THE RELATIONSHIP BETWEEN OCCUPATIONAL NOISE EXPOSURE AND STRESS IN LONG-TERM CARE FACILITY WORKERS

by

Pey-Yuan (Emily) Hsiung

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Abstract

The sound characteristics of many healthcare settings have been documented to be very poor. There has been extensive research about the adverse effects of noise, especially on patients in acute care settings, but little research has examined long-term residential care workers' exposure to noise. Excessive noise exposure has been associated with burnout in critical care nurses as well as with health problems, such as adverse cardiovascular effects. However, there is a lack of research evaluating the effects of occupational noise exposure on healthcare providers' health status and stress levels. Hence, a non-experimental, correlational study was undertaken to answer the research question, "What is the relationship between occupational noise and healthcare workers' stress in long-term care facilities?" A stratified sample of 6 long-term care facilities was obtained within Vancouver Coastal Health and convenience samples of healthcare workers were recruited from each facility. Repeated exposure (noise) and outcome (stress) assessments over four sampling days were conducted utilizing noise dosimeters and biophysiological and self-reported measures, including salivary cortisol, heart rate variability, and Cohen's Perceived Stress Scale. Participants were exposed to mean A-weighted average sound pressure levels ranging between 74.4 to 74.8 dB(A) and C-weighted peaking sound pressure levels as high as 143.5 dB(C). Bivariate correlation analyses revealed statistically significant correlations between the A-weighted average sound pressure levels and heart rate variability indices (i.e., standard deviation of the NN intervals and low frequency to high frequency ratios), and the type of shift worked (i.e., evening/night versus day shift). Healthcare workers who worked day shifts were exposed to higher sound levels, and those who were

exposed to higher noise levels experienced more stress. Linear regression analyses were conducted to explore the interrelationships among the statistically significant correlations. A-weighted average sound pressure levels made a statistically significant contribution to two heart rate variability indices: standard deviation of NN intervals and low frequency to high frequency ratios throughout the four sampling days, when the shift worked was controlled.

Preface

The research presented here was derived from a larger research study conducted at the University of British Columbia, School of Population and Public Health by Dr. George Astrakianakis (principal investigator) and Dr. Murray Hodgson, Dr. Pamela Ratner, and Mrs. Maureen Haddock (co-investigators). The aims of the larger study, funded by WorkSafeBC, were to characterize the acoustical environments of several long-term care facilities and to examine the effects of background noise levels on the staff. As a research assistant, I assisted in the development of the sampling manual, the formatting of the sampling and data collection tools, recruitment of many of the study participants, ongoing communication with the study participants, data collection and fieldwork, and data management. The analyses presented here were based on a subset of the data collected for the larger study.

Ethics approval was obtained from the University of British Columbia, Clinical Research Ethics Board (UBC CREB: H10-00591).

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Dedication

This work is dedicated to my beloved family, my best friend Jennifer Chang, and my school comrades Jennifer Switzer and Catherine McAskill. Thank you for the motivation, unconditional love, and emotional support throughout my schooling and countless nights of writing. I love you all!

1 Introduction

Healthcare professionals employed in various clinical settings are exposed to different types of biological, chemical, and physical hazards, such as body fluids, blood products, pharmaceuticals, sterilizing agents, and radiation. Noise, a potentially hazardous physical energy, and its effect on the health of patients and healthcare professionals, has been well studied in acute and critical healthcare settings. However, little empirical research has examined the relationship between occupational noise exposure and healthcare workers' stress, particularly in long-term care facilities. Long-term care facilities often differ from other healthcare settings in terms of their jurisdictional building code requirements and their floor plans, which may affect their acoustical characteristics. Many of these facilities are aged and consequently may not have up-to-date and preferable acoustical building materials, which are designed to minimize noise. Hence, this thesis describes a study that was designed to answer the question, "What is the relationship between occupational noise exposure and long-term care workers' stress?" and to test the hypothesis that long-term care workers who work in noisy environments experience higher levels of stress.

1.1 Purpose and Objective of the Study

The purpose of this study was to establish whether there is a relationship between noise exposure (the explanatory variable) and long-term care healthcare workers' stress (the outcome variable). The understanding of such a relationship could assist residential facility managers and senior policy makers in developing policies and strategies to promote noise reduction or

prevention, refine building codes for future facility development, and bring awareness of the potential effects of noise on health outcomes and stress levels on healthcare workers.

Objective

To establish whether there is a relationship between occupational noise exposure, in the long-term care environment, and healthcare workers' stress responses.

1.2 Definition of Terms

Noise

Noise is traditionally defined as unwanted sounds, which may range from conversations, music playing, to an airplane taking off. Noise is essentially sound pressure waves that travel through the human ear and auditory canal. Subsequently, these sound waves are converted into neural impulses, which then travel through the central auditory nuclei terminating in the auditory area of the temporal lobe for further interpretation (Christensen, 2002). Sound or noise levels are usually measured in decibels (dB), which is a unit established on a logarithmic scale. That is, for every three dB increase or decrease, there is a doubling or halving effect in sound intensity (Cherrie, Howie, & Semple, 2010). As a wide range of frequencies exist, instruments used to measure noise levels usually "weight" the signals to approximate to the response of the human ear. Among the different weightings, the noise level in A-weighting is often used because it is the most comparable to the sound frequencies that the human ear is accustomed to hearing (Cherrie et al., 2010).

Occupational noise is defined as the unwanted sounds that employees are exposed to at their workplaces. Leading international, national, and state/provincial organizations, such as the World Health Organization (WHO), the US Occupational Safety and Health Administration, and WorkSafeBC have established acceptable noise levels for various work settings, including healthcare environments such as hospitals and long-term care facilities. The origins of noise within long-term care facilities may include residents' call bells; telephones; transportation of supply carts; ventilation systems; cleaning services activities; and residents', staff members', or visitors' voices, in addition to the sources from the external environment, such as roadway traffic. In addition to identifying the sources of noise and measuring the noise levels, the type of noise, whether it is intermittent or continuous, and the duration of exposure are also important factors to consider when evaluating its adverse effects.

Unlike other work environments, noise levels in healthcare settings may not be at the level or duration where they will lead to permanent hearing damage. Nevertheless, research has shown that noise can be the most annoying when it is repetitive – independent of its intensity or duration (Sanchez, Pardo, Sanchez, Gelado, & Garcia, 2008). In fact, noise is often described as an "ambient" environmental stressor because it varies in intensity and duration; hence, noise can often be ignored or tolerated for long periods of time before it starts causing bodily harm (Holmberg & Coon, 1999). Researchers have suggested that stimulation of the autonomic nervous system, namely a stress response, may occur with noise levels that are as low as 65 dB (Buelow, 2001).

Stress

Stress may be the result of exposure to various personal and environmental factors. Generally speaking, stress can be categorized into two types – physiological and psychological. When exposed to various stress-causing stimuli, the human body produces numerous hormonal and physiological adjustments. These physiological indicators of stress may include stimulation of the sympathetic nervous system, which can manifest in several symptoms, including increased mental alertness; decreased blood flow to the skin, kidneys, and digestive organs; and increases in blood pressure, heart rate, and respiration. Such physiological stress responses are also mediated by the sympathetic nervous system and the hypothalamic-pituitary-adrenocortical axis (Day, Paul, Williams, Smeltzer, & Bare, 2007). In 1936, a well-known scientist, Hans Selye (1984), pointed out that the human body responds to and copes with stress in stages (Day et al., 2007). In the first stage, the alarm phase, the body starts to respond to a stressful event by producing adrenaline, which later initiates the release of cortisol. In the resistance phase, the second stage of the stress response, the body begins to adapt to the stressful stimuli; however, the body cannot cope with persistent stress indefinitely before its resources are depleted. In this particular phase, the body continues to produce various hormonal side effects and abnormal cardiovascular symptoms. If the stressful event continues, the body eventually depletes its resources and disruption of homeostatic regulation results. This is the third and final phase of Selye's stress model, the exhaustion stage. In this final stage, there may not only be permanent damage to the physical body, but also to the psychological wellness of the affected person.

Psychological stress is perhaps more difficult to define when compared with the established physiological stress responses. As discussed previously, cumulative physiological

stress from various environmental stressors may have detrimental effects on one's psychological health. Psychological stress is essentially the subjective reaction of an individual in response to stressors of various natures. Psychological symptoms of stress may include general irritability, annoyance, distraction, anxiety, as well as impaired concentration (Day et al., 2007). Additionally, psychological stress is affected by the complex interactions among the stressors themselves, personal control, and health outcomes (Topf, 1994; Veitch & Arkkelin, 1995). Topf (2000) developed an environmental stress model wherein she described noise-induced stress as a subjective experience that is related to the degree of control over, and awareness of, the environmental hazard. Noise, because of its ambient and unpredictable nature, is therefore considered an environmental stressor that may be associated with psychological stress. What follows is a literature review of what is known about the relationship between noise and the stress responses and health of healthcare workers.

2 Literature Review

Healthcare professionals across the various clinical settings may be exposed to many occupational hazards, including body fluids, blood products, needles and scalpels, noise, and radiation. Among these occupational hazards, noise and its effects on healthcare professionals' stress responses and health are possibly the least well understood; yet, noise continues to be recognized as a very significant occupational hazard (World Health Organization, 1997). The Canadian Centre for Occupational Health and Safety (CCHOS) recommends that for an eight-hour working period, an individual is allowed to be exposed to noise levels of no more than 90 decibels in A-weighting (i.e., dB(A)) (CCHOS, 2011).[1] WorkSafeBC (2005) also specifies that a worker should not be exposed to a noise level of 85 dB(A),[2] while the World Health Organization (1999) states that sound levels in hospitals should not exceed 40 dB during the night or 30 dB during the day and evening.[3]

The negative effects of noise exposure have been well established by researchers, and include: interference with communication (Blomkvist, Eriksen, Theorell, Ulrich, & Rasmanis, 2005; Goines & Hagler, 2007), hearing impairment (Goines & Hagler, 2007), and adverse cardiovascular effects (Goines & Hagler, 2007; Lusk, Gillespie, Hagerty, & Ziemba, 2004).

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[1] People's sensitivity to sound corresponds with the frequency or pitch of the sound. Some frequencies are better heard than are others. Two sounds of the same sound pressure and of different frequency may appear to differ in terms of their loudness because people hear high frequency sounds better than low frequency sounds. Noise assessments are typically adjusted to correspond with this particular characteristic of human hearing. An A-weighting filter built into a sound monitoring device de-emphasizes low frequencies. Decibels measured using this filter are A-weighted and are called dB(A) (Canadian Centre for Occupational Health and Safety, 2006; Cherrie, Howie, & Semple, 2010).

[2] Over the course of 40 hours of week, hearing damage is possible at 85 dB(A).

[3] Note that the World Health Organization limits are not on the A scale.

Noise has also been found to be significantly associated with medication errors, which could potentially result in compromised patient safety (Mahmood, Chaudhury, & Valente, 2011). There is emerging consensus that there is excessive noise in a variety of healthcare settings, although mostly in hospital environments. For example, sound levels have been found to exceed 40 dB(A) in critical care (Ryherd, Ljungkvist, & Waye, 2008), medical-surgical units (Christensen, 2005; McLaren & Maxwell-Armstrong, 2008), emergency departments (Short, Short, Holdgate, Ahern, & Morris, 2010), operating rooms (Hodge & Thompson, 1990; Tsiou, Efthymiatos, & Katostaras, 2008), long-term care facilities (McClaugherty, Valibhai, & Womack, 2000), and paediatric units (Chang, Lin, & Lin, 2001; DePaul & Chambers, 1995). At times, peak levels between 90 and 127 dB(A) have been recorded (Pope, 2010; Tijunelis, Fitzsullivan, & Henderson, 2005).

Despite the established presence of excessive noise in various healthcare settings, few researchers have explored the relationship between noise exposure and the psychological and physiological health status of healthcare workers, including their stress responses, particularly in long-term care facilities. It is imperative to explore the effects of noise on healthcare workers' stress because there is mounting evidence of a link between chronic stress and ill health, including cardiovascular disease, mood disorders, and substance misuse or abuse (McEwen & Gianaros, 2010). A comprehensive literature review was carried out to examine the published research related to the relationship between occupational noise exposure and healthcare workers' stress. The goal of this review was to examine thoroughly the relevant methodologies used by other researchers, to critically appraise the quality of their studies, and to identify gaps in knowledge and needs for future research.

2.1 Search Strategy

A comprehensive literature search was conducted in two databases, CINAHL and Medline, utilizing various combinations of key words that were relevant to the proposed research question. Articles that were commentaries or reviews, and those that only evaluated noise levels were excluded from this review. Articles that were in languages other than English were also excluded. A total of 14 primary research articles, conducted between the years 1988 and 2011, were retrieved (see Table 1 for details of search strategy and results). The goal of this literature review was to establish what is known about noise-induced stress in healthcare workers.

Table 1. Literature Search Strategy

DATABASE	SEARCH QUERY	NUMBER OF CITATIONS RETRIEVED	NUMBER OF RELEVANT CITATIONS
CINAHL	((MM "Stress") OR "stress" OR (MM "Stress, Occupational") OR (MM "Stress, Physiological") OR (MM "Stress, Psychological")) **AND** ((MM "Noise") OR "noise") **AND** ((MM "Nursing Staff, Hospital") OR (MM "Nursing Home Personnel") OR "nursing staff" OR (MM "Staff Nurses")) **Limiters** - Exclude MEDLINE records	5	0
MEDLINE	((MM "Stress, Physiological") OR (MM "Stress, Psychological") OR "stress" OR (MH "Attitude of Health Personnel")) **AND** ((MM "Noise") OR "noise" OR (MM "Noise, Occupational")) **AND** ((MM "Nursing Staff") OR "nursing staff" OR (MM "Nursing Staff, Hospital") OR (MM "Health Facility Environment"))	72	14

2.2 Description of the Studies

Foci and Study Designs of Research Described in the Retrieved Literature

The majority of the research studies retrieved through the literature search was descriptive in nature; the researchers utilized non-experimental and cross-sectional survey designs to answer their research questions (Bayo, Garcia, & Garcia, 1995; Blomkvist et al., 2005; Gladd & Saunders, 2011; Mahmood et al., 2011; Ryherd et al., 2008; Sanchez et al., 2008;

So & Chan, 2004; Walsh, McCullough, & White, 2006). One of the eight articles was unique in that the researchers examined the impact on staff of different acoustical conditions within the workplace before and after structural changes were undertaken (Blomkvist et al., 2005). In five studies the researchers utilized non-experimental and correlational designs to explore the association between noise and healthcare workers' stress (Applebaum, Fowler, Fiedler, Osinubi, & Robson, 2010; Morrison, Haas, Shaffner, Garrett, & Fackler, 2003; Okcu, Ryherd, Zimring, & Samuels, 2011; Topf, 1988; Topf & Dhillon, 1988). Okcu et al. (2011) also contributed unique research by comparing the soundscape characteristics of two intensive care units with different acoustical building materials. There was one study that employed a mixed method design with both quantitative and qualitative methods (Dube et al., 2008); the quantitative approach described the noise levels and the qualitative content analysis provided survey data of nurses' perceptions of the noise present in their work environment (Dube et al., 2008).

The Settings and Samples of the Research Described in the Retrieved Literature

Convenience sampling of sites, clinical locations, and study participants was the primary sampling method employed in the 14 relevant studies. Several studies involved evaluations of critical care settings (So & Chan, 2004), including neurological (Ryherd et al., 2008), cardiac (Blomkvist et al., 2005;Topf, 1988; Topf & Dhillon, 1988), medical-surgical (Topf, 1988; Topf & Dhillon, 1988), urological (Topf, 1988; Topf & Dhillon, 1988), and neonatal or pediatric intensive care units (Morrison et al., 2003; Topf, 1988; Topf & Dhillon, 1988; Walsh et al., 2006). Two of the studies were conducted in acute care settings, including a 500-bed level I trauma centre (Applebaum et al., 2010) and four different acute care hospitals (Mahmood et al.,

2011). In one instance, the researchers carried out their study within four different hospitals with three distinct patient populations (i.e., an intensive care unit, surgical units, and pediatric units) (Sanchez et al., 2008). Okcu et al. (2011) compared a neurological and a medical-surgical intensive care unit, which had different types of sound absorbing building materials. The other research sites and clinical settings included two clinic hospitals (Dube et al., 2008), a university hospital located in an urban area that was surrounded by busy streets (Bayo et al., 1995), and an outpatient chemotherapy clinic (Gladd & Saunders, 2011).

The researchers of the 14 studies recruited various regulated nursing personnel (Applebaum et al., 2010; Bayo et al., 1995; Blomkvist et al., 2005; Dube et al., 2008; Gladd & Saunders, 2011; Mahmood et al., 2011; Morrison et al., 2003; Okcu et al., 2011; Ryherd et al., 2008; Sanchez et al., 2008; So & Chan, 2004; Topf, 1988; Topf & Dhillon, 1988; Walsh et al., 2006), nurses' aides (Dube et al., 2008), unit secretaries and clerks (Dube et al., 2008), and clinical leaders such as charge nurses or clinical coordinators (Mahmood et al., 2011). The most common demographic and background information that was collected about these workers included their marital status, ethnicity, type of nursing degree held, type of shifts worked (i.e., day, evening, or night), job designation, age, gender, length of nursing experience, nature of contract or employment (full time, part time, permanent, or temporary), and medical history. One group of researchers indicated that socio-demographic information was collected, but not included in their published report because their institutional review board requested that it be kept confidential (Applebaum et al., 2010); however, the rationale behind such a requirement was not provided. In the aggregate, the majority of the study participants were female. The sample sizes varied greatly, ranging from 9 to 7,677 study participants. The response rates of the

studies that relied upon questionnaires to evaluate the workers' stress and subjective perceptions of noise also varied widely, ranging from 35% to 100%. In addition to the enrollment of workers, some researchers measured the noise levels of either general areas within hospitals' grounds or clinical areas, or within specific clinical units or offices (Bayo et al., 1995; Blomkvist et al., 2005; Dube et al., 2008; Gladd & Saunders, 2011; Morrison et al., 2003; Okcu et al., 2011; Ryherd et al., 2008; Walsh et al., 2006).

The Measurement Approaches of the Research Described in the Retrieved Literature

There were a limited number of articles that measured noise levels objectively using various sound measuring devices (Bayo et al., 1995; Dube et al., 2008; Gladd & Saunders, 2011; Morrison et al., 2003; Okcu et al., 2011; Ryherd et al., 2008; Walsh et al., 2006). Among these studies, the most common unit of measurement for noise levels was decibels in A-weighting (dB(A)) or equivalent A-weighted sound pressure levels (LAeq) because most of the authors indicated that A-weighting most resembled the characteristics of human hearing (Bayo et al., 1995; Blomkvist et al., 2005; Dube et al., 2008; Morrison et al., 2003; Ryherd et al., 2008). There were also instances where the researchers utilized a combination of different weightings in their noise level measurements. For example, some authors employed A-weighting for lower range sound levels (minimum sound level "LAmin") and C-weighting for louder sound levels (peaking sound level "LCpeak") (Gladd & Saunders, 2011; Okcu et al., 2011).[4] Okcu et al.

[4] The human ear's response to higher sound levels, those that are 100 dB and louder, is flatter. Therefore, sound levels in C-weighting are often used to reflect this particular characteristic of human hearing. Sound levels that are

(2011) also included noise levels that were unweighted to represent the maximum sound pressure levels (Lmax).[5] Finally, there was one study where the researchers did not specify whether unweighted or weighted units of measurement were utilized for describing the sound levels (Walsh et al., 2006).

Most researchers utilized sound level meters (Bayo et al., 1995; Gladd & Saunders, 2011; Morrison et al., 2003; Okcu et al., 2011; Walsh et al., 2006), whereas others used personal noise dosimeters (Dube et al., 2008) to measure sound levels. There was one study where the authors employed both sound level meters and personal noise dosimeters (Ryherd et al., 2008). Various brands and types of sound level meters and dosimeters were employed, including the Bruel and Kjaer 2260 model sound level meter (Ryherd et al., 2008), the Quest Advanced 1900 precision sound level meter (Morrison et al., 2003), the Realistic sound level meter from Tandy Corporation (Walsh et al., 2006), the Quest Technology dosimeter (Dube et al., 2008), the CESVA SC10 sound level meter (Bayo et al., 1995), and the Larson Davis 824 sound level meter (Okcu et al., 2011). One group of researchers did not specify the brand, type, or name of the instruments they used to collect objective noise data (Blomkvist et al., 2005).

Accuracy, reliability, and validity of the noise measurements were maintained through calibration of the instruments in accordance with the manufacturers' user manuals and guidelines

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measured in the C-weighting scale include more of the lower frequency range of sounds, when compared with A-weighting scale (NoiseMeters Limited, no date; Witt, 2012).

[5] The maximum sound level is simply the highest value that is measured by the sound-measuring device over a period of time; therefore, it is "time weighted". It is distinctly different from peak sound levels. A peak sound level is defined as the "maximum value reached by the sound pressure" where there is no time-constant applied to it (NoiseMeters Limited, no date).

(Dube et al., 2008; Gladd & Saunders, 2011; Morrison et al., 2003; Walsh et al., 2006). In addition to calibration, some researchers hired industrial hygienists to conduct the noise measurements to ensure data reliability and validity (Dube et al., 2008). In some cases, the researchers explicitly ensured that their study participants were given clear instructions about how to position and mount the personal noise dosimeters to safeguard the accuracy and reliability of the noise data collected (Ryherd et al., 2008). On the other hand, there were four studies where the researchers did not outline any strategies undertaken to ensure reliability and accuracy of their noise data (Bayo et al, 1995; Blomkvist et al., 2005; Okcu et al., 2011; Ryherd et al., 2008). In addition to measuring sound levels objectively, sources of noise were also evaluated and identified in several studies through subjective measures including the administration of questionnaires (Dube et al., 2008; Okcu et al., 2011) and observations made at the research sites by the researchers (Bayo et al., 1995).

The researchers employed various data collection approaches to obtain their noise assessments, including relying on different locations to place their microphones, employing different timings and duration of measurement, and employing different observation or recording techniques for specific auditory events. In some studies, the microphones were placed in close proximity to patients' heads or beds; they ranged from 0.1 to 1.7 meters (Morrison et al., 2003; Walsh et al., 2006; Ryherd et al., 2008). In addition to the placement of sound level meters, some researchers also recorded auditory events, including alarms, telephones, and conversations (Morrison et al., 2003), or placed personal noise dosimeters on nurses' shoulders to evaluate noise levels (Ryherd et al., 2008). There were five studies where the authors outlined unique data

collection procedures for noise monitoring, as detailed below (Bayo et al., 1995; Blomkvist et al., 2005; Dube et al., 2008; Gladd & Saunders, 2011; Okcu et al., 2011).

Bayo et al. (1995) conducted noise measurements by sound level meters inside a hospital building across 15 different floors between the hours of 0900 to 1400 and 1600 to 2000, as well as along the external perimeters of the hospital during the daytime. The areas within and outside of the hospital grounds were firstly divided into grid points. Then, measurement times were designated, such as one minute for grid points that were inside the building, five minutes for external perimeters, and ten minutes for external streets. In addition, sources of noise were observed and recorded subjectively by the researchers on site.

In Dube et al.'s (2008) study, noise dosimeters were placed at central desk locations on 31 units in two hospitals over a 24-hour period, and a journal was placed on the unit for the staff to record occurrences that might explain unusual sound readings. Gladd and Saunders (2011) placed sound level meters at the center of a chemotherapy clinic with a microphone, located about one foot from the ceiling, in place on Mondays and Thursdays between 0700 to 1800 hours. Blomkvist et al. (2005) divided their assessment into three periods: (a) a baseline period to assess the feasibility of the instruments and data collection procedures, (b) a sound reflective period with sound reflective ceiling surface installed throughout the entire cardiac unit, and (c) a sound absorbing period with class A sound absorbing ceiling tiles installed throughout the unit. During the latter two study periods, noise levels were measured for one week in three different rooms as well as in the main work area.

Okcu et al. (2011) compared noise levels in two different intensive care units with different building materials. Sound measurements were made in both units, including 45-minute sound recordings in patients' rooms with ventilators, 45-minute sound monitoring in empty rooms, 15-minute sound samples at corridors taken at random times during the day and night, and 24-hour continuous sound level measurements during one weekday. During the sound measurements, microphones were placed either 1.4 meters above the finished floor in the corridors or 1.8 meters above the finished floor in patients' rooms and nursing stations.

Stress

Only one group of researchers measured stress objectively by using heart rate assessment and salivary amylase assays, as well as subjectively through the administration of questionnaires (Morrison et al., 2003). In this study, the researchers determined the average heart rate for every 30-minute period, the maximum and minimum heart rate for each 30-minute period, the percentage of time the study participants spent in tachycardia,[6] and the number of ectopy episodes experienced (Morrison et al., 2003). [7] Heart rate data were obtained with a portable cassette battery-driven Holter monitor that was of the GE Marquette 8600 series (Morrison et al.,

[6] This was defined as a heart rate greater than 100 beats per minute.

[7] Cardiac rhythm is partly produced and regulated by the electrical conduction system of the human heart. In normal circumstances, electrical impulses are initiated at the primary pacemaker – the sinoatrial (SA) node, and then pass through the left and right atria The impulses subsequently travel through the Bundle of His, atrioventricular (AV) node, right and left bundle branches, the Purkinje fibers, and finally end at the ventricular myocardium. Ectopy or an ectopic beat is a disturbance of this cardiac rhythm when there is an electrical activation of the heart that originates outside of the SA node. It often comes in the form of premature atrial or ventricular contractions or complexes seen on an electrocardiogram (ECG), and may be induced during times of stress, anxiety, exercise, or medical emergencies (Aehlert, 2007; Venes, 2005).

2003).[8] Salivary amylase, used to assess stress levels, was obtained by having the study participants chew citric acid impregnated cellulose sponges (Morrison et al., 2003). The subjective assessments of stress included self-reported stress and annoyance ratings obtained via the Specific Rating of Event Scale, originally designed for the United States Army Research Laboratory Stress program (Morrison et al., 2003). This scale required participants to rate their stress levels on a scale ranging from 0 to 100, where 0 represented "not at all stressful" and 100 represented "most stress possible." For all three measures utilized in Morrison et al.'s (2003) study, there was no indication that the authors evaluated the reliability and validity of their instruments.

The vast majority of the studies included in this literature review employed various scales, surveys, and questionnaires aimed at assessing healthcare workers' perceptions of how workplace noise affected their health and stress levels. Noise-induced stress was measured with a modified 24-item Disturbance Due to Hospital Noise Scale (DDHNS) (Topf; 1988; Topf & Dhillon, 1988). The DDHNS specifically evaluates stress that might be caused by hospital sounds on a 5-point scale ranging from "not at all" to "extremely," where higher scores mean a greater degree of noise-related disturbance. Topf (1988) and Topf and Dhillon (1988) added 14 items to the scale to identify specific noise sources that were typical of critical care units. They assessed the reliability of the revised DDHNS and obtained a Cronbach's alpha coefficient of .92

[8] A Holter monitor is a lightweight, battery operated, portable recorder that can be worn by an individual over the shoulders or around the waist to enable heart monitoring during ambulation or normal daily activities. It is also referred to as an ambulatory ECG where electrodes are attached to an individual's chest to detect, monitor, and record the electrical signals from the heart (HealthLinkBC, 2012).

(Topf, 1988; Topf & Dhillon, 1988). In addition to noise-induced stress, potentially confounding variables, including life stress, occupational stress, sensitivity to noise, and burnout were measured using the Life Experience Survey, the Nursing Stress Scale, Weinstein's Noise Sensitivity Scale, the Maslach Burnout Inventory, and Jones's Staff Burnout Scale of Health Professionals, respectively. The reliability and validity of these scales were thoroughly examined prior to implementation of the study (Topf, 1988; Topf & Dhillon, 1988).

Gladd and Saunders (2011) adapted the 20-item Topf Sound Disturbance Survey to evaluate healthcare workers' perceptions of noise related to talking, environmental sounds, and equipment. Additional questionnaire items were incorporated to allow the study participants to identify how loud the noises were, whether they believed that noise induced stress, and whether noise was associated with difficulty in concentration or poor job performance (Gladd & Saunders, 2011). These researchers did not evaluate the reliability or validity of the adapted questionnaire.

So and Chan (2004) administered a Chinese version of the ICU Environmental Stressor Scale, which included 42 items on a 4-point Likert-type scale, ranging from "very stressful (4)" to "not stressful (1)" with "not applicable (0)" also being a response option. Of these 42 items, six items pertained to environmental sounds and noise levels and the remainder evaluated other environmental hazards (So & Chan, 2004). A pilot study was carried out to evaluate the questionnaire with five ICU nurses and five ICU patients. It was found that the pilot study participants had difficulty interpreting the meaning of "stress" (So & Chan, 2004). Consequently, an information sheet, attached to the questionnaire, was provided to explain the terminology

(So& Chan, 2004). Once again, there was no indication as to whether the reliability or validity of the instrument was evaluated (So & Chan, 2005).

In Applebaum et al.'s (2010) study, subjective measurement of noise-induced stress was achieved via a 36-item questionnaire adapted from the MD Anderson Patient Contact Survey, which assessed various environmental hazards, one of them being noise, and the 10-item Perceived Stress Scale (PSS) (Cohen, Kamarck, & Mermelstein, 1983). The reliability and validity of the two instruments were evaluated and a Cronbach's alpha coefficient of .70 was reached for the items evaluating noise levels, and .76 to .87 for the items in the PSS (Applebaum et al., 2010). Blomkvist et al. (2005) employed a Swedish-language questionnaire with psychosocial items that evaluated healthcare professionals' working conditions, including the pace of work, quantity of work, decision latitude, competency, quality of care, and social support at work. In addition to the psychosocial items, there were assessments done on various mood states, including hastiness, calmness, irritation, anxiety, tension, happiness, sadness, anger, depression, stress, and fatigue (Blomkvist et al., 2005). The items in the instrument were measured using visual analogue scales with one-decimeter horizontal lines. The participants were asked to mark a cross on the visual analogue scales to describe their current state (Blomkvist et al., 2005). Once the surveys were completed, the distance on the visual analogue scales was measured from zero to the marked cross. The researchers examined the literature to compare their results with those derived from the original version of the scale, which employed ordinal scaling (Blomkvist et al., 2005). They concluded that the results from both versions were comparable statistically.

Although the majority of the research articles evaluated noise-induced stress with established instruments, a few of the research groups had developed new questionnaires for their studies (Bayo et al., 1995; Dube et al., 2008; Mahmood et al., 2011; Okcu et al., 2011; Ryherd et al., 2008; Sanchez et al., 2008; Walsh et al., 2006). For example, Bayo et al. (1995) developed a questionnaire that contained 20 items to collect personal job information, subjective information about general working conditions, and noise-related items. They evaluated the questionnaire qualitatively by conducting a pilot study with 10 participants, and made revisions to the tool based on the participants' interviews prior to the initiation of their study. Walsh et al. (2006) developed a structured questionnaire with nine items that employed scale-type responses, ranging from "strongly disagree" to "strongly agree" to assess nurses' subjective perceptions of the potential adverse effects of the structural design of their patients' rooms in a neonatal intensive care unit. Written comments were received from the study participants and subsequently analyzed as qualitative data (Walsh et al., 2006). There was, however, no reporting of reliability and validity assessments. Dube et al. (2008) asked healthcare staff to rate the noise levels in their workplace using a 5-point Likert type scale ranging from "very quiet" to "very loud" at four different times (0700 - 1200 hours, 1200 - 1700 hours, 1700 - 2200 hours, and 2200 - 0700 hours). The study participants identified the most bothersome noises by picking from a list that contained multiple choices. They also were given the options of recording noise sources that were not mentioned in the list and to identify strategies that they believed would assist in alleviating the noise. The noise control interventions, identified by the staff, were then implemented before the commencement of a subsequent phase of the study (Dube et al., 2008).

Different data collection procedures were implemented to evaluate stress, such as how, when, and where the researchers distributed their questionnaires and monitored the biophysiological aspects of stress. In Morrison et al.'s (2003) study, the participants were escorted to a quiet room where an audiogram was conducted and information was collected about their demographics, medical histories, and nursing experience.[9] Then, Holter monitors were placed on the study participants, baseline salivary amylase samples were collected, baseline blood pressure and heart rate readings were obtained, and baseline stress ratings were collected. Each nurse then returned to her or his patient care activities and was observed by the research staff over a 3-hour period; the number of patients in the room, census of the unit, and the Pediatric Risk of Mortality Scores (Pollack, Ruttimann, & Getson, 1988) of the patients were recorded.[10] During this 3-hour period, continuous heart rate recordings with the Holter monitor were performed. The nurses were asked to rate their stress, using the Specific Rating of Events Scale, at 30-minute intervals throughout the 3-hour study period. Once the data were collected, the salivary amylase samples were frozen, transported for storage, later thawed at room temperature, and the salivary amylase concentration was determined. By the end of their study, Morrison et al. (2003) had collected 69 salivary amylase samples and 11 sets of heart rate data.

The majority of the researchers administered surveys or questionnaires in a paper-based format to evaluate healthcare workers' perceptions of their noise exposure (Applebaum et al., 2010; Bayo et al., 1995; Blomkvist et al., 2005; Gladd & Saunders, 2011; Mahmood et al., 2011;

[9] The audiograms were conducted to establish that the nurses had normal hearing.

[10] The Pediatric Risk of Mortality Score (PRISM) estimates pediatric patients' risk of mortality based on various physiological predictors. Having patients with higher scores likely influence nurses' stress levels.

So & Chan, 2004, Topf, 1988; Topf & Dhillon, 1988; Walsh et al., 2006). There were two studies where the researchers administered electronic and web-based surveys (Dube et al., 2008; Okcu et al., 2011). In Dube et al.'s (2008) study, a website link to an electronic questionnaire was distributed through a staff e-mail list. The response rates for the surveys were different between those administered in paper format and those completed electronically; the response rates of electronic surveys were lower than those of paper-based surveys (30-40% versus 70-100%). There were two studies where the researchers did not specify how the questionnaires were distributed (Ryherd et al., 2008; Sanchez et al., 2008). In terms of who administered the surveys, some researchers handed out questionnaires to the healthcare workers directly (Bayo et al., 1995; Blomkvist et al., 2005; So & Chan, 2004; Topf, 1988; Topf & Dhillon, 1988; Walsh et al., 2006), while others placed the questionnaires in the staff's mailboxes and instructed the participants to return the completed questionnaires, in self-addressed stamped envelopes, to the principal investigator (Applebaum et al., 2010). Other researchers had hospital administrators distribute their study questionnaires and they asked the participants to mail their completed questionnaires to the researchers (Mahmood et al., 2011). There was one study where the researchers indicated that their questionnaires were handed out by office assistants, completed anonymously by the participants, and later collected by the office assistants in an envelope (Gladd & Saunders, 2011). Only two of the study reports indicated that a small incentive, such as a $10 gift card, was given to the study participants (Applebaum et al., 2010; Mahmood et al., 2011).

2.3 The Research Findings Described in the Retrieved Literature

Sources of Noise

The sources of noise to which healthcare workers were exposed were identified in six studies (Bayo et al., 1995; Dube et al., 2008; Gladd & Saunders, 2011; Okcu et al., 2011; Sanchez et al., 2008; Topf & Dhillon, 1988). There was consistency across these studies in identifying the major sources to be: the beeping of patients' monitors, equipment alarms, telephones, excessive traffic related to visitors, greater numbers of personnel during shift changes, staff conversations, patients' vocalizations, and the opening and closing of doors. The voices of the staff were perhaps the most bothersome noise source mentioned.

Noise Levels

Generally speaking, the evaluation of noise levels identified could be categorized into three groups: those that described the noise levels measured both internally and externally to the buildings (Bayo et al., 1995), those that compared sound levels between two different time periods (Blomkvist et al., 2005) or two different clinical environments (Okcu et al., 2011), and those that monitored noise within the clinical units, patients' rooms, or specific locations within the clinical units where healthcare professionals worked (Dube et al., 2008; Gladd & Saunders, 2011; Morrison et al., 2003; Ryherd et al., 2008; Walsh et al., 2006). Bayo et al. (1995) found that almost one third of their sound measurements exceeded 70 dBA, when the mean noise level was 66.9 dB(A) in the surrounding streets. Within the premises of the university hospital they studied, 16% of the sound measurements exceeded 70 dB(A), and the mean noise level was 64.1 dB(A). The healthcare staff rated the sound levels in their workplace on a scale of 1 (quiet) to 10 (noisy). A mean score of 6.5 was obtained, indicating a somewhat noisy working environment.

Blomkvist et al. (2005) attempted to compare noise levels between two different time periods after manipulating the acoustical building materials in place. The sound levels produced with sound-reflective and sound-absorbing materials did not vary greatly; they were 57 and 56 dB(A) in the main work area, respectively. However, there was a more meaningful sound level reduction of 5 to 6 dB(A) in two patients' rooms between the two time periods.[11] Moreover, the sound level measurements indicated that the central area of the unit was the noisiest of all locations. Okcu et al. (2011) compared the noise levels of two different intensive care units within one hospital. The overall mean noise levels in the two units were between 57 and 58 dB(A), with unweighted maximum sound pressure levels ranging between 97 and 195 dB, and C-weighted peak sound levels of 113 to 120 dB(C). In both intensive care units, the maximum sound pressure levels exceeded 70 dB more than 98% of the time, and the peak sound pressure levels exceeded 80 dB(C) more than 80% of the time. Overall, the maximum sound levels exceeded 70 dB more than 98% of the time while the peaking sound levels exceeded 80 dB(C) more than 54% of the time across the nursing stations, occupied and unoccupied patient rooms, and the corridors in both units. The results of this particular study indicated that the sound levels present in the intensive care environment, especially its maximum and peaking sound levels, exceeded several organizations' standards and guidelines.

In the other five studies that measured noise objectively, the average sound pressure levels ranged from 52 dB to 71 dB. In some cases, peak sound pressure levels were well over 70

[11] The unit of measurement for noise "decibels" is based on a logarithmic scale. Therefore, there is a doubling effect with every three decibels increase (Cherrie, Howie, & Semple, 2010).

to 90 dB (Gladd & Saunders, 2011; Ryherd et al., 2008). Ryherd et al. (2008) monitored the background noise and found that noise levels averaged between 47 to 48 dB(A), with a maximum sound level ranging between 52 and 53 dB(A) and peak sound levels between 71 to 72 dB(C). Various factors were found to contribute to increased, maximum, and peaking sound levels, including heavy patient caseloads (Gladd & Saunders, 2011), a higher daily patient census (Morrison et al., 2003), ventilation systems (Ryherd et al., 2008), continuous positive airway pressure (CPAP) machines, and audible alarms (Walsh et al., 2006). Of interest, Morrison et al. (2003) also found that when nurses were caring for patients with higher Pediatric Risk of Mortality scores, the noise levels in the patients' rooms were significantly lower. This perhaps was due to the healthcare workers, visitors, or pediatric patients' family members making an effort to reduce unnecessary stimulation from the environment.

Effects of Noise on Healthcare Staff

Morrison et al. (2003) showed that exposure to higher sound pressure levels was significantly associated with faster heart rates; however, there was no indication that noise levels were related to salivary amylase concentrations. Although there was a significant relationship found between noise and heart rate, there were additional variables that predicted the faster heart rates, including caffeine intake, years of experience (junior nurses had faster heart rates), and the shift worked (day shift workers had faster heart rates). When evaluating the participants' subjective perceptions of stress, the results revealed that higher sound levels were significantly associated with higher stress ratings, although the multivariate analyses indicated that caffeine intake and working day shift also were associated higher stress ratings. In summary, multiple

variables contributed to these healthcare workers' stress, including noise, relatively lower caffeine intake, few years of work experience, and working day shifts (presumably when there are more work demands relative to other shifts).

In the studies where stress was measured subjectively, there was a general consensus that increasing noise levels in the working environment had negative impacts on healthcare workers' stress levels, wellbeing, and other health outcomes (Blomkvist et al., 2005; Gladd & Saunders, 2011; Mahmood et al., 2011; Okcu et al., 2011; Ryherd et al., 2008; Sanchez et al., 2008; So & Chan, 2004; Topf, 1988; Topf & Dhillon, 1988; Walsh et al., 2006). Specifically, two of the studies that compared the impact of sound levels at two different time periods found that healthcare workers' stress levels and pressure were reduced when the soundscape environment in their workplace was improved (Blomkvist et al., 2005; Walsh et al. 2006). Implementation of sound absorbing building materials improved the psychosocial aspects of the work environment, and nurses subsequently experienced lower levels of stress (Blomkvist et al., 2005). In the Walsh et al. (2006) study, it was found that a newly designed neonatal intensive care unit with sound absorbing materials resulted in a quieter nursing environment, and the nursing staff experienced lower levels of stress. Some of the physical symptoms that the healthcare staff reported when they worked in a noisy environment included irritation (Ryherd et al., 2008), fatigue (Ryherd et al., 2008), difficulty with concentration (Gladd & Saunders, 2011; Ryherd et al., 2008; Sanchez et al., 2008), and headaches (Ryherd et al., 2008). These physiological symptoms could be manifestations of stress (Day et al., 2007). In other cases, there were nurses who reported that the noise levels in their workplace were unbearable (Sanchez et al., 2008), and over 60% of one study's participants reported that noise was very problematic (Mahmood et al., 2011). In

addition, some nurses reported that noise was most annoying when it was repetitive, independent of its intensity or duration (Sanchez et al., 2008).

In terms of the noise sources considered to be the most stressful, some staff reported that hearing buzzers and alarms from equipment, heart monitor alarms, patients crying out, unfamiliar and unusual noises, nurses and doctors talking loudly, and telephones ringing were major contributors to their stress (So & Chan, 2004). It is noteworthy that some healthcare workers reported being more concerned about the effects of noise on their patients, rather than on themselves; Bayo et al. (1995) speculated that this might indicate that healthcare staff do not appreciate how noise in their workplace negatively affects their health. Of all the studies included in this literature review, only Applebaum et al. (2010) found noise to be negatively associated with perceived stress (r = -.18; p = .05). They proposed that some noises, produced by intravenous pumps, monitors, and audio alarms, might be of comfort to healthcare workers because they provide a sense of reassurance or familiarity, and therefore reduce their stress levels.

2.4 Limitations of the Available Research and Implications for Future Research

Most of the published research related to healthcare workers' noise exposure is descriptive wherein healthcare workers' subjective perceptions of noise and its impact on their stress levels are examined. Relying solely on subjective evaluations of healthcare workers' stress may have introduced some bias. Convenience sampling of research sites has been the most common method of sampling, which may limit the representativeness and generalizability of the

study results. Small sample sizes of clinical sites and participants may also further negatively affect the strength of the evidence. Additionally, most of the sampling of noise levels, across the 14 studies, involved one-time measurements, making it questionable whether the noise evaluation truly represented the average occupational exposure. In some cases, the researchers conducted continuous on-site observations to identify key contributors to the noise levels, which may have increased the risk of a Hawthorne effect.[12] In several studies, there was a lack of stringent assessment of the employed instruments' reliability and validity, which may have negatively influenced the accuracy and consistency of the data, as well as the soundness of the evidence (Polit & Beck, 2012). This lack of reliability and validity evaluation may have been a contributor to the non-significant correlations found between noise and the selected subjective and biophysiological stress measures employed by Applebaum et al. (2010) and Morrison et al. (2003).

Upon examination of the currently available literature, it is apparent that the acoustical environment in various clinical settings is relatively poor and their noise levels frequently exceed national and international standards and guidelines. Healthcare professionals perceive and report different noise sources and workplace noise as major contributors to their relatively poor health and high stress levels. However, the bulk of the literature evidence focuses on acute care

[12] The Hawthorne effect was a phenomenon discovered in a study that included a series of experiments in an electrical corporation at the Hawthorne plant in which various working conditions, such as lighting and working hours were manipulated to test workers' productivity. The researchers later discovered that the knowledge of being included in the study or being observed by others had a significant effect on the study participants' behaviour. The workers' productivity increased regardless of whether the lighting was better or worse, and whether their working hours were longer or shorter (Polit & Beck, 2012).

settings; there is a lack of research that has explored the relationship between noise and healthcare workers' stress in long-term care facilities. There are also several weaknesses in the study designs, sampling procedures, measures and instruments used, and data collection methods employed across the 14 studies. Consequently, it is imperative to undertake further, and better designed, research to explore the relationship between noise and healthcare workers' stress in long-term care settings; that is, with a larger sample, triangulation of multiple measures used to assess stress, and reliable and valid instruments used to measure the explanatory and outcome variables. Another goal of a stronger study would be the inclusion of repeated measurements of the study variables to gain a more representative overview of occupational noise exposure and its association with healthcare workers' stress.

3 Research Design and Methods

3.1 Research Question

The current research was designed to answer the question: What is the relationship between occupational noise exposure and long-term healthcare workers' stress? To address the identified limitations of the research reviewed in the previous chapter, the study was designed to maximize the representativeness of the study sites and to objectively quantify long-term healthcare workers' noise exposure and stress levels.

3.2 Methods

3.2.1 Overview

A non-experimental, correlational design was undertaken to explore whether there is a relationship between occupational noise exposure and long-term healthcare workers' stress. The research data were collected with a combination of objective and subjective measures to assess the noise levels in long-term care facilities and to evaluate the perceived experience and effects of healthcare workers' noise exposure. Data collection was geared toward minimal disruption of routine nursing care and activities. Validated instruments were used to obtain the exposure measurements as well as the outcome assessments. The exposure measurements consisted of the objective assessment of noise levels to which healthcare workers were exposed in the personal areas of the residents of the enrolled long-term care facilities. The outcome assessments included both objective and subjective measures of the healthcare workers' stress responses, including biophysiological indicators and indicators obtained through the completion of daily logs. The

biophysiological indicators included salivary cortisol levels and several heart rate variability indices; the subjective experience of stress was evaluated through the completion of questionnaires included in the daily logs.

3.2.1 The Setting and Sample Selection Procedures

Sample selection occurred at multiple levels, including the selection of long-term care facilities, healthcare workers, and repeated measurements of the study variables. Sample size determination for multi-level sampling is complex. It was recognized that in multilevel designs it is advisable to have as many sampling units as possible at the top level of the multi-level hierarchy. It was determined that 15 long-term care facilities were feasible to include in the study, given the resources available, and that about 15 workers would be assessed within each facility to achieve sufficient statistical power to detect an association if one exists. Snijders (2005) explained that the size of the cluster (number of workers) is not as important as is the highest level of hierarchy in determining the power of a statistical test. Thus, the number of facilities is the principal limiting factor of a study design.

A stratified random sampling approach was undertaken to select the long-term care facilities from within the participating health authority to maximize the representativeness of the facilities and to strengthen the generalizability of the findings (Polit & Beck, 2012). There are 49 long-term care facilities within the participating health authority; however, only 33 facilities had the necessary information available, such as building specifications, for stratification to occur. These 33 facilities were firstly divided into groups according to several categorical noise factor variables (see Appendix A, Table 16), including whether they were located on a busy road, the

types of windows in place, whether they had carpeting, the presence of acoustical tiles for noise reduction, whether they were wood frame buildings, and the type of heating, ventilation, and air conditioning systems they had in place. Descriptive statistics of the continuous noise factor variables, including the means, standard deviations, medians, and ranges, were explored, including the floor size in square feet, the number of beds, the floor size/bed ratio, the year built, the number of floors in the building, the number of elevators, and the year of the most recent building renovations (see Appendix A, Table 17). These descriptive statistics were further grouped into ordinal categories (see Appendix A, Table 18).

A listing was then produced to describe the specific noise factors of the eligible facilities (see Appendix A, Table 19). Finally, a table was developed to summarize the information provided to indicate the number of times each facility was mentioned. From this categorization, six different groupings were formed (see Appendix A, Table 20). Stratified random sampling using the Excel random number generator was then employed to select two facilities from each category. At the end of the sampling procedure, 12 long-term care facilities were selected. Two additional facilities with specific and rare building specifications were selected outside of the sampling procedure: one facility was the oldest, smallest, and had the least number of beds, while the second facility had single-paned windows and was located on a busy street. One additional facility was added at the specific request of its administrators, following a presentation about the project. In summary, 15 long-term care facilities were initially enrolled in the study, and from which the healthcare workers were to be recruited.

A convenience sample of 15 healthcare workers was sought from each of the 15 enrolled long-term care facilities. Convenience sampling was employed because it was not practical to randomly select the healthcare workers. The research team could not be provided with a listing of all the healthcare workers employed by the facilities because of the employers' duty to protect the personal privacy and information of their employees (i.e., the British Columbia Personal Information Protection Act and the Freedom of Information and Protection of Privacy Act). The eligibility criteria for the healthcare workers included: being able to speak fluent English, being a provider of direct resident care, being a registered nurse, a licensed practical nurse, or a (registered) care aide.[13] To minimize the chance of confounding, such as having higher stress levels arising from working a combination of shifts, only full-time workers working one of the following shifts were initially recruited: day shift (0700 to 1500 hours), evening shift (1500 to 2300 hours), or night shift (2300 to 0700 hours). However, this criterion greatly limited the availability of eligible workers. Consequently, this last inclusion criterion was removed and those healthcare workers who were interested in participating in the study were enrolled regardless of their working hours and the nature of their employment (full-time, part-time, or casual). The exclusion criteria included having had a recent stroke or myocardial infarction, and being pregnant.

The third level of sampling involved repeated measurements of the study variables. Each participant completed two cycles of data collection that were at least two weeks apart (each cycle

[13] In British Columbia, care aides who wish to be employed by a publicly funded employer must be credentialed or "registered" by the BC Care Aide and Community Health Worker Registry (www.cachwr.bc.ca).

consisted of sampling on two consecutive working days). The goal was to select two back-to-back working shifts to gain a representative overview of the employees' noise exposure and stress responses. Overall, the goal of the larger study was to sample 225 healthcare workers in 15 long-term care facilities over 900 sampling days.

After ethics approval was obtained from the health authority and the University of British Columbia, Clinical Research Ethics Board, recruitment of the selected sites and participants commenced. Site visits were conducted to request access and to establish rapport with the facility managers, administrators, or leaders. During the information sessions, the research staff outlined: (a) the goals of the study, (b) the timeline and resources needed, (c) what was required of the participants, (d) the process by which the researchers would share the findings, and (e) the strategies to be employed to safeguard the participants' privacy. The participants were recruited in a similar fashion, where the research staff spoke directly with the healthcare workers and provided a brochure (see Appendix B), distributed posters in the facilities with a brief description of the study, offered an incentive of a $40 gift certificate for participation, and provided the research team's contact information. Once recruited, the research staff met with each participant to provide more details about the study and to explain what was expected, including the instructions for data collection and an overview of the equipment to be used for sampling. During this face-to-face meeting, informed consent was obtained; the participants signed two copies of the consent form (see Appendix C) and retained a copy for their own records.

3.2.2 Measures

To examine the relationships between the study variables, both biophysiological and self-reported measures were used. The exposure assessment and outcome measures had been tested for their feasibility in an earlier, phase-one pilot study (Sbihi, Hodgson, Astrakianakis, & Ratner, 2010). Critical appraisal of the reliability and validity of the measures was also conducted to safeguard the rigour of the study.

Exposure Assessment: Noise

Noise measurements were conducted using Casella® Cel-350 dBadges, also called personal noise dosimeters. These personal noise dosimeters are lightweight and battery operated, and the workers were asked to wear them on their uniforms. They are easy to operate and did not interfere with the tasks being performed by the participants. Before acquiring the sound measurements, the dosimeters were configured to display in the ISO view where the following result values were displayed: battery and memory status, duration of measurement, instantaneous sound pressure levels and time, LAEQ, LCPK, PA^2 hours, and PROJ DOSE.[14] Several strategies were implemented to ensure the reliability and accuracy of the data. First, the dBadges met the WorkSafeBC (2012) guidelines and Canadian Standards Association's (2011) standards for the measurement of occupational noise exposure and the specifications for personal noise dosimeters. Calibration of the dosimeters was conducted prior to and after the sound measurements in accordance with the manufacturer's instructions (Casella®, 2007). If a 0.5

[14] Instantaneous sound pressure level is displayed as "LAF" in dB. LAEQ and LCPK are the time averaged and peak noise data, respectively. PA^2 hours represent the calculated noise exposure data, and PROJ DOSE represents the projected noise exposure data (Casella® Cel, 2011, June).

dB(A) difference was noted between calibrations, the device would have been returned to the manufacturer for inspection (Cherrie et al., 2010); however, there was no occurrence of such instrument malfunction throughout the data collection. Human tampering also needed to be minimized to protect the reliability of the data. This involved locking off the key tabs and the screen of the noise dosimeter so that the participants could not intentionally or accidentally turn the device off. This approach had been advised by the manufacturer to reduce a participant's urge to shout into the microphone (Casella®, 2007), which would have resulted in inaccurate data. Finally, before every sound measurement, the dosimeter's battery life was verified to prevent data inaccuracy or loss.

Outcome Measures: Stress

Salivary Cortisol

Salivary cortisol has been used frequently in stress research to evaluate the response of the hypothalamic-pituitary-adrenocortical axis (Hansen, Garde, & Persson, 2008). Accumulative stress (allostatic load) stimulates the production of neuroendocrine hormones and the autonomic nervous system mediators (McEwen, 1998). One of the contributors to allostatic load is the release of cortisol, regulated by the hypothalamic-pituitary-adrenocortical axis (Hansen et al., 2008). The secretion of cortisol originates from the adrenal glands and it follows a distinct diurnal cycle where a profound increase is found immediately after waking. This particular increase at awakening is a common phenomenon named the "cortisol awakening response" (Fries, Dettenborn, & Kirschbaum, 2009). The cortisol awakening response represents a specific feature of the hypothalamus-pituitary-adrenal axis, and researchers have hypothesized that it is

associated with the anticipation of demands of the upcoming day (Fries et al., 2009). Once cortisol levels peak in the morning immediately after awakening, the levels decrease throughout the day with the nadir occurring in the late evening (Golden, Wand, Malhotra, Kamel, & Horton, 2011; Hansen, Persson, Garde, Karlson, & Orbaek, 2006). This particular circadian change of salivary cortisol can be used to assess the overall secretions over a period of time through the area under the curve computations from repeated measurements (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). Area under the curve with respect to ground uses a formula that calculates the total area under the curve of all cortisol measurements as the area of interest (Pruessner et al., 2003). Thus, the difference between single measurements, representing the change over time, and the distance of multiple measures from ground, representing the level at which changes over time occur, are both accounted for (Pruessner et al., 2003). The hypothesis is that with a high stress burden, an individual's salivary cortisol levels will be elevated even later in the day.

Research has shown that the total diurnal salivary cortisol pattern (in nmol/L), generated from multiple samples from awakening to midnight, has the best test-retest reliability (r = .63 to .84) compared with a single awakening sample (at 0800 hours) (r = .18 to .47; collected 1 to 26 weeks apart) and a single evening sample (at 2300 hours) (r = .78; collected 1 to 5 weeks apart) (Golden et al., 2011). However, Golden et al. found that one-time evening collections might not detect low-level hypercortisolism or excess production of cortisol, which occurs in people with depression and metabolic disorders, and thus recommended multiple salivary cortisol measurements be taken from awakening to evening. A research study involving an elderly population also indicated that the test-retest reliability of multiple samples collected over two (r

= .78) or three (r = .84) days is satisfactory (Kraemer et al., 2006). Salivary cortisol sampling has been assessed in samples of healthy adults of both genders and individuals with cardiovascular conditions (Golden et al., 2011).

Salivette® (Sarstedt, Germany) was the salivary cortisol collection system used for this study; it uses cotton swabs that are placed in test tubes. When compared with a collection method that relies on passive drooling, stronger correlations were found between Salivette®-cortisol levels and free serum cortisol levels (r = .81) and total serum cortisol levels (r = .84) (Poll et al., 2007). More statistically significant correlations (66.7% of 12 data collection times) have been observed between Salivette®-cortisol levels and total serum cortisol and free serum cortisol levels (Poll et al., 2007).

The Salivette® system was selected because the collection of samples is pain free (i.e., venipunctures for serum samples are not required) and the specimens are easily stored in a standard freezer. This is a particular strength because the pain from venipuncture could, in itself, induce a stress response (Kirschbaum & Hellhammer, 2000). It also allows researchers to collect large amounts of data, in the field, without impeding the study participants' daily routines (Golden et al., 2011). Finally, stability of salivary cortisol samples has been established when they are stored at room temperature and with repeated freezing and thawing (Garde & Hansen, 2005). The saliva samples can be stored at 5°C for three months or -20° to -80°C for a year (Garde & Hansen, 2005). In the currently study, the cortisol samples were stored in an upright,

household freezer prior to shipment for analysis.[15] The first batch of cortisol samples was stored in the freezer for as much as three months while the second batch was stored for as much as six months and then shipped to a German laboratory for analysis.

The Salivette®-cortisol samples were shipped to the Biopsychologie Laboratory of the Technical University of Dresden, Germany, which is led by Dr. Clemens Kirschbaum. Prior to shipment, strict procedures were followed according to the laboratory's specifications on how to label the cortisol samples to ensure data accuracy. The laboratory used the Salimetrics® Saliva Assay Kit to extract and analyze the cortisol samples (Salimetrics®, 2011). To ensure inter-rater reliability, the laboratory technicians followed a strict protocol, developed by Salimetrics®.

The cortisol awakening response represented the difference in cortisol levels between the first (immediately after awakening) and second (30 minutes after awakening) salivary swabs. Hence, for the analyses reported here, the data were considered missing if either of these two salivary cortisol swabs was not collected or the cortisol levels were not detectable by the laboratory. The general guideline applied for the current study, in calculating the cortisol area under the curve with respect to ground, was that the participants were required to have provided the first two salivary cortisol measurements with an additional measurement from one of the other three salivary swabs (4 hours after awakening, 8 hours after awakening, or before bedtime). That is, a total of three salivary cortisol measurements were required for the area under the curve with respect to ground computations.

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[15] Most household freezers maintain a temperature of -18° to -23°C.

Heart Rate Variability

Heart rate variability (HRV) has been used in research to evaluate autonomic nervous system activity and its effects on the cardiovascular system (Dekker et al., 2000; Task Force of the European Society of Cardiology and the North American Society of Packing and Electrophysiology, 1996). It represents the variations in heart rate that arise from fluctuations in the activity of the autonomic nervous system (Dekker et al., 2000), which is modulated by the sympathetic and parasympathetic pathways (Kubios®, 2012). HRV has been shown to decrease when people are exposed to stress; it increases at rest. Low HRV has been linked with higher prevalence rates of cardiovascular disease, and is an indicator of poor general health (Dekker et al., 2000). The measurement of HRV has typically required an electrocardiogram; however, newer technologies, such as Polar® heart rate monitors, which are portable, lightweight, and equipped with chest belts or wrist bands, may be superior for short-term monitoring especially because they can be used while the wearer is active. With companion software, such as Polar ProTrainer®, both time- and frequency-domain variability of short- or long-term heart rate data can be calculated. Additional computer software, such as the Kubios® program (Tarvainen & Niskanen, 2012, July) can be used to correct data artifacts, and calculate the most common indices for time- and frequency-domain heart rate data with its graphical interface.[16] We relied upon the Kubios® program.

[16] The Kubios® heart rate variability program was developed by the BioSignal Analysis and Medical Imaging Group at University of Eastern Finland to provide clinicians and researchers with an advanced tool to study and analyze the variability of heart beat intervals.

With the Polar® monitor, HRV indices from both the time- and frequency- domains can be calculated. Time domain data include the heart rate at a particular time or the time intervals between two consecutive heartbeats, also called the R-R interval, which is represented in milliseconds (ms).[17] These values can be averaged, the standard deviation can be calculated, and the difference between the longest and the shortest R-R interval can be determined (Kubios®, 2012). The standard deviation of the R-R intervals (the SDNN) is the standard deviation of normal-to-normal intervals. The SDNN index is the 5-minute standard deviation of R-R intervals or the variability of cycles shorter than five minutes. The SDANN is the measure of variation (standard deviation) of the average R-R interval obtained from cycles longer than five minutes (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996).

Frequency domain data are collected in terms of the low-frequency power range of HRV, which is reflective of both sympathetic and parasympathetic activity. The normalized low-frequency/high-frequency ratio can be computed to represent the sympathovagal balance (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). The Kubios® (2012) software calculates the frequency-domain HRV indices with two different power spectral densities – analyzed with parametric-based autoregressive (AR) time series modelling and a Fast Fourier transform (FFT)-based digital spectral method (Gayda et al., 2012). The AR modelling technique tends to concentrate its

[17] The R-R interval is the time interval measured from the peak of the QRS complex, the graphical deflection seen on an ECG that corresponds with the depolarization of the heart, to the peak of the next complex, which ascertains the ventricular heart rate.

analysis on significant peaks, whereas the FFT-based method includes all data points (Berntson et al., 1997). Researchers have suggested that many similarities reside with both spectrums and therefore they generally lead to equivalent results (Berntson et al., 1997). Data from the frequency domain that are computed with the FFT-based spectral method are analyzed here as this technique includes all data components.

There is considerable research available about the reliability and validity of heart rate monitors (Polar®, no date). For example, it has been found that Polar® heart rate monitors, worn with chest belts, exhibit better ability and consistency in detecting the heart rate when a participant's body motions are excessive (i.e., walking 4.5 or 6 miles per hour) when compared with Smarthealth® watches worn on the wrist (Lee & Gorelick, 2011). Large Pearson correlations have been established between data collected with a conventional electrocardiogram (ECG) and a Polar® monitor: r = .99 for the mean R-R interval, .86 for low-frequency data, and .87 for the low- frequency/high-frequency ratio (LF/HF) (Nunan et al., 2009; Porto & Junqueira, 2009). More specifically, satisfactory interclass correlation coefficients have been found in various time- and frequency-domain HRV indices for those collected with Polar® instruments and conventional ECG readings during exercise (i.e., the root mean square successive difference between RR intervals (RMSSD), r = .93; the successive differences in the RR interval for which the absolute value exceeds 50 ms (pNN50), r = .87; low frequency power in normalized units (LFnu), r = .97; high frequency power in normalized units (HFnu), r = .97; and the LF/HF, r = .942) (Vanderlei, Silva, Pastre, Azevedo, & Godoy, 2008). In another study, Polar® heart rate monitors were found to exhibit agreement with ECG-based assessments for time-domain indices, including the mean R-R interval, the SDNN, and the RMSSD (Porto & Junqueira, 2009).

Correlations of heart rate measures obtained with the Polar® and with an ECG for within-subject comparisons ranged from r = .75 to 1.00 (Goodie, Larkin, & Schauss, 2000). In addition, between-task comparisons during rest periods (r = .99), mental exercises (r = .98), and handgrip tasks (r = 1.00) revealed large correlations between the ECG data and the Polar® data (Goodie et al., 2000). Overall, Polar® heart rate monitors are reliable and convenient instruments that can be used to evaluate HRV indices.

Self-Reported Stress Measure

Cohen et al.'s (1983) Perceived Stress Scale (PSS) (see Appendix D) was incorporated to measure "the degree to which a situation in an individual's life is appraised as stressful" (p. 385), especially for those stressors that are unpredictable and uncontrollable. A short 4-item scale, utilized in the current study, can be made from questions 2, 4, 5, and 10 of the original 10-item PSS (Cohen, 1994). The scale items are easy to understand and the response options are relatively easy to grasp (i.e., 0 = "never"; 1 = "almost never"; 2 = "sometimes"; 3 = "fairly often" and 4 = "very often") (Cohen et al., 1983). Cohen et al. collected data about the scale's reliability and validity from three different samples – two consisting of college students and one with a heterogeneous group of individuals enrolled in a smoking-cessation program. The Cronbach's alpha values for the PSS were .84, .85, and .86 for the three samples, respectively. Test-retest reliability of the scale was .85 when Cohen et al. administered the scale to 82 college students (repeated at two days and six weeks). Concurrent and predictive validity of the PSS also have been established; the scale was found to be a better predictor of stress and health-related outcomes when compared with other scales (Cohen et al., 1983). In comparison with a depressive symptomatology scale, the PSS items were found to assess and detect a different and

independently predictive construct related to the physical symptomatology of stress (Cohen et al., 1983). In addition, the overall validity of the PSS was found to be unaffected by the respondents' age or gender. In summary, the PSS is a reliable and valid tool that can be used to evaluate the subjective experience of stress.

Two of the four PSS items were reverse coded so that higher scores were indicative of higher levels of stress. The four items were summed such that total scores could range from 0 to 16. A rule was established that if one of the four items was not answered, a value equivalent to the average response of the three completed items would be imputed.

Demographic Information

Information about the participants' socio-demographic characteristics, including age, and gender were collected through the administration of questionnaires, separate from the daily logs.

3.2.3 Data Collection Procedures

After informed consent was obtained from the participants, repeated measurements of the relevant variables were performed over a total of four sampling days. A brief description of the data collection schedule is provided in Appendix E.

Noise Exposure Assessment

The researchers met with the individual participants, at their worksite, at the beginning and end of their shift to set up and remove the noise dosimeters. A dosimeter was clipped to the participants' clothing, on the side of a shoulder in close proximity to the ear to capture the sound or noise levels to which the participants were exposed throughout their working shifts. In the

event that the researchers were not present to remove the noise dosimeters and the dosimeters were removed by the participants and left running, the researchers ensured that the data extracted reflected what the workers were exposed during their working periods (i.e., the data were truncated to correspond with the shift worked).

Biophysiological Measures

On each sampling day, the participants were required to collect five salivary cortisol samples (at the time of awakening, 30 minutes after waking, 4 hours after waking, 8 hours after waking, and at bedtime). The participants' adherence to the sample collection times was crucial to ensure the reliability of the data (Golden et al., 2011). Therefore, Medication Event Monitoring System (MEMS™) caps and a daily cortisol log (see Appendix F) were implemented to monitor the participants' compliance with the collection schedule.[18] The MEMS™ caps were attached to the bottles that contained the Salivette® cotton swabs and the date and time were recorded when the participants opened the bottle to remove the collection swabs. The participants were instructed to record the times of sample collection on the daily cortisol log and to indicate whether they consumed food or fluids or smoked before the saliva collection because these have been found to influence cortisol levels (Golden et al., 2011). Another strategy employed to ensure compliance was to provide both verbal and written instructions (see Appendix G) for the sample collections. All of the data collection instruments were delivered to

[18] MEMS™ monitors are containers with electronic micro circuitry, which were designed to compile the dosing histories of people taking prescribed medications. Each monitor consists of a conventional medicine bottle fitted with a special closure that records the date and time of each opening and closing of the container through integrated micro circuitry. A reader then transfers the dosing history data from the MEMS™ monitor to a computer.

the participants in a small and portable cooler on the day before the commencement of data collection, and were collected after each sampling cycle. The HRV monitoring occurred simultaneously with the noise measurements and salivary cortisol collections. The researchers planned to meet with the participants at the beginning and end of their shifts to set up and remove the Polar® heart rate monitors.

Self-Reported Measures and Potential Confounders

The PSS items were recorded in a short daily log, as described previously, and the socio-demographic information was collected separately through a questionnaire. The daily diaries and questionnaires were given to the participants when the coolers for the cortisol collections were delivered. The daily diaries were retrieved at the end of each sampling cycle with the questionnaires being collected at the end of the second cycle to allow adequate time for completion.

Training

An operational manual (sampling protocol) was prepared and included: the study goals, proposed research questions and hypotheses, ethics certificate, instruments employed and the accompanying manufacturers' manuals, data collection procedures, data management and analysis protocols, data entry templates, code books, training materials, and participant files containing personal information. The use of an operational manual ensured that all of the research personnel were provided with the same information and were trained consistently to safeguard the consistency of data collection. Additional personnel training was provided through trial runs with all the instruments utilized in the study.

Data Storage

Data gathered from the personal noise dosimeters and heart rate monitors were downloaded to a field laptop after each sampling day to prevent data loss. The laptop was secured with a username and password that were known only by the research staff. The data were later downloaded to a secured file server. The participants' daily diaries were stored in a locked office to which only the research staff had access. Finally, the salivary cortisol swabs, after being labelled with a unique identifier, were stored in a freezer located in a locked laboratory. The swabs remained in the freezer for approximately three to six months before shipment to the German laboratory (Dresden Lab Service, GmbH) for extraction and analysis.

3.2.4 Data Analysis Strategies

Before data entry and management began, a codebook was developed to outline how the study variables were defined, labelled, and assigned numerical values for the survey responses and missing values. The noise and heart rate variability data were inspected with their respective software to assess for equipment malfunction. If malfunction was detected, the segments of erroneous data were removed. Salivary cortisol collection information was compared with the daily cortisol logs to ensure that there were no missed samples and that they corresponded with the correct participants. Subsequently, noise (LAeq and CpeakMax), heart rate variability (LF and LF:HF ratio in FFT spectrum), salivary cortisol (cortisol awakening response and cortisol area under the curve with respect to ground computations), perceived stress scale (total PSS

scores) data, and the daily log and socio-demographic information were entered into a pre-established Excel template.[19]

The Excel formatted research data were later imported into the IBM® SPSS® Statistics v.20 program for data verification, cleaning, and analyses. Once the data were verified, they were presented in frequency distributions, bar graphs, box plots, or histograms in accordance with their level of measurement to identify their distributional properties and the presence of any outliers. Missing values were identified and checked for patterns of randomness so that deletions or imputations, as appropriate, could be made (Polit & Beck, 2012). After data verification and cleaning, the principal analyses began. Descriptive statistics including graphs of histograms, bar graphs, and box plots were produced to examine the study variables for normality and homogeneity of variance so that appropriate inferential statistical methods could be used (Pallant, 2010).

Bivariate correlations were conducted separately for the four sampling days. Pearson's *r* was computed to examine the correlations between the noise exposure levels and the biophysiological and PSS stress scores. Prior to Pearson's *r* correlation analyses, Mahalanobis distance was examined to identify the presence of multivariate outliers with $p < .001$ for all four sampling days. Correlational matrices were then created to examine the relationships among noise, the stress measures, and extraneous factors to identify potential confounders. The final

[19] LAeq = average sound pressure in A weighting; CpeakMax = peaking sound pressure in C weighting; LF = low frequency as one of the heart rate variability indices; LF:HF ratio = low frequency to high frequency ratio as one of the heart rate variability indices; FFT spectrum = fast Fourier transform spectrum for heart rate variability analysis.

step was to conduct multiple linear regression analyses between the noise and stress measures, while entering statistically significant confounding variables as additional predictors in the regression equation. The statistical analyses were based on a significance level of .05 and a two-tailed test.

3.2.5 Ethics and Human Subjects' Issues

Declaring the potential risks and benefits of study participation to the participants was a key strategy in protecting them from any possible harm (Polit & Beck, 2012). In this project, the potential risks included some physical discomfort that may have arisen from wearing the Polar® chest belt and some loss of personal time associated with saliva sample collection and completion of the logs and questionnaire. There might also have been some emotional discomfort during equipment setup when the researchers had close physical contact with the participants. To minimize these risks, the research staff obtained the participants' consent before any physical contact was made, ensured that the chest belts were not too tightly secured, and protected the participants' privacy, at all times. Conversely, there may have been some potential benefit in participating. A major benefit was that the research team promised to share the study findings with the participants, their employers, and WorkSafeBC, which could contribute to understanding how noise, an occupational hazard, affects the stress levels of healthcare workers in long-term care facilities. If an association were to be found, steps could be taken to mitigate the stressor. Another benefit was a monetary incentive provided in the form of a $40 gift certificate. This honorarium was given partly to offset the lost time and to express gratitude for the participants' effort.

Before acquiring signed consent, the research staff gave the participants verbal explanations and written materials about the study's goals, data collection procedures, time commitments, funding sources, a risk-benefit assessment, a confidentiality pledge, and the offer of the honorarium. The participants also were advised of their rights to withdraw from the study, at any time, and to withhold information, as they deemed appropriate. Documentation of such informed consent was obtained by having the participants sign two copies of the consent form (see Appendix C). The researchers kept one copy of the signed consent form for record keeping while the participants retained the other copy. The participants were encouraged to contact the research team if questions were to arise; the contact information was provided in the consent form. Finally, continuous evaluation of informed consent was conducted throughout the study.

Safeguarding the participants' confidentiality was another important task in conducting this research. Complete anonymity was not possible in this study because face-to-face contact was required throughout the data collection, and the participants were required to wear the noise dosimeters on their uniforms during their working shifts. However, several strategies were employed to ensure confidentiality. First, the participants were given a unique subject identification number. Second, only the identification number appeared on the stored data in the computer files as well as on the completed questionnaires and logs. Any identifying information was kept in a separate locked office where only the research staff had access. The participants and their employers were told that when the aggregated study findings across the different facilities were shared, all identifying information would be permanently removed.

4 Research Findings

4.1 Rate of Participation

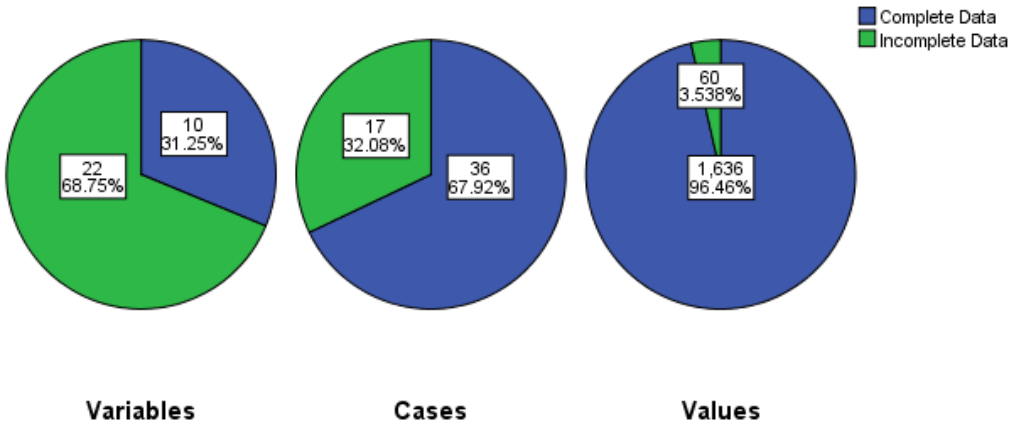
A total of 102 participants, who met the inclusion criteria, in the six participating long-term care facilities were invited to participate in the study. We had determined that 15 long-term care facilities were desirable, but recruitment was more challenging than anticipated. Of the facilities that were approached during recruitment, some of their administrators stated that they were busy with internal changes of personnel, construction, or gastrointestinal infection outbreaks among the residents; thus six facilities participated in the study. Of the 102 healthcare workers approached in these facilities, 49 refused to participate (52% participation rate). The most common reason for refusal was that the worker was too busy.

4.2 Missing Data

Not all the participants completed all four sampling days and some participants did not provide complete data for each sampling day. Data were collected for 32 variables related to noise exposure and stress across the four sampling days. Of these 32 variables, there were 10 (31.3%) variables with complete data for all participants. Of the 53 enrolled participants, 36 (67.9%) provided complete data. Figure 1 provides an overall summary of the proportion of missing data by variables, participants (cases), and possible values of all variables. Figure 2 shows the pattern of missing values by participant. There were 11 unique patterns with at least two variables with missing data. The maximum number of variables with missing data was 16 for one participant who did not complete the second cycle of sampling. This participant had developed a skin rash in the area of the Polar® heart rate monitor chest belt, during Cycle 1, and

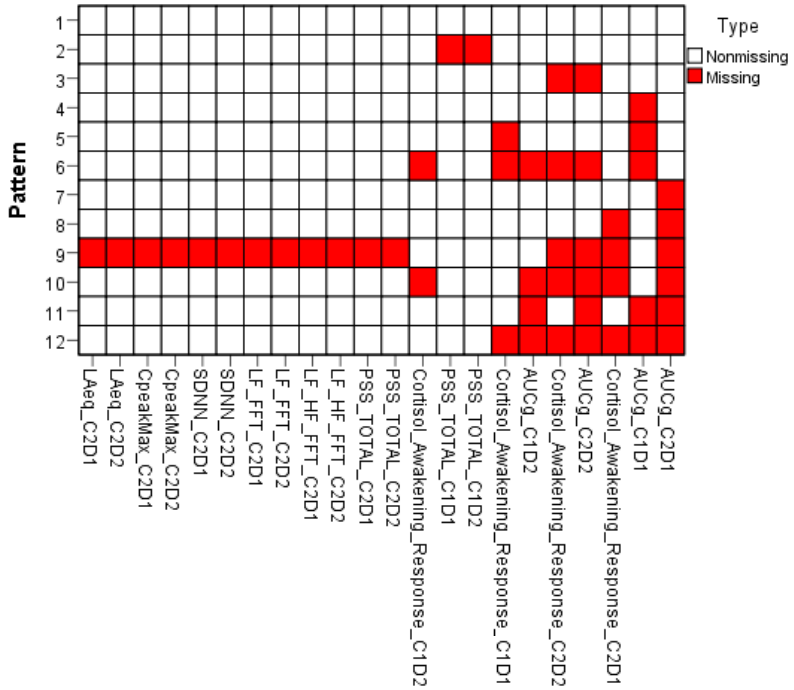
declined to continue in the study. The frequency of occurrence of the missing value patterns is shown in Figure 3. In addition to the missing data for the noise exposure and stress variables, nine participants did not provide their age and ten participants did not provide their height and weight.

Figure 1. Overall Summary of Missing Values



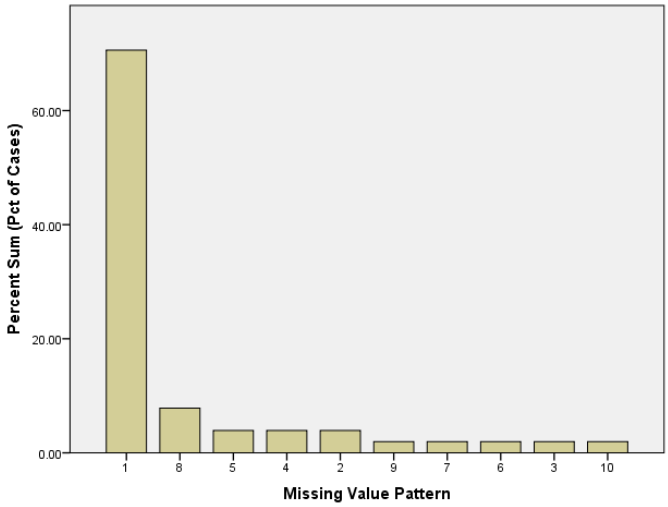
Note. Variables = the number of variables across four sampling days; Cases = the number of participants; Values = the number of possible data points.

Figure 2. Missing Value Patterns



Note. Truncated with variables with complete data omitted. LAeq = average sound pressure in A weighting; CpeakMax = peaking sound pressure in C weighting; SDNN = standard deviation of NN intervals (heart rate variability index); LF_FFT = low frequency (heart rate variability index) in FFT (fast Fourier transform) spectrum; LF_HF_FFT = low frequency to high frequency ratio (heart rate variability index) in FFT (fast Fourier transform) spectrum; PSS_total = Perceived Stress Scale total score; AUCg = cortisol area under the curve with respect to ground; C1D1 = Cycle 1, Day 1; C1D2 = Cycle 1, Day 2; C2D1 = Cycle 2, Day 1; C2D2 = Cycle 2, Day 2.

Figure 3. The Ten Most Frequently Occurring Missing Value Patterns



Note. Truncated with variables with complete data omitted. The pattern number corresponds to the pattern numbers shown in Figure 2.

4.3 Sample Demographics

The demographic characteristics of the sample are presented in Table 1. The average age of the participants was 47.3 years of age (S.D. = 10.0), with the youngest participant being 25 years and the oldest being 63 years. The majority of the sample was female (88.7%) and over one half (58.5%) were registered care aides. The participants worked various shifts and had various shift rotations; day shift was the most commonly (> 60%) sampled shift.

Table 2. Characteristics of Study Participants

Characteristic	Descriptive Statistic[1] (N = 53) n (%)
Age (mean (SD))[2]	47.3 (10.0)
Gender	
Male	6 (11.3)
Female	47 (88.7)
Body Mass Index (mean (SD))[3]	24.2 (3.3)
Job Title	
Registered Care Aide	31 (58.5)
Licensed Practical Nurse	7 (13.2)
Registered Nurse	15 (28.3)
Facility	
Facility A	3 (5.7)
Facility B	3 (5.7)
Facility C	15 (28.3)
Facility D	7 (13.2)
Facility E	10 (18.9)
Facility F	15 (28.3)
Shift Worked	
Sampling Cycle 1	
Day	34 (64.2)
Evening	14 (26.4)
Night	5 (9.4)
Sampling Cycle 2[4]	
Day	33 (63.5)
Evening	12 (23.1)
Night	7 (13.4)

[1] Figures are numbers (percentage) unless stated otherwise.
[2] Nine participants did not provide their age.
[3] Ten participants did not provide height and weight information.
[4] In sampling Cycle 2, only 52 participants provided data.

4.4 Noise Exposure

The average sound pressure levels (A weighting) and the peaking sound pressure levels (C weighting) for the four sampling days are presented in Table 3. On average, the participants were exposed to an A-weighted average sound pressure level of 74.4 to 74.8 dB(A) (SD = 3.1 and 3.3, respectively) during their eight-hour work shift. The minimum time averaged sound pressure level that the workers were exposed to was 64.1 dB(A) and the maximum average sound pressure level was 82.1 dB(A). These healthcare workers were exposed to mean C-weighted peaking sound pressure levels ranging from 124 to 126 dB(C) during an eight-hour shift. The minimum C-weighted peaking sound pressure level was 113.3 dB(C) and the maximum peaking sound pressure level was 143.5 dB(C).

Table 3. Measured Sound Level Values

Sound Level Value	Shift Sampled			
	Cycle 1 Day 1 Mean (SD) in decibels (*dB*)	Cycle 1 Day 2 Mean (SD) in decibels (*dB*)	Cycle 2 Day 1 Mean (SD) in decibels (*dB*)	Cycle 2 Day 2 Mean (SD) in decibels (*dB*)
Time Averaged Parameter (LAeq[1])	74.4 (3.1)	74.7 (3.2)	74.4 (3.3)	74.8 (3.1)
Peak Value (CpeakMax[2])	126.8 (7.4)	124.6 (6.2)	126.7 (7.3)	125.9 (6.3)

[1] LAeq = the A-weighted equivalent level. It is the level that would contain the same amount of noise energy as in the actual noise, effectively giving an average level over the measurement period. Doubling the energy results in a 3 dB change in the Leq. For example, if the noise level was a constant 85 dB and the measurement period was 4 hours, the LAeq would be 85 dB(A) (Casella® Cel, 2011). [20]

[2] CpeakMax = the maximum level in dB reached by the sound pressure any instant during the measurement period, measured with C weighting. It is the true peak level of the pressure wave.

4.5 Stress

4.5.1 Salivary Cortisol

The means and standard deviations of the cortisol measures, including cortisol awakening response and cortisol area under the curve with respect to ground, are presented in Table 4. Over the course of the four sampling days, the average cortisol awakening response was between 7.4 and 8.5 nmol/L (SD = 8 .0 and 12.0, respectively). The lowest cortisol awakening response level detected was -31.2 and the maximum was 43.8 nmol/L. The mean cortisol area under the curve

[20] Lex is the noise exposure level, energy-averaged over 8 hours. The shift time correction from Leq to Lex is zero when the shift duration is 8 hours (WorkSafeBC, 2007).

with respect to ground ranged between 137.8 and 174.2 nmol/L*h (SD = 46.9 and 63.0, respectively).[21] The lowest cortisol area under the curve with respect to ground detected was 23.9 nmol/L*h and the maximum was 880.2 nmol/L*h.

Table 4. Measured Cortisol Values

Cortisol Indices	Shift Sampled			
	Cycle 1 Day 1 Mean (SD) in nmol/L	Cycle 1 Day 2 Mean (SD) in nmol/L	Cycle 2 Day 1 Mean (SD) in nmol/L	Cycle 2 Day 2 Mean (SD) in nmol/L
Cortisol Awakening Response (CAR)	8.5 (12.0)	8.4 (8.0)	8.0 (10.5)	7.4 (10.5)
Area Under the Curve with respect to Ground (AUCg)	138.8 (46.9)	137.8 (56.0)	174.2 (63.0)	139.6 (63.0)

Note. The unit of measurement for area under the curve with respect to ground (AUCg) is nmol/L*h, where "h" represents "hour".

4.5.2 Heart Rate Variability

The means and standard deviations of the heart rate variability indices, the standard deviation of NN intervals (SDNN), low frequency (LF) in FFT spectrum, and low frequency to high frequency (LF: HF) ratio in FFT spectrum are presented in Table 5. The mean SDNN for

[21] The unit of measurement for area under the curve (with respect to ground) salivary cortisol computations is nmol/L*h, where "h" represents "hour".

the participants ranged between 72.5 and 73.7 ms (SD = 21.4 and 23.8, respectively) for the four sampling days. The minimum SDNN recorded was 34.4 ms and the maximum SDNN was 161.1 ms. On average, the participants' low frequency heart rate variability index was between 11.1% and 11.8 % (SD = 4.6 to 5.7). The minimum low frequency recorded was 2.6% and the maximum low frequency recorded was 26.0%. In terms of the heart rate variability index LF:HF ratio, the mean ranged between 4.7 and 5.1 ms^2 (SD = 2.4 and 2.9, respectively) for the four days. The minimum LF:HF ratio computed was 0.7 ms^2 and the maximum LF:HF ratio was 13.8 ms^2.

Table 5. Measured Heart Rate Variability Indices

Heart Rate Variability Indices	Shift Sampled			
	Cycle 1 Day 1 Mean (SD)	Cycle 1 Day 2 Mean (SD)	Cycle 2 Day 1 Mean (SD)	Cycle 2 Day 2 Mean (SD)
SDNN (ms)[1]	72.5 (22.3)	73.7 (21.4)	73.4 (22.7)	73.4 (23.8)
LF in FFT Spectrum (%)[2]	11.1 (5.0)	11.6 (4.6)	11.8 (5.7)	11.6 (5.2)
LF:HF Ratio in FFT Spectrum (ms^2)[3]	4.7 (2.4)	4.7 (2.7)	5.0 (2.7)	5.1 (2.9)

[1] SDNN = time domain measurement of heart rate variability. It is the standard deviation of normal-to-normal (NN) intervals (the intervals between adjacent QRS complexes in a continuous echocardiogram recording) (Task Force of the European Society of Cardiology the North American Society of Pacing Electrophysiology, 1996).
[2] LF in FFT spectrum = low frequency of heart rate variability in non-parametric method (fast Fourier transform). Low frequency often is said to depict both parasympathetic and sympathetic activity (Tarvainen & Niskanen, 2012, July).
[3] LF:HF Ratio in FFT Spectrum = low frequency and high frequency ratio in non-parametric method (fast Fourier transform) (Tarvainen & Niskanen, 2012, July).

4.5.3 Perceived Stress

The average perceived stress scale (PSS) scores over the four sampling days and their associated standard deviations are presented in Table 6. The mean PSS scores were between 4.7 and 5.3 with standard deviations of 2.5 and 2.8, respectively. The minimum PSS score obtained was 0 and the maximum score obtained was 12.

Table 6. Perceived Stress Scores

Stress Measure	Shift Sampled			
	Cycle 1 Day 1 Mean (SD)	Cycle 1 Day 2 Mean (SD)	Cycle 2 Day 1 Mean (SD)	Cycle 2 Day 2 Mean (SD)
Perceived Stress Scale Scores[1]	4.7 (2.5)	4.7 (2.7)	5.0 (2.5)	5.3 (2.8)

[1] The greatest perceived stress scale score a participant can obtain is 16; the higher the score, the more stressed the participant.

4.6 The Relationship between Noise Exposure and Stress

Bivariate correlational analyses were conducted for all four sampling days. Prior to the bivariate correlational analyzes, we searched for multivariate outliers with Mahalanobis distance with a significance level of $p < .001$ for all four sampling days.[22] There were no multivariate outliers identified through the Mahalanobis distance analyses.

4.6.1 Cycle 1 Day 1

The bivariate correlation analyses (see Table 7) revealed statistically significant positive relationships between the A-weighted average sound pressure levels and several of the stress indicators. Those participants who were exposed to higher A-weighted average sound pressure levels, during a shift, experienced higher stress levels, as measured by the heart rate variability

[22] The identification of multivariate outliers through Mahalanobis distance was carried out by inspecting critical values. The critical value of χ^2 with degrees of freedom of 9 ($p < .001$) is 27.88; therefore, any Mahalanobis distance value that was greater than 27.88 would be considered to be an outlier. The critical value of χ^2 with 8 degrees of freedom ($p < .001$) is 26.13; therefore, any Mahalanobis distance value greater than 26.13 would have been considered an outlier (Tabachnick & Fidell, 2006).

index, the low frequency to high frequency ratio ($r = .41$, $p < .01$), their cortisol awakening response on the morning following the shift (Cycle 1, Day 2 of sampling; $r = .31$, $p < .05$), their cortisol level, area under the curve with respect to ground ($r = .49$, $p < .01$), and their perceived stress scale score ($r = .39$, $p < .01$). A significant inverse relationship was found between the A-weighted average sound pressure level and the participants' heart rate variability index, the standard deviation of NN intervals ($r = -.28$, $p < .05$), indicating that when the participants were exposed to higher A-weighted average sound pressure levels, they experienced reduced heart rate variability (indicative of higher levels of stress). The A-weighted sound pressure levels were negatively correlated with the type of shift worked during the sampling cycle ($r = -.28$, $p < .05$), meaning that the participants who were working day shifts were exposed to higher levels of sound. The only stress measure that was not found to be statistically significantly correlated with the A-weighted average sound pressure levels was the low frequency indicator of heart rate variability ($r = .03$, $p > .05$). The C-weighted peaking sound pressure was not found to correlate with any of the stress measures.

Among the statistically significant correlations identified, the A-weighted average sound pressure level explained the greatest amount of variance in the cortisol area under the curve with respect to ground (24.0%), followed by the low frequency to high frequency ratio (16.8%), the perceived stress scale scores (15.2%), the cortisol awakening response measured the following morning (9.6%), and the standard deviation of the NN intervals (8.4%).

Table 7. Pearson Correlations of Sound Measures, Heart Rate Variability, Cortisol Values, Perceived Stress Scores, and Demographic Variables, Cycle 1, Day 1 (N = 39 to 53)

Variable	2	3	4	5	6	7	8	9	10	11	12	13	14
	r	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*
1. Average sound pressure (A weighting)	0.17	-0.29*	0.03	0.41**	0.15	0.31*	0.49**	0.39**	-0.28*	-0.08	0.20	-0.22	0.25
2. Peaking sound pressure (C weighting)	1.00	-0.01	0.07	0.11	0.01	-0.05	0.08	-0.03	-0.01	0.12	0.23	-0.15	0.16
3. Standard deviation of NN intervals		1.00	-0.03	-0.40**	0.08	0.00	0.11	0.10	0.02	-0.08	-0.10	0.01	-0.19
4. Low frequency			1.00	0.05	-0.08	0.09	0.08	0.06	-0.16	0.23	-0.02	0.05	-0.50**
5. Low frequency to high frequency ratio				1.00	0.09	0.10	0.05	0.07	-0.32*	0.15	0.15	-0.19	-0.12
6. Cortisol awakening response Day 1					1.00	0.23	0.23	0.23	-0.09	-0.11	-0.03	0.20	-0.12
7. Cortisol awakening response Day 2						1.00	0.24	0.25	-0.27	-0.01	-0.12	0.10	-0.20
8. Cortisol area under the curve (ground)							1.00	0.22	-0.47**	0.01	0.05	-0.10	-0.01
9. Perceived stress scale total score								1.00	-0.16	-0.32*	0.16	-0.11	-0.18
10. Shift worked for cycle 1 (Day = 0; night/evening = 1)									1.00	-0.14	-0.09	0.17	0.22
11. Gender (female = 0; male = 1)										1.00	-0.06	0.04	-0.31*
12. Job title (other = 0; RCA = 1)											1.00	-0.46**	-0.04
13. Job title (other = 0; LPN = 1)												1.00	-0.10
14. Age													1.00

*. Correlation is significant at the .05 level (2-tailed). **. Correlation is significant at the .01 level (2-tailed).

4.6.2 Cycle 1 Day 2

The bivariate correlation analyses for the second day of the first sampling cycle (see Table 8) revealed some statistically significant positive relationships between A-weighted average sound pressure levels and some of the stress indicators. Those participants who were exposed to higher A-weighted average sound pressure levels, during their shift, experienced higher levels of stress, as measured by the heart rate variability index, low frequency to high frequency ratio ($r = .39$, $p < .01$). A significant inverse relationship was found between the A-weighted average sound pressure levels and the participants' heart rate variability index, standard deviation of NN intervals ($r = -.30$, $p < .05$), indicating that when the participants were exposed to higher A-weighted average sound pressure levels, they experienced reduced heart rate variability (indicative of higher levels of stress). The A-weighted sound pressure levels were negatively correlated with the type of shift worked during the sampling cycle ($r = -.35$, $p < .05$), meaning that the participants who worked a day shift were exposed to higher levels of sound. Several stress measures were not found to be statistically significantly correlated with the A-weighted average sound pressure levels, including the low frequency indicator of heart rate variability ($r = -.02$, $p > .05$), the cortisol area under the curve with respect to ground ($r = -.05$, $p > .05$), and the perceived stress scale score ($r = .07$, $p > .05$). The C-weighted peaking sound pressure values were not found to correlate with any of the stress measures. Among the statistically significant correlations identified, the A-weighted average sound pressure explained the greatest amount of variance in the low frequency to high frequency ratio (15.2%), followed by the standard deviation of the NN intervals (9.0%).

Table 8. Pearson Correlations of Sound Measures, Heart Rate Variability, Cortisol Values, Perceived Stress Scores, and Demographic Variables, Cycle 1, Day 2 (N = 42 to 53)

	2	3	4	5	6	7	8	9	10	11	12	13
	r	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*
1. Average sound pressure (A weighting)	0.36**	-0.30*	-0.02	0.39**	0.31*	-0.05	0.07	-0.35*	-0.18	0.13	0.02	0.35*
2. Peaking sound pressure (C weighting)	1.00	-0.04	-0.22	0.05	0.10	0.08	-0.04	-0.01	-0.17	0.29*	-0.22	0.30
3. Standard deviation of NN intervals		1.00	-0.06	-0.45**	0.04	0.14	0.19	0.02	-0.06	-0.05	-0.09	-0.30*
4. Low frequency FFT spectrum			1.00	0.05	0.01	-0.06	0.00	-0.27*	0.33*	-0.01	0.16	-0.51**
5. Low frequency to high frequency ratio FFT spectrum				1.00	0.17	-0.04	-0.05	-0.24	0.06	0.00	0.01	0.01
6. Cortisol awakening response					1.00	0.20	0.13	-0.27	-0.01	-0.12	0.10	-0.20
7. Cortisol area under the curve (ground)						1.00	0.20	0.08	-0.06	0.08	-0.04	-0.10
8. Perceived stress scale total score							1.00	-0.10	-0.30*	0.12	-0.24	-0.19
9. Shift worked cycle 1 (Day = 0; night/evening = 1)								1.00	-0.14	-0.09	0.17	0.22
10. Gender (female = 0; male = 1)									1.00	-0.06	0.04	-0.31*
11. Job title (Other = 0, RCA = 1)										1.00	-0.46**	-0.04
12. Job title (Other = 0, LPN = 1)											1.00	-0.10
13. Age												1.00

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

4.6.3 Cycle 2 Day 1

The bivariate correlation analyses for the first day of the second sampling cycle (see Table 9) revealed a statistically significant relationship between the A-weighted average sound pressure levels and two of the stress indicators. Those participants who were exposed to higher A-weighted average sound pressure levels, during their shift, experienced more stress, as measured by the heart rate variability index, low frequency to high frequency ratio ($r = .33$, $p < .05$). A significant inverse relationship was found between A-weighted average sound pressure levels and the participants' heart rate variability index standard deviation of NN intervals ($r = -.31$, $p < .05$), indicating that when the participants were exposed to higher A-weighted average sound pressure levels, they experienced reduced heart rate variability (indicative of higher levels of stress). The A-weighted sound pressure level, during this particular sampling day, was not found to significantly correlate with the type of shift worked ($r = -.27$, $p > .05$). There were several stress measures that were found not to be statistically significantly correlated with the A-weighted average sound pressure levels, including the cortisol awakening response measured on the following morning (Cycle 2, Day 2; $r = -.17$, $p > .05$), the cortisol area under the curve with respect to ground ($r = -.14$, $p > .05$), and the perceived stress scale score ($r = .07$, $p > .05$). Among the statistically significant correlations identified, the A-weighted average sound pressure levels explained 10.9% of the variance in the low frequency to high frequency ratio, and 9.6% of the variance in the standard deviation of NN intervals.

Table 9. Pearson Correlations of Sound Measures, Heart Rate Variability, Cortisol Values, Perceived Stress Scores, and Demographic Variables, Cycle 2, Day 1 (N = 41 to 52)

	2	3	4	5	6	7	8	9	10	11	12	13	14
	r	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*
1. Average sound pressure (A weighting)	0.09	-0.31*	0.00	0.33*	0.36*	-0.17	-0.14	0.07	-0.27	-0.06	-0.11	-0.05	0.11
2. Peaking sound pressure (C weighting)	1.00	0.10	0.24	0.11	0.11	0.02	-0.07	0.06	-0.04	0.07	-0.15	0.10	-0.04
3. Standard deviation of NN intervals		1.00	-0.12	-0.38**	-0.15	0.08	0.02	-0.12	0.08	0.02	0.00	0.05	-0.35*
4. Low frequency FFT spectrum			1.00	0.15	0.26	-0.06	-0.02	0.04	-0.30*	0.24	-0.13	-0.01	-0.41**
5. Low frequency to high frequency ratio FFT spectrum				1.00	0.09	-0.18	-0.18	-0.05	-0.26	-0.03	0.10	-0.09	0.09
6. Cortisol awakening response Day 1					1.00	-0.05	0.01	0.12	-0.20	0.12	-0.06	0.06	0.10
7. Cortisol awakening response Day 2						1.00	0.29	0.23	0.11	-0.13	-0.01	-0.07	0.01
8. Cortisol area under the curve (ground)							1.00	0.02	0.25	0.12	-0.13	-0.03	0.07
9. Perceived stress scale total score								1.00	0.07	-0.32*	0.00	-0.10	0.09
10. Shift worked cycle 2 (Day = 0, night/evening = 1)									1.00	-0.02	-0.11	0.17	0.18
11. Gender (female = 0; male = 1)										1.00	-0.06	0.04	-0.31*
12. Job title (other = 0, RCA = 1)											1.00	-0.46**	-0.04
13. Job title (other = 0, LPN = 1)												1.00	-0.10
14. Age													1.00

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

4.6.4 Cycle 2 Day 2

The bivariate correlation analyses for the fourth and final sampling day (see Table 10) revealed statistically significant relationships between the A-weighted average sound pressure levels and two of the stress measures. Those participants who were exposed to higher A-weighted average sound pressure levels, during their shift, experienced higher stress levels, as measured by the heart rate variability index, low frequency to high frequency ratio ($r = .34$, $p < .05$). A significant inverse relationship was also found between the A-weighted average sound pressure levels and the participants' heart rate variability index, the standard deviation of NN intervals ($r = -.35$, $p < .05$), indicating that when the participants were exposed to higher A-weighted average sound pressure levels, they experienced reduced heart rate variability (indicative of higher levels of stress). The A-weighted average sound pressure levels were negatively correlated with the type of shift worked during the sampling cycle ($r = -.29$, $p < .05$), meaning that the participants who worked a day shift were exposed to more sound. There were several stress measures that were not found to be statistically significantly correlated with the A-weighted average sound pressure levels, including the heart rate variability index, low frequency ($r = .17$, $p > .05$), the cortisol area under the curve with respect to ground ($r = -.13$, $p > .05$), and the perceived stress scale scores ($r = .03$, $p > .05$). The C-weighted peaking sound pressure was not found to correlate with any of the stress measures. Among the statistically significant correlations identified, the A-weighted average sound pressure level explained 12.3% of the variance in the standard deviation of NN intervals, and 11.6% of the variance in the low frequency to high frequency ratio.

Table 10. Pearson Correlations of Sound Measures, Heart Rate Variability, Cortisol Values, Perceived Stress Scores, and Demographic Variables, Cycle 2, Day 2 (N = 38 to 52)

	2	3	4	5	6	7	8	9	10	11	12	13
	r	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*
1. Average sound pressure (A weighting)	0.21	-0.35*	0.17	0.34*	-0.04	-0.13	0.03	-0.29*	-0.23	-0.07	0.07	0.24
2. Peaking sound pressure (C weighting)	1.00	0.22	0.06	-0.11	0.05	0.01	0.23	-0.04	-0.13	-0.01	0.01	-0.08
3. Standard deviation of NN intervals		1.00	-0.10	-0.47**	0.03	0.17	0.04	0.20	0.10	-0.07	0.17	-0.31*
4. Low frequency FFT spectrum			1.00	0.10	-0.16	-0.10	-0.01	-0.37**	0.08	-0.16	-0.13	-0.45**
5. Low frequency to high frequency ratio FFT spectrum				1.00	-0.10	-0.24	-0.18	-0.23	-0.05	0.15	-0.13	0.09
6. Cortisol awakening response					1.00	0.35*	0.07	0.11	-0.13	-0.01	-0.07	0.01
7. Cortisol area under the curve (ground)						1.00	0.11	0.32*	0.04	0.10	0.01	0.03
8. Perceived Stress Scale Total Score							1.00	0.25	-0.29*	0.12	-0.16	0.03
9. Shift worked for cycle 2 (Day = 0; night/evening = 1)								1.00	-0.02	-0.11	0.17	0.18
10. Gender (female = 0, male = 1)									1.00	-0.06	0.04	-0.31*
11. Job title (other = 0, RCA= 1)										1.00	-0.46**	-0.04
12. Job title (other = 0, LPN = 1)											1.00	-0.10
13. Age												1.00

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

4.7 Multiple Linear Regression Analyses

Once the bivariate correlation analyses of the relationships among the noise measures, stress indicators, and demographic variables were completed, multiple linear regression analyses were conducted with the predictor variables of stress that were found to be statistically significant. Although statistically significant, age was excluded from these analyses because it was missing for nine participants and the reduction in power that would result from listwise deletion was a significant problem.

4.7.1 Cycle 1 Day 1

Linear regression analysis (see Table 11) was conducted to assess the ability of the A-weighted average sound pressure levels and the type of shift worked during the first day of Cycle 1 to predict the participants' stress levels, as measured with the heart rate variability indices, the cortisol measures, and the perceived stress scale scores. The regression model that included both the A-weighted average sound pressures and the type of shift worked explained 8.0% of the variance in the standard deviation of the NN intervals, F (2, 50) = 2.38, p = .10, and 21% of the variance in the low frequency to high frequency ratio, F (2, 50) = 6.81, p < .01. The A-weighted sound pressure levels made the strongest unique contribution in explaining the variability in the low frequency to high frequency ratios ((β = .35, p < .05), followed by the standard deviation of the NN intervals (β = -.31, p < .05). The type of shift worked in Cycle 1 did not make a statistically significant contribution to either of these heart rate variability indices, after the A-weighted average sound pressure level was controlled.

The regression model that included both the A-weighted average sound pressure levels and the type of shift worked explained 14.0% of the variance in the cortisol awakening response (measured on the following day of the sampling cycle), F (2, 48) = 3.80, $p < .05$, and 37.0% of the variance in the cortisol area under the curve with respect to ground, F (2, 43) = 12.60, $p < .01$. The A-weighted average sound pressure made the strongest unique contribution in explaining the cortisol area under the curve with respect to ground ($\beta = .40$, $p < .05$), followed by the cortisol awakening response measured during Cycle 1, Day 2 ($\beta = .26$, $p < .05$). Although the type of shift worked during Cycle 1 did not make a statistically significant contribution to the cortisol awakening response, it did make a statistically significant contribution to the cortisol area under the curve with respect to ground ($\beta = -.37$, $p < .05$).

Finally, the regression model that included both the A-weighted average sound pressure and the type of shift worked explained 16.0% of the variance in the perceived stress scale scores, F (2, 48) = 4.50, $p < .05$. The A weighted average sound pressure made a significant and unique contribution to explaining the perceived stress scale scores ($\beta = .38$, $p < .05$). The type of shift worked during Cycle 1 did not make a statistically significant contribution to the explanation of the perceived stress scale scores.

Table 11. Linear Regression of Stress Indicators on Noise Exposure and Shift Worked (Cycle 1, Day 1)

	Stress Indicators									
	Standard Deviation of NN intervals		Low frequency to high frequency ratio		Cortisol awakening response, Day 2 (next morning)		Cortisol area under the curve (ground)		Perceived stress scale score	
	b (95% C.I.)	β	b (95% C.I.)	β	b (95% C.I.)	β	b (95% C.I.)	β	b (95% C.I.)	β
Explanatory Variables										
Average sound pressure (A weighted)	-2.20* (-4.22, -0.12)	-0.31*	0.27* (0.07, 0.48)	0.35*	0.66 (-0.06, 1.38)	0.26	5.91* (2.13, 9.68)	0.40*	0.30* (0.08, 0.52)	0.38*
Shift worked (Night/evening vs. day shift)	-2.85(-15.86, 0.15)	-0.06	1.14 (-2.46, 0.18)	-0.23	-3.56 (-8.22, 1.10)	-0.21	-35.40* (-59.38,-11.42)	-0.37*	-0.32 (-1.73, 1.10)	-0.06
Model Statistics										
R-squared	0.08		0.21		0.14		0.37		0.16	

*. Coefficient is significant at < .05 level (2-tailed).

4.7.2 Cycle 1 Day 2

Linear regression analysis (see Table 12) was conducted to assess the ability of the A-weighted average sound pressure levels and the type of shift worked during the second day of Cycle 1 to predict the participants' stress levels, as measured with the heart rate variability indices, standard deviation of NN intervals and low frequency to high frequency ratio. The regression model that included both the A-weighted average sound pressures and the type of shift worked explained 10.0% of the variance in the standard deviation of the NN intervals, F (2, 50) = 2.69, p = .08, and 17% of the variance in the low frequency to high frequency ratio F (2, 50) = 4.97, $p <$ .05. The A-weighted average sound pressure levels made the strongest unique contribution in explaining the variability in the low frequency to high frequency ratios (β = .35, $p <$ .05), followed by the standard deviation of NN intervals (β = -.33, $p <$ .05). The type of shift worked in Cycle 1 did not make a statistically significant contribution to either of these heart rate variability indices, after the A-weighted average sound pressure level was controlled.

Table 12. Linear Regression of Stress Indicators on Noise Exposure and Shift Worked (Cycle 1, Day 2)

	Stress Indicators			
	Standard deviation of NN intervals		Low frequency to high frequency ratio	
	b (95% C.I.)	β	b (95% C.I.)	β
Explanatory Variables				
Average sound pressure level (A weighted)	-2.23 (-4.17, -0.30)*	-0.33*	0.29 (0.06, 0.53)*	0.35*
Shift worked (Night/evening vs. day shift)	-4.27 (-17.02, 8.48)	-0.10	-0.66 (-2.19, 0.87)	-0.12
Model Statistics				
R-squared	0.10		0.17	

*. Coefficient is significant at < .05 level (2-tailed).

4.7.3 Cycle 2 Day 2

Linear regression analysis (see Table 13) was conducted to assess the ability of the A-weighted average sound pressure levels and the type of shift worked during the second day of Cycle 2 to predict the participants' stress levels, as measured with the heart rate variability indices, the standard deviation of the NN intervals and low frequency to high frequency ratio. The regression model that included both the A-weighted average sound pressures and the type of shift worked explained 13% of the variance in the standard deviation of NN intervals, F (2, 49) = 3.79, $p < .05$, and 13% of the variance in the low frequency to high frequency ratios, F (2, 49) = 3.75, $p < .05$. The A-weighted average sound pressure levels made the strongest unique contribution in explaining the variability in the standard deviation of NN intervals ($\beta = -.32$, $p < .05$), followed by the low frequency to high frequency ratio ($\beta = .29$, $p < .05$). The type of shift worked in Cycle 2 did not make a statistically significant contribution to either of these heart rate variability indices, after the A-weighted average sound pressure level was controlled.

Table 13. Linear Regression of Stress Indicators on Noise Exposure and Shift Worked (Cycle 2, Day 2)

	Outcome Variables			
	Standard Deviation of NN intervals		Low frequency to high frequency ratio	
	b (95% C.I.)	β	b (95% C.I.)	β
Explanatory Variables				
Average sound pressure level (A weighted)	-2.45 (-4.58, -0.33)*	-0.32*	0.27 (0.01, 0.53)*	0.29*
Shift Worked (Night/evening vs. day shift)	5.12 (-8.52, 18.76)	0.11	-0.89 (-2.55, 0.78)	-0.15
Model Statistics				
R-squared	0.13		0.13	

*. Coefficient is significant at < .05 level (2-tailed).

5 Discussion

5.1 Summary

On average, the participants in the study were exposed to A-weighted average sound pressure levels ranging from 74.4 to 74.8 dB(A), which did not exceed the standards and guidelines specified by the Canadian Centre for Occupational Health and Safety (CCHOS, 2011) and WorkSafeBC (2005).[23] However, the A-weighted average sound pressure levels detected were well above the guidelines provided by the WHO (1999), which recommended that sound levels should not exceed 40 dB during the night, and 30 dB during the day or evening. In comparison to the current literature, the A-weighted average sound pressure levels detected were above those measured in acute care settings, which have ranged from 45 dB(A) (Okcu et al., 2011) to 71 dB(A) (Ryherd et al., 2008). Researchers have shown that a stress response originating from the autonomic nervous system could occur with sound levels as low as 65 dB (Buelow, 2001); the participants of this study were exposed to sound levels well above that limit. On average, the long-term care healthcare workers enrolled in this study were exposed to C-weighted peaking sound pressure levels ranging between 124.6 and 126.8 dB(C), which are much higher than those reported in critical care settings. Although these healthcare workers might not have been exposed to high sound levels continuously during their working shifts,

[23] The Canadian Centre for Occupational Health and Safety (CCHOS, 2011) outlined that a worker should not be exposed to a sound level of 90 dB(A) in an eight-hour working shift, while WorkSafeBC (2005) specified that the limit is 85 dB(A).

repetitive, instantaneous, and fluctuating sound pressure levels could still be considered annoying (Sanchez et al., 2008).

The bivariate correlations and multiple linear regression analyses revealed that the healthcare workers who were exposed to higher sound levels experienced more stress, which is consistent with the evidence found in the current literature. A-weighted average sound pressure levels were significantly and consistently correlated with two heart rate variability indices, the standard deviation of the NN intervals and the low frequency to high frequency ratio, for each of the four sampling days. The strength of the correlations found was between small to medium (r = -.29 to .41). Statistically significant correlations were found between the type of shift the participants worked and the A-weighted average sound pressure levels in three of the sampling days (i.e., Cycle 1, Day 1; Cycle 1, Day 2; and Cycle 2, Day 2). Several published research reports have also noted that the type of shift is significantly associated with noise and thus noise-induced stress (Topf & Dhillon, 1988) and with sound characteristics (Blomkvist et al., 2005). The A-weighted average sound pressure levels were found to make the most unique contribution to explaining the variability of the two relevant heart rate variability indices: the standard deviation of the NN intervals and the low frequency to high frequency ratio. The type of shift worked, however, was not found to make a significant contribution to either of these heart rate variability indices after the A-weighted average sound pressure level was statistically controlled. Overall, of the stress indicators examined, two heart rate variability indices, the standard deviation of the NN intervals and the low frequency to high frequency ratio, were the only stress measures that were found to be associated with the average sound pressure levels.

5.2 Strengths and Limitations of the Study

This study contributes to the current scientific knowledge of healthcare workers' exposure to sound energy, and the relationship between noise and workers' stress in long-term care facilities. A strength of the current study was the attempt to enhance the representativeness of the sample by employing a stratified randomization procedure in selecting the research sites. Another strength was the improvement in the noise exposure assessment and stress response measurements with the utilization of repeated measurements over four sampling days. In addition, triangulation of biophysiological and subjective measures to evaluate the participants' stress responses also strengthened the study findings. Critical and detailed evaluation of the reliability and validity of various measures and instruments was carried out prior to selection and data collection to ensure data accuracy and consistency as well as to improve the overall soundness of the results (Polit & Beck, 2012).

There were some weaknesses of the study worthy of mention, including the inability to reach the goal of recruiting 15 long-term care facilities with 15 enrolled participants from each site. This problem resulted in a smaller sample size, which limited the statistical power available. Although the analysis presented here was based on a smaller sample size than was initially hoped for, the regression models were still able to explain a relatively large proportion of the variability in the stress indicators. Another weakness of the study was the amount of missing data associated with some of the demographic variables and stress indicators. More specifically, the participants' age had to be excluded from the multiple regression analysis of the Cycle 1, Day 2 data, even though it was significantly correlated with the A-weighted average sound pressure levels and the standard deviation of the NN intervals.

5.3 Implications for Practice and Future Research

Results of the current study suggest that healthcare workers in the long-term care environment are exposed to sound levels that are higher than those found in acute care settings. It also has been revealed that when these healthcare workers are exposed to greater sound levels, they experience higher levels of stress. Thus, strategies and interventions should be employed by regulatory bodies, facilities, and employers to reduce the noise levels in these workplaces. Indeed, many researchers have suggested that it is crucial to examine the sources of noise, in addition to general sound level monitoring, to identify and implement effective noise reduction interventions (Dube et al., 2008; Gladd & Saunders, 2008; Morrison et al., 2003; Sanchez et al., 2008). Some of the most common noise reduction interventions that have recommended include making modifications to equipment and patient monitoring devices (Gladd & Saunders, 2011; Ryherd et al., 2008), improvements to staff communication through behaviour modification (Gladd & Saunders, 2011; Morrison et al., 2003), and changes to the architectural design of the work area (Sanchez et al., 2008).

Before the implementation of various noise reduction interventions, further research is required to determine the major sources of noise in the long-term care setting. More important, it may be necessary to examine additional acoustical characteristics (Ryherd et al., 2008), such as reverberation times[24] and speech intelligibility,[25] within long-term care facilities to provide

[24] Reverberation time, a common acoustical descriptor, refers to the time required (in seconds) for the average sounds levels in an enclosed space to decrease by 60 decibels after a source stops generating sound (Acousitcs.com, 2004).

[25] Speech intelligibility or speech clarity refers to the quality of speech transfer to listeners. Speech intelligibility is often affected by background noise, reverberation times, and echoes (Ecophon Group, 2013).

researchers, healthcare workers, and employers with a better understanding of how structural factors affect the soundscape of the environment. Assessments of acoustical characteristics would also assist the facilities in identifying the most effective and appropriate noise reduction strategies. Researchers may also want to consider the special resident population and architectural designs (i.e., age of the building, types of flooring, ventilation systems, and the presence of acoustical building materials) of the long-term care facilities because they may differ from those in acute care settings. Research that employs a similar methodology, which includes a random sampling procedure, triangulation of measures, and repeated measurements of study variables with a larger sample size is required to provide healthcare professionals and their employers a better overview of how the acoustical environment affects the working conditions and stress levels of long-term care employees.

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Appendix A

The Setting and Sample Selection Procedures

Table 14. Availability of General Information about Long-Term Care Facilities by Location

Location	N (information available)	N (no information available)
Contracted Facility (Vancouver)[26]	21	7
VCH operated (Vancouver)	3	1
Providence Health Care	5	0
North Shore	3	4
Richmond	1	4
Total	33	16

Note. VCH = Vancouver Coastal Health.

Table 15. Type of Facility by Name (of those with information available)
[the names are not given to protect the facilities' privacy]

Type of Facility	Name of Facility
Contracted facilities in Vancouver	Facility A
	Facility B
	Facility C
	Facility D
	Facility E
	Facility F
	Facility G
	Facility H
	Facility I
	Facility J
	Facility K
	Facility L
	Facility M
	Facility N
	Facility O

[26] Vancouver Costal Health (VCH) operates some long-term care facilities, and contracts other private facilities.

Type of Facility	Name of Facility
	Facility P
	Facility Q
	Facility R
	Facility S
	Facility T
	Facility U
VCH operated facilities in Vancouver	Facility V
	Facility W
	Facility X
Providence Health facilities	Facility Y
	Facility Z
	Facility AB
	Facility AC
	Facility AD
North Shore facilities	Facility AE
	Facility AF
	Facility AG
Richmond facilities	Facility AH

Note. VCH = Vancouver Coastal Health.

Table 16. Frequency Distributions of Categorical Noise Factors

Noise Factor	N = 33 n (%)
On a busy road	18 (55)
Windows	
Single-pane windows	5 (16)
Double-pane windows	27 (84)
On a busy road and single-pane windows	2 (6)
Carpeting	
None	5 (15)
Minimal	11 (33)
Some	17 (52)
Acoustical ceiling tiles	24 (75)
Wood frame building	9 (27)
HVAC	
None	1(3)
Heating and ventilation (no cooling)	5 (15)
Full	27 (82)

Note. HVAC = Heating, Ventilation, and Air Conditioning.

Table 17. Descriptive Statistics of Continuous Noise Factor Variables

Noise Factor	N = 33 (%)	Mean (SD)	Median	Range
Floor size (feet^2)	32 (97)	81,886 (39,143)	74,474	25,124-186,000
Number of beds	33 (100)	136 (58)	127	55-300
Floor size/bed ratio	32 (97)	629 (227)	558	272-1432
Year built	33 (100)	1977 (18)	1981	1914-2003
Number of floors	33 (100)	3.9 (3.1)	3	1-15
Number of elevators	32 (97)	2.2 (0.8)	2	0-4
Year of most recent renovation	22 (67)	1997 (5)	1997	1988-2011

Table 18. Frequency Distributions of the Categorized Continuous Noise Factor Variables

Noise Factor	N = 33 (%)
Number of beds (3 categories)	
< 100	10 (30)
100-150	12 (36)
> 150	11 (34)
Floor size – feet^2 (4 categories)	
< 50,000	6 (19)
50,000 – 74,999	10 (31)
75,000 – 99,999	8 (25)
> 99,999	8 (25)
Year built (3 categories)	
< 1970	10 (30)
1970 – 1989	13 (40)
> 1989	10 (30)

Table 19. Noise Factors by Facility Name

Noise Factor	N	Facility
Single pane windows	4	Facility V; Facility C; Facility AB; Facility T
No carpeting	5	Facility Y; Facility I; Facility K; Facility AH; Facility S
No or minimal acoustical ceiling tiles	7	Facility C; Facility I; Facility K; Facility M; Facility N; Facility R; Facility S
Wood frame	9	Facility B; Facility W; Facility I; Facility Z; Facility K; Facility M; Facility O; Facility R; Facility S
No HVAC	1	Facility C
Vent and Heating (no cooling)	5	Facility B; Facility G; Facility W; Facility J; Facility X

Noise Factor	N	Facility
HVAC noise problem complaints; HVAC system was turned on only during the day	1	Facility R
Number of beds		
Least	3	Facility O; Facility H; Facility A
Median	1	Facility AF
Most	3	Facility X; Facility AH; Facility AC
Floor size		
Smallest	3	Facility B; Facility A; Facility O
Median	1	Facility AF
Largest	3	Facility AG; Facility W; Facility X
Floor size/number of beds ratio		
Smallest	3	Facility S; Facility B; Facility I
Median	1	Facility X
Largest	3	Facility W; Facility AG; Facility AD
Year built		
Earliest	3	Facility O; Facility AB; Facility W
Median	1	Facility D
Most recent	3	Facility G; Facility P; Facility A
Renovations		
Earliest	3	Facility Z; Facility M; Facility O
Median	2	Facility Y; Facility K
Most recent	3	Facility U; Facility D; Facility AC
Single pane and on a busy road	2	Facility AB; Facility T
No acoustical ceiling tiles and no carpeting	3	Facility I; Facility K; Facility S
No acoustical ceiling tiles and minimal carpeting	2	Facility M; Facility AD

Table 20. Number of Times Facility Mentioned in Table 19

Facility	N	Facility	N
Facility W	5	Facility AG	2
Facility I	5	Facility AH	2
Facility K	5	Facility AC	2
Facility X	5	Facility AD	2
Facility O	5	Facility T	2
Facility S	5	Facility V	1
Facility B	4	Facility H	1
Facility M	4	Facility J	1
Facility A	3	Facility N	1

Facility	N	Facility	N
Facility C	3	Facility P	1
Facility AB	3	Facility U	1
Facility R	3	Facility E	0
Facility D	2	Facility F	0
Facility Y	2	Facility AE	0
Facility AF	2	Facility L	0
Facility G	2	Facility Q	0
Facility Z	2		

Stratified random sample was obtained with Excel random number generator. Two facilities were selected from each of the six discrete numeric counts listed in Table 20.

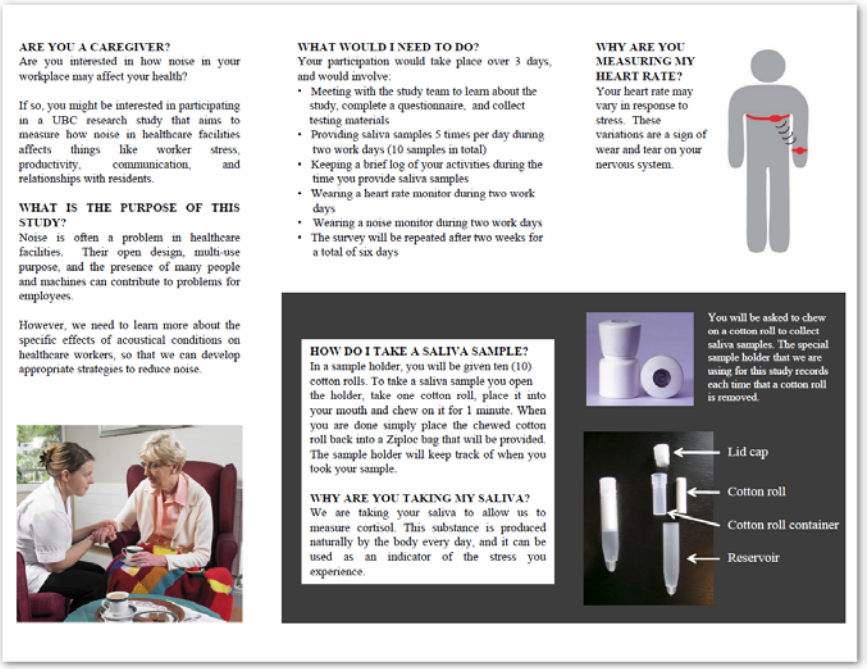
Table 21. Facilities Randomly Selected for Study

Facility	Number of Mentions in Table 19
Facility I	5
Facility X	5
Facility M	4
Facility B	4
Facility AB	3
Facility R	3
Facility AH	2
Facility N	1
Facility J	1
Facility F	0
Facility Q	0

Three facilities were added to the random sample:
Facility O (i.e., oldest, least number of beds, and the smallest), Facility T (single pane windows and on a busy street), and Facility AI (became interested after the pilot study presentation)

Appendix B

Study Brochure



Appendix C

Consent Form

SUBJECT INFORMATION AND CONSENT FORM

The Evaluation of Acoustical Environments in Long Term Care Facilities and the risk of Aggressive Behaviour and Work Place Stress

Principal Investigator: George Astrakianakis, PhD
School of Population and Public Health, UBC

Co-Investigator(s): Murray Hodgson, PhD, C.Eng
School of Population and Public Health, UBC

Mrs Maureen Haddock, B.S.R
Ergonomics: Facilities Planning and Project Development Vancouver Coastal Health Authority

Pamela Ratner, PhD
School of Nursing, UBC

Sponsor: WorkSafeBC

1. INVITATION TO PARTICIPATE

You are being invited to take part in this research study which evaluates the effects of the acoustical environment in your workplace. We have recently conducted a pilot study of residential care facilities showing that the acoustical quality of some Long Term Care working environments may be poor. However, we need to learn more about the specific effects of noise and acoustical conditions on your health and more broadly on the healthcare workforce. As a professional caregiver, we would like to invite you to participate in our study.

2. YOUR PARTICIPATION IS VOLUNTARY

Your participation is entirely voluntary, so it is up to you to decide whether or not to take part in this study. Before you decide, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen to you during the study and the possible benefits, risks and discomforts.

If you wish to participate, you will be asked to sign this form. If you do decide to take part in this study, you are still free to withdraw at any time and without giving any reasons for your decision.

If you do not wish to participate, you do not have to provide any reason for your decision not to participate. Whether or not you participate will have no effect on your employment status.

3. WHO IS CONDUCTING THE STUDY?

This study is being funded by WorkSafeBC, the provincial workers' compensation Board. You may request details of the funding, if you wish to do so.

The principal investigator has no conflict of interest in undertaking this study.

4. BACKGROUND

Noise is an increasing a problem in healthcare facilities. Long Term Care facilities are no exception: many have open plan designs, use multi-purpose rooms, and along with the presence of many people and machines can contribute to noise problems for both patients and employees. While there is good evidence on the effects of poor acoustical conditions on patients (for example on sleep quality), little is known about the effect on staff. Our goal is to learn more about specific effects of noise and acoustical conditions on healthcare workers (nurses, nurses' assistants, rehabilitation workers) so that we can develop appropriate strategies to reduce noise and ultimately have healthy working conditions.

5. WHAT IS THE PURPOSE OF THE STUDY?

The purpose of this study is to evaluate the effects of acoustical conditions on aspects like stress, productivity, communication and relationships with patients, particularly aggressive behaviors. You will be asked to fill out a questionnaire as well as a short daily survey (daily diary) for two consecutive days at the end of each shift. We will also be measuring your cortisol levels using saliva samples and monitoring your heart rate for two consecutive days in order to measure your physiologic responses with respect to the acoustical quality of your workplace.

We will ask you to complete this procedure two (2) times; an initial 2-day sample collection and then again following a two-week interval, a second 2-day sample collection.

You will also be asked to wear a sampling device that will collect data on the noise levels during your workday. You will need to wear this only while at work.

6. WHO CAN PARTICIPATE IN THE STUDY?

If you are a professional caregiver (e.g. RN, LPN, nurse assistant) and if you work full-time, you are eligible to participate in the study.

7. WHO SHOULD NOT PARTICIPATE IN THE STUDY?

If you have had a heart-attack or stroke in the past 6 months, if you suffer from heart conditions, and work only part-time, you cannot participate in the study. Participants who are pregnant are also asked not to participate as their samples will likely distort the results.

8. WHAT DOES THE STUDY INVOLVE?

Overall, the total amount of time required for your participation is 3 hours. This would take place over 3 days, and would involve:

