Participants were excluded if they reported a positive smoking status (nicotine and marijuana products), a lack of employment in the home healthcare field, they did not work day shift, or a diagnosis of Cushing's Syndrome.

Each participant received a work stress diary, a sampling log, a study protocol, saliva sampling vials (Salimetrics, State College, PA, USA), and a cryostorage box (Salimetrics, State College, PA, USA) inside a Styrofoam cooler with two moisture-resistant ice packs. During their work week, participants were asked to record any stress-inducing incidents in the diary. The diary entries included the date, day of the week, time, stress intensity (0–10 scale; none to highest), stress duration, situation description, triggering event (if applicable), any emotional or behavioral reactions, and an assessment of whether the day was typical of their job. Besides increasing the specificity of the stress intensity from a 5-point scale to a 10-point scale, the diary remained identical to the previous methodology validation study.

The participants were asked to provide three saliva samples per day: at the beginning of their shift, the start of their lunch break, and the end of their shift. However, as they did not have designated lunch breaks and often ate while traveling to a patient's home, they were asked to provide the second sample approximately halfway through their shift. It was emphasized that they should avoid eating or drinking anything other than water for twenty minutes before each sample collection. The participants were instructed to keep the samples cold in the provided cooler during the workday and to freeze them after work. Sampling logs documented the time and vial used for each sample collection.

This study was conducted from January to March 2023, with the principal investigator collecting materials at the end of the week for enzyme-linked immunosorbent assay (ELISA) analysis in the laboratory. Upon collection at the end of each study week, all samples underwent an enzyme-linked immunosorbent assay (ELISA) analysis. This process was performed identically to a previous salivary cortisol study conducted by the research team [27] and followed the guidelines provided in the ELISA kit (Salivary Cortisol Enzyme Immunoassay Kit, Salimetrics, State College, PA, USA). Following the raw data collection, calculations were performed to determine the cortisol levels in each sample.

2.2. Personal Exposure Monitoring

Along with the cortisol collection, the participants were also given a personal air quality monitor (Flow-2, Plume Labs Inc., Paris, France). This monitor recorded levels of PM_{10}, $PM_{2.5}$, PM_1, NO_2, and volatile organic compounds (VOCs) at one-minute intervals. The participants were instructed to attach this monitor to their backpacks or laptop bags during work hours. The data from each pollutant were extracted and averaged for each hour preceding saliva collection. The daily cortisol values were then averaged to give a single daily value, and a standard deviation was calculated for each of these averages. This standard deviation was divided by the corresponding averaged cortisol level to derive a coefficient of variation, referred to in this study as the "Relative Cortisol Index" or "RCI". The RCI was then compared to the daily averaged pollutant levels using Pearson correlation coefficients.

2.3. Statistical Analysis

This study employed two-way ANOVA, Pearson correlations, and linear regression models to probe the relationships between occupational stressors, air pollution exposure, and cortisol levels. Finally, a qualitative summary details the types of occupational stress experienced by the participants. Statistical analyses were conducted using SigmaPlot 15.0 (Inpixon, Palo Alto, CA, USA) and Excel (Microsoft, Redmond, WA, USA). A two-way ANOVA was performed to assess the correlations between the time of day when a sample was taken and the corresponding cortisol concentration. Pearson correlations were utilized to analyze the relationships between the cortisol levels in a given sample and the self-reported stress levels of the nearest stressor event logged in the diary, as well as the air pollutants. The time of day was categorized into three groups: start of shift, mid-shift, and end of shift. The threshold for statistical significance was set at $p < 0.05$.

Additionally, a qualitative analysis and summary of the stressor events and subjective stress levels were completed. Lastly, the relationship between air pollution exposure and cortisol levels was examined by averaging the three daily cortisol samples, calculating the standard deviation of these averages, and dividing this by the average value to determine the coefficient of variation, or the RCI. A higher RCI indicates a greater dispersion between cortisol levels. The RCI was then compared to the average pollutant level the participant was exposed to during the corresponding times using a Pearson correlation model.

3. Results

3.1. Study Demographics and Differences within Work Shifts

The study demographic information recorded in the enrollment surveys is outlined below in Table 1. All the study participants were female, falling within an age range of "30–39" to "60–69" and represented a broad spectrum of disciplines within the home healthcare field. The participants' experience in home healthcare varied from "less than 5 years" (41.7%) to "26–35 years" (16.7%) and most worked for their present employer "less than 5 years" (66.7%). All the participants worked during the day shift, with schedules of mostly five eight-hour shifts or four ten-hour shifts. One participant had an alternating day shift schedule, consisting of two to three eleven-hour shifts supplemented by one to two additional shifts that ranged from 4 to 7 h in length. This participant also worked every other weekend. The participants' commute times to clients' homes ranged from 5 to 75 min. With regard to exposure to poor air quality (including cigarette smoke, poor ventilation, allergens, or strong disinfectant chemicals), the participant responses varied: 8.3% stated they experienced this rarely, 33.3% sometimes, 50% often, and 8.3% always. Notably, 33.3% of the participants reported having some form of respiratory disease, with two of these individuals attributing their conditions to occupational exposures.

Table 1. Participant Demographic Information.

Demographic	Count
Gender	
Female	12
Age	
30–39	7
40–49	2
50–59	2
60–69	1
Job Category	
Physical Therapist	4
Medical Social Worker	1
RN	2
Occupational Therapist	3
Speech Language Pathologist	1
Developmentally Disabled	1
HHCW Career Length	
Less than 5 years	4
5–15 years	3
16–25 years	2
26–35 years	3

Table 1. *Cont.*

Demographic	Count
Length With Present Employer	
Less than 5 years	8
5–15 years	1
16–25 years	3
Style of Shift	
Five Day Workweek	6
Four Day Workweek	4
Three 12-h shifts	1
Complex Workweek	1
Typical Commute Times to Homes	
0–15 min	3
16–34 min	6
35–45 min	3
Experience Poor Air Quality at Work	
Rarely	1
Sometimes	4
Often	6
Always	1
Diagnosis of Respiratory Disease	
No	8
Yes	4
Respiratory Disease Affected by Job	
No	2
Yes	2

Due to interpersonal differences associated with cortisol, to compare the values, the samples were log-transformed and averaged so each participant had three bars displayed in Figure 1. The first bar was the average of the start-of-shift samples provided, the second bar was the averaged mid-shift samples, and the third bar was the averaged end-of-shift samples. Surprisingly, none of the samples followed typical diurnal patterns, and Figure 1 shows that every participant's cortisol levels appeared to either increase toward the end of their shift or, in the case of participants eleven and twelve, increase during their shift prior to slightly declining before it concluded. Participant one's second daily mean was well below the lower limit of the graph as these samples were determined to be nearly a concentration of 0 μg/dL.

3.2. Correlation between Cortisol Level, Sampling Time, and Self-Reported Stressor

The results from the two-way ANOVA indicated that the differences in the mean salivary cortisol levels were not statistically significant based on the time of day the sample was collected ($p = 0.86$). However, the analysis did show statistically significant differences in the cortisol levels between the participants ($p < 0.001$). While some participants' cortisol levels demonstrated typical diurnal patterns, decreasing throughout the day, many either increased or fell below the detection limit of 1.0 ng/mL. As nearly all the participants did not have a prescribed lunch break, they were instructed to provide saliva samples at the start of their shift, the middle of their shift, and at the end of their shift. While differences between individuals were observed, no significant variation was detected based on the time of day. A further analysis was conducted using a linear regression model that pooled all the participant data points (n = 169) to determine the relationship between the self-reported stressor levels from the participants' diaries and the cortisol levels in the saliva samples collected immediately after the reported stressor event. However, this relationship was not found to be statistically significant ($p = 0.754$). The constant variance test, the Spearman rank correlation, passed, but it only had a power of 0.05 and an R-squared value of less than 0.1, indicating a very weak association.

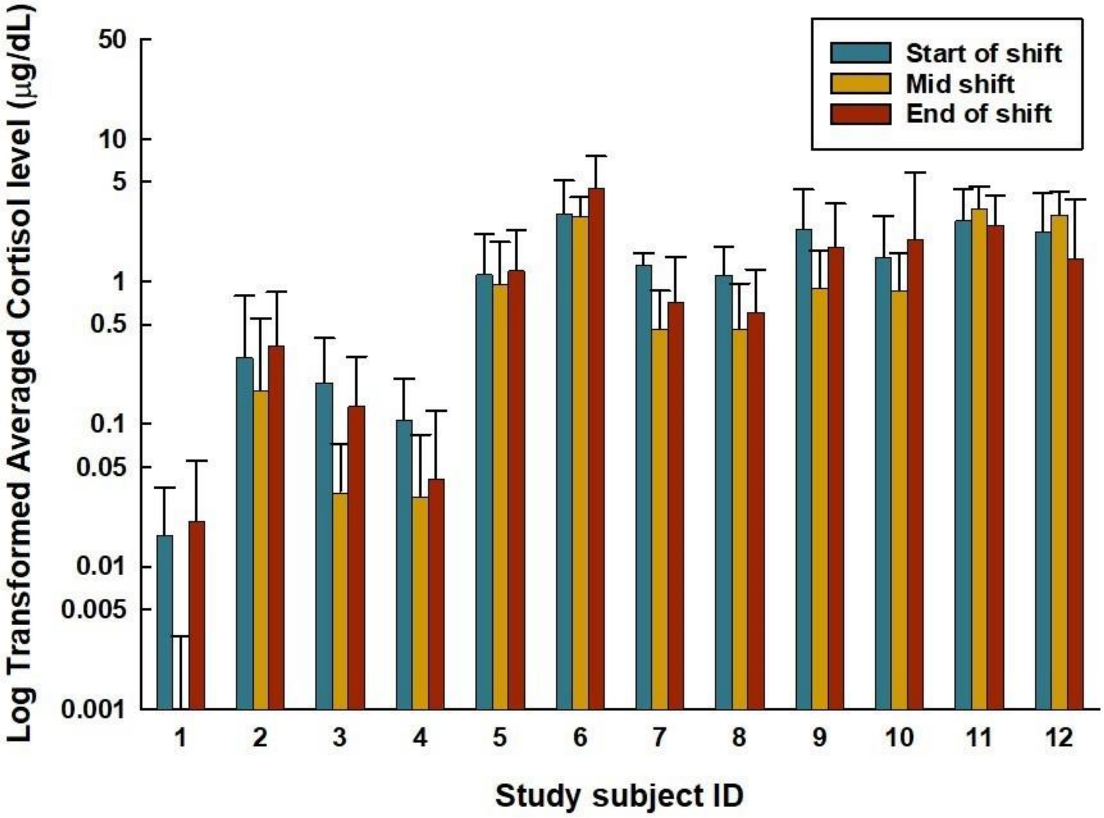

Figure 1. Log-transformed graph of interpersonal differences between sampling times.

3.3. Personal Exposure to Air Pollutants

The Pearson correlation coefficient was calculated for each type of airborne pollutant compared with the Relative Cortisol Index (RCI) values. This comparison did not reveal a statistically significant relationship between the pollutants and the RCI values. The Pearson correlation coefficients ranged from 0.16 (PM_{10}) to 0.31 (VOC), as outlined in Table 2 (see below). At best, only two air pollutants (PM1 and VOC) showed a weak relationship, with a correlation coefficient above 0.25.

Table 2. Pearson Correlation Results.

Relationship	Coefficient
RCI vs. NO_2	0.16
RCI vs. VOC	0.31
RCI vs. PM_{10}	0.16
RCI vs. $PM_{2.5}$	0.22
RCI vs. PM_1	0.27

Table 3 shows the average levels of the air pollutants to which each participant was exposed and is presented graphically for the pooled data in Figure S1 (Supplementary Materials, https://doi.org/10.6084/m9.figshare.23717106.v2, accessed on 9 February 2023).

These averages varied markedly between the participants. For instance, participants 4 and 5 experienced similar exposure levels across all pollutants, as did the pairs of participants 9 and 11, and 10 and 12. However, when comparing the exposure levels across all twelve participants, the range of exposure to each pollutant varied considerably. The smallest variation was a 60% increase (comparing VOC values between participant 9 and 8), while the largest variation was more than a tripling of the exposure levels (comparing NO_2 values between participant 3 and 4).

Table 3. Average Pollutant Levels Exposed to Each Participant.

Participant	NO_2 (ppb)	VOC (ppb)	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	PM_1 (μg/m^3)	Stress Level
1	10.5	205.3	18.3	5.2	3.5	4.2
2	6.0	127.7	11.3	3.1	1.4	5.0
3	3.4	144.7	12.5	3.8	2.1	1.8
4	11.7	168.8	17.7	5.4	3.6	1.5
5	11.7	194.5	19.4	5.5	3.7	5.9
6	7.2	124.3	11.2	3.1	1.4	4.8
7	5.8	124.7	13.1	3.5	1.5	2.9
8	10.4	208.7	18.5	8.2	3.2	4.7
9	6.9	124.0	11.7	3.2	1.4	7.2
10	4.3	160.3	12.4	3.7	1.9	1.4
11	4.9	142.4	14.7	3.4	2.4	1.3
12	4.5	155.3	12.9	4.9	1.5	4.5
Average	7.3 ± 3.0	156.7 ± 31.6	14.5 ± 3.1	4.4 ± 1.5	2.3 ± 0.9	3.8 ± 1.9

3.4. Stress Diary Record

Despite the lack of a statistically significant relationship between the cortisol levels and reported stress levels, the diary entries revealed a broad spectrum of stressors and emotional reactions. While the home healthcare professionals frequently acknowledged the stresses associated with their occupations, the number of stressor events reported in their diaries varied widely. For instance, one participant recorded multiple daily entries, many linked to their stressors outside of work and concerns about their patients. This participant recorded one level 4 stressor, two level 5 stressors, four level 6 stressors, five level 7s, and nine level 9s. In contrast, another participant reported only one level 3 stressor and one level 4 stressor across two days.

Variability in the diary entries was common among the participants. The first physical therapist recorded entries associated with commuting stress, while one of the other participant's stressors revolved around social issues arising from working with a developmentally disabled client. The first occupational therapist reported non-work-related stressors, like managing her children's schedules and navigating inclement weather. Similarly, the second occupational therapist reported stressors on only three of her four workdays, while the medical social worker listed 14 stressors, primarily work related, across a four-day work week.

One of the two registered nurses and one of the four physical therapists experienced 10 stressors over a five-day work week, with a mix of personal and work-related issues. Further disparities were noted between the second registered nurse and two of the four physical therapists. The third physical therapist experienced 16 stressor events, primarily work related, while one of the registered nurses reported mostly positive or neutral events and 5 minor stressors. The fourth physical therapist reported 13 stressors, mainly work related and tied to scheduling or patient issues.

The Supplementary Materials, Table S1, summarizes the high-level occupational stressors (ranked six or above) experienced by the participants (https://doi.org/10.6084/m9.figshare.23717106.v2, accessed on 9 February 2023). The most frequently reported stressors were related to personal issues, commuting, or patient concerns. Among the stressors ranked six or above (n = 51), 22 were reported by a speech-language pathologist, 16 by the physical therapists, 7 by the medical social worker, 4 by the specialist for the developmentally disabled, and 2 by one of the registered nurses. Table 4 shows the frequency of emotional descriptors used in the diary entries. Frustration/aggravation/anger were the most commonly reported emotions, accounting for 22.4% of the total emotions expressed. This was followed by feelings of overwhelmed/inadequacy/exhaustion (15.7%), irritation/annoyance (9.7%), and nervousness/anxiety/uncomfortableness/drained (7.5%). The least reported emotions included feelings of shame/being unheard (two occurrences) and distraction (one occurrence). These emotions were typically associated with common stressors, such as personal issues, commuting, and patient care.

Table 4. Emotional Behavioral Reaction Frequencies in the Work Stress Diaries.

Emotional Behavioral Reaction	Count	Percent
Frustration/Aggravated/Mad/Anger	30	22.4%
Overwhelmed/Inadequacy/Depleted/Fatigue/Tired/Exhausted/Insufficient	21	15.7%
Irritated/Annoyed	13	9.7%
Nervous/Anxious/Uncomfortable/Drained	10	7.5%
Stress	9	6.7%
Worry	9	6.7%
Fear/Afraid/Scared/Concerned/Cautious	8	5.9%
Rushed	7	5.2%
Happy/Good/Hopeful/At Ease/Excited	6	4.5%
"Increased Heart Rate"	6	4.5%
Calm/Satisfied/Accomplishment/Relief	5	3.7%
Sad/Disappointed/Unvalued/Grief	5	3.7%
Ashamed/Unheard	2	1.5%
Tension	2	1.5%
Distracted	1	0.8%
Total	134	100%

4. Discussion

4.1. Correlation between Cortisol Level, Sampling Time, and Self-Reported Stressor

The results from this study suggest that there was no significant relationship between the cortisol levels and the sampling time. Despite expecting a diurnal trend, no consistent decrease in the cortisol levels was observed throughout the day. The participants were instructed to collect the samples in the middle of their shift due to the lack of defined lunch breaks, which may have contributed to these findings. Further, there was no statistically significant relationship found between the cortisol levels and stress levels documented in the stress diaries for any of the twelve participants ($p = 0.754$, R-squared = 0.000587). We could not establish that there was a statistical relationship between the subjective stress levels reported during a stressor event and the physiological response, as indicated by the release of cortisol. This might be due to several factors, such as the difficulty in quantifying stress levels, the lack of statistical power due to the small sample size, or potential issues with the saliva sample collection and preservation methods, in that HHCWs have rigorous schedules of commuting from patient to patient, and therefore saliva collection adhered to their schedule. Additionally, the practice of storing saliva samples in a Styrofoam cooler with an ice pack was less than ideal compared to using a freezer.

Interestingly, one participant had a detailed stress diary with eleven stressors recorded over five days; her average cortisol levels were lower compared to the others. This discrepancy might be due to the duration of the study and the type of events that the participants experienced, both of which might have contributed to the poor model variance. To improve this, the study could be extended or the reason why some participants reported fewer and less intense stressor events could be further investigated. Given the known high levels of stress in healthcare professions, the number and intensity of the stress events reported was surprisingly low. Including more participants in the study could help determine if the observed pattern was representative.

Five of the healthcare workers had higher average cortisol levels at the end of their shifts compared to the beginning. Two others had the highest cortisol levels in the middle of their shifts, which might indicate exposure to stressors, even if they were not related to their work or documented in their stress diaries. Regardless, none of the participants showed the typical diurnal pattern of cortisol levels being highest at the start of the shift and declining as the shift progresses. This suggests that the occupational stresses experienced by home healthcare workers may not align with typical cortisol patterns and deserves further investigation. Due to the small sample size, we were not able to stratify the participants by sources of chronic stress in their lives.

4.2. Personal Exposure to Air Pollutants

Compared to the WHO's guidance on recommended air quality levels, the participants' average air pollutant data were all below these thresholds [28]. Of the listed pollutants, the WHO recommends average maximum exposure levels of 10 μg/m^3 of $PM_{2.5}$, 20 μg/m^3 of PM_{10}, and 40 μg/m^3 of NO_2, annually. Our data also fall within the ranges of various air pollutants measured in many other works of literature on indoor air exposure, with levels ranging from 1.7 to 428.6 $PM_{2.5}$, 11.0 to 1275 PM_{10}, and 3.4 to 1210 for NO_2 [29]. However, when comparing these levels of indoor air quality with various areas in a hospital, the VOC (156.7 $\pm$ 31.6 ppb) concentrations were comparable to what was monitored at on-campus locations, including a reception area, an orthopediatric area, and an otorhinolaryngology area (VOCs = 0.110–0.312 ppm) [30]. On the other hand, the data collected by the home healthcare population had lower levels of $PM_{2.5}$ exposure (4.4 $\pm$ 1.5 μg/m^3) than the on-campus settings (20.0–49.6 μg/m^3) [30].

The correlations observed in this study between the Relative Cortisol Index (RCI) and the levels of volatile organic compounds (VOC) and PM1 were weak. Several factors could contribute to these results. First, there were gaps in the data collected by the low-cost air pollution sensors. The sensors were designed to record data every minute; however, there were multiple gaps in the data that ranged from ten minutes to a few hours. These gaps would have affected the average pollutant values, thereby impacting the observed correlations. Imputation was not conducted because, in some cases, there were too many data missing.

Second, the frequency of the saliva sample collection might have affected the findings. In this study, the saliva samples were collected only three times per day. Increasing the frequency of saliva collection could provide higher resolution in the measurement of cortisol levels and potentially enhance the accuracy and specificity of the summary statistics used to calculate the RCI values. Lastly, in our study, we did not find a statistically significant association between the air pollution levels and the cortisol levels. Future studies should address our aforementioned concerns regarding air pollution sensor data reliability and the frequency of biological sample collection. The relationship between air pollution and cortisol levels remains a relevant topic that could be explored further in future research.

4.3. Stress Diary Record

This study sheds light on the intensity and frequency of stressful events experienced by HHCWs and the associated emotional responses. The most intense stressors, those rated as six or higher on a nine-point scale, accounted for more than 40% of the total 122 events documented. This indicates a significant level of high-intensity stressors within the HHCW population. Moreover, the type of worker experiencing these high-intensity stressors varied; occupational therapists reported none, while a speech-language pathologist reported multiple, including nine level 8 stressors and four level 9 stressors.

The emotional responses associated with these stressors provide additional insights. The most frequently reported emotions were frustration, aggravation, and anger, accounting for 22.4% of all responses. Emotions associated with burnout such as overwhelmed, depletion, fatigue, exhaustion, inadequacy, and insufficiency accounted for 15.7%. This suggests a high level of emotional strain among HHCWs. The source of these stressors also blurs the line between personal and professional life, as seen in previous studies by our group [31,32]. This suggests that the stress experienced by HHCWs is not only related to job tasks but also to the unique challenges of managing a work–life balance for home healthcare workers. This observation warrants further investigation, as it could have implications for stress management strategies in this field.

4.4. Limitations

One limitation of this study arises from its recruitment process, which employed a convenience sampling methodology within a large, midwestern metropolitan area. This study population was finalized upon reaching the target number of participants. With many participants coming from specific healthcare fields such as occupational or physical therapy, this study may not accurately represent the variety of occupational stressors that the broader home healthcare workforce faces, particularly those in different geographic areas or those serving distinct patient demographics. This may have also led to the small sample size related to not many stressors documented by some of the participants.

The data collected from the stress diaries are subjective as they represent individual perceptions of stress. This subjectivity could mean that an event classified as a level 5 stressor by one individual might only be considered a level 3 stressor by another. Additionally, some stressful events might not have been recorded in the diaries due to their personal nature or if the participant simply forgot to document them when time allowed. Some participants logged numerous stressors daily, whereas others recorded a few over the entire work week which made determining relationships between stress exposure and increases in cortisol difficult.

The final limitation pertains to the quality of the air monitors used in this study. A higher-grade air monitor could provide more reliable data on the exposed pollutants. However, this would incur a higher cost and these higher-precision sensors tend to have a bulkier design than the model utilized in the current study. A bulkier design may put additional burden on participants.

5. Conclusions

This study explores the various stressors encountered by a group of home healthcare workers during typical work weeks, with representation from healthcare sectors, such as developmental disability care, occupational therapy, physical therapy, speech-language pathology, medical social work, and registered nursing. Unexpectedly, the levels of salivary cortisol did not conform to the expected diurnal patterns. Neither did they correlate with exposure to occupational stressor events, the primary hypothesis of this study. Further, the air pollutant exposures poorly compared with other air quality studies.

Forty percent of the stressor events documented were classified as major stressors, rated level 6 or higher out of 10. There were notable variations in the reported stressors by occupation, with no reports of stressor events coming from occupational therapists, whereas multiple reports came from speech-language pathology. In the future, a more robust study would include a larger sample size with a longer duration to provide adequate statistical power to detect these associations. Additionally, the inclusion of more robust air quality monitors would most likely provide better quality data associated with the participants' exposures, though a larger research budget would be necessitated. Providing training to participants to "level set" their perceptions of stress and intentionally recruiting a representative sample of home healthcare occupations would improve the external validity. Studies, including ours, demonstrate relatively high levels of stress in home healthcare workers; future work could also examine interventions that could help to reduce these stressors.

Supplementary Materials: The following supporting information can be downloaded at: https://doi.org/10.6084/m9.figshare.23717106.v2 (accessed on 9 February 23), Table S1: Summary of the intense occupational stressors experienced by participants (intensity of stress = 6–10) and Figure S1: Average air pollutant exposures among participants.

Author Contributions: T.G., N.N. and J.W. conceived the presented idea and developed the study protocol. T.G. and J.W. both performed the computations while J.W. verified the analytical methods. J.W. encouraged T.G. to investigate physiological responses to occupational stress exposure, as well as effects of air pollution upon cortisol, and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: Thomas Gerding is a doctoral candidate sponsored by the National Institute for Occupational Safety and Health (NIOSH) University of Cincinnati Education and Research Center (#T42/OH008432), and this study was made possible with support from the Targeted Research Training (TRT) program. Jun Wang also acknowledges NIOSH for providing support on occupational-related stress research through the intergovernmental personnel act (#21IPA2014120). Note: The content is solely the responsibility of the authors and does not necessarily represent the official position of NIOSH nor the Centers for Disease Control and Prevention.

Institutional Review Board Statement: This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of the University of Cincinnati (protocol #2022-0782, 01/03/2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data that support the findings of this study are openly available in Figshare at https://figshare.com/articles/dataset/HHCW_Master_Data_Sheet/22806917 (accessed on 9 February 23).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Aro, S. Occupational stress, health-related behavior, and blood pressure: A 5-year follow-up. *Prev. Med.* **1984**, *13*, 333–348. [CrossRef] [PubMed]
2. Malamardi, S.N.; Kamath, R.; Tiwari, R.; Nair, B.V.; Chandrasekaran, V.; Phadnis, S. Occupational stress and health-related quality of life among public sector bank employees: A cross-sectional study in Mysore, Karnataka, India. *Indian J. Occup. Environ. Med.* **2015**, *19*, 134–137.
3. Kang, S.; Jo, H.S.; Boo, Y.J.; Lee, J.S.; Kim, C.S. Occupational stress and related factors among surgical residents in Korea. *Ann. Surg. Treat. Res.* **2015**, *89*, 268–274. [CrossRef] [PubMed]
4. Sun, W.; Wu, H.; Wang, L. Occupational stress and its related factors among university teachers in China. *J. Occup. Health* **2011**, *53*, 280–286. [CrossRef] [PubMed]
5. Soori, H.; Rahimi, M.; Mohseni, H. Occupational stress and work-related unintentional injuries among Iranian car manufacturing workers. *East. Mediterr. Health J.* **2008**, *14*, 697–703.
6. Wieclaw, J.; Agerbo, E.; Mortensen, P.B.; Bonde, J.P. Occupational risk of affective and stress-related disorders in the Danish workforce. *Scand. J. Work. Environ. Health* **2005**, *31*, 343–351. [CrossRef]
7. Goh, J.; Pfeffer, J.; Zenios, S.A. The relationship between workplace stressors and mortality and health costs in the United States. *Manag. Sci.* **2015**, *62*, 608–628. [CrossRef]
8. World Health Organization. Mental Health at Work. Available online: https://www.who.int/teams/mental-health-and-substance-use/promotion-prevention/mental-health-in-the-workplace (accessed on 5 March 2023).
9. Nelson, M.E.; Lee, S.; Allen, T.D.; Buxton, O.M.; Almeida, D.M.; Andel, R. Goldilocks at work: Just the right amount of job demands may be needed for your sleep health. *Sleep Health* **2022**, *9*, 40–48. [CrossRef]
10. The Economic Cost of Poor Employee Mental Health. Available online: https://www.gallup.com/workplace/404174/economic-cost-poor-employee-mental-health.aspx (accessed on 22 April 2023).
11. Li, H.; Cai, J.; Chen, R.; Zhao, Z.; Ying, Z.; Wang, L.; Chen, J.; Hao, K.; Kinney, P.L.; Chen, H.; et al. Particulate Matter Exposure and Stress Hormone Levels. *Circulation* **2017**, *136*, 618–627. [CrossRef]
12. Planche, K.; Chan, J.F.; Di Nota, P.M.; Beston, B.; Boychuk, E.; Collins, P.I.; Andersen, J.P. Diurnal Cortisol Variation According to High-Risk Occupational Specialty Within Police. *JOEM* **2019**, *61*, e260–e265. [CrossRef]

13. Hellhammer, D.H.; Wust, S.; Kudielka, B.M. Salivary cortisol as a biomarker in stress research. *Psychoneuroendocrinology* **2009**, *34*, 163–171. [CrossRef]
14. Mayo Clinic. Addison's Disease. Available online: https://www.mayoclinic.org/diseases-conditions/addisons-disease/symptoms-causes/syc-20350293 (accessed on 17 April 2023).
15. Oregon Health & Science University. Cushing Disease/Cushing Syndrome. Available online: https://www.ohsu.edu/brain-institute/cushing-disease-cushing-syndrome (accessed on 17 April 2023).
16. Bauer, M.E.; Jeckel, C.M.M.; Luz, C. The Role of Stress Factors during Aging of the Immune System. *Ann. N. Y. Acad. Sci.* **2009**, *1153*, 139–152. [CrossRef]
17. Aguilera, J.; Jeon, S.; Raysoni, A.U.; Li, W.; Whigham, L.D. Decreased Moderate to Vigorous Physical Activity Levels in Children with Asthma Are Associated with Increased Traffic-Related Air Pollutants. *J. Environ. Health* **2023**, *85*, 16–17.
18. Zoeckler, J.M. Occupational Stress Among Home Healthcare Workers: Integrating Worker and Agency-Level Factors. *New Solut. J. Environ. Occup. Health Policy* **2018**, *27*, 524–542. [CrossRef] [PubMed]
19. Markkanen, P.; Quinn, M.; Galligan, C.; Sama, S.; Brouillette, N.; Okyere, D. Characterizing the nature of home care work and occupational hazards: A developmental intervention study. *Am. J. Ind. Med.* **2014**, *57*, 445–457. [CrossRef] [PubMed]
20. Quinn, M.M.; Markkanen, P.K.; Galligan, C.J.; Sama, S.R.; Kriebel, D.; Gore, R.J.; Brouillette, N.M.; Okyere, D.; Sun, C.; Punnett, L.; et al. Occupational health of home care aides: Results of the safe home care survey. *Occup Env. Med.* **2016**, *73*, 237–245. [CrossRef]
21. Park, M.M.; Han, S.J. Relations of job satisfaction with emotional labor, job stress, and personal resources in home healthcare nurses. *J. Korean Acad. Community Health Nurs.* **2013**, *24*, 51–61. [CrossRef]
22. Benjamin, M. Cleaning Product Chemical Exposures Measured in a Simulated Home Healthcare Work Environment. Master's Thesis, University of Cincinnati, Cincinnati, OH, USA, December 2019.
23. Hittle, B.; Agbonifo, N.; Suarez, R.; Davis, K.G.; Ballard, T. Complexity of occupational exposures for home health-care workers: Nurses vs. *home health aides. J. Nurs. Manag.* **2016**, *24*, 1071–1079.
24. Mallach, G.; Shutt, R.; Thomson, E.M.; Valcin, F.; Kulka, R.; Weichenthal, S. Randomized cross-over study of in-vehicle cabin air filtration, air pollution exposure, and acute changes to heart rate variability, saliva cortisol, and cognitive function. *Environ. Sci. Technol.* **2023**, *57*, 3238–3247. [CrossRef]
25. Hajat, A.; Hazlehurst, M.F.; Golden, S.H.; Merkin, S.S.; Seeman, T.; Szpiro, A.A.; Kaufman, J.D.; Roux, A.D. The cross-sectional and longitudinal association between air pollution and salivary cortisol: Evidence from the multi-ethnic study of Atherosclerosis. *Environ. Int.* **2019**, *131*, 105062. [CrossRef]
26. Sanger, J.; Bechtold, L.; Schoofs, D.; Blaszkewicz, M.; Wascher, E. The influence of acute stress on attention mechanisms and its electrophysiological correlates. *Front. Behav. Neurosci.* **2014**, *8*, 353. [CrossRef]
27. Gerding, T.; Wang, J. Stressed at Work: Investigating the Relationship between Occupational Stress and Salivary Cortisol Fluctuations. *Int. J. Environ. Res. Public Health* **2022**, *19*, 12311. [CrossRef] [PubMed]
28. World Health Organization (WHO). Air Quality Guidelines. *Global Update 2021.* Available online: https://apps.who.int/iris/handle/10665/345329 (accessed on 28 August 2023).
29. Vardoulakis, S.; Giagloglou, E.; Steinle, S.; Davis, A.; Sleeuwenhoek, A.; Galea, K.S.; Dixon, K.; Crawford, J.O. Indoor Exposure to Selected Air Pollutants in the Home Environment: A Systematic Review. *Int. J. Environ. Res. Public Health* **2020**, *17*, 8972. [CrossRef] [PubMed]
30. Lee, H.J.; Lee, K.H.; Kim, D.K. Evaluation and Comparison of the Indoor Air Quality in Different Areas of the Hospital. *Medicine* **2020**, *99*, e23942. [CrossRef]
31. Gerding, T.; Syck, M.; Daniel, D.; Naylor, J.; Kotowski, S.E.; Gillespie, G.L.; Freeman, A.M.; Huston, T.R.; Davis, K.G. An Assessment of Ergonomic Issues in the Home Offices of University Employees Sent Home Due to the COVID-19 Pandemic. *Work* **2021**, *68*, 981–992. [CrossRef] [PubMed]
32. Gerding, T.; Davis, K.G.; Wang, J. An Investigation into Occupational Related Stress of At-Risk Workers During COVID-19. *Ann. Work. Expo. Health* **2022**, *67*, 118–128. [CrossRef]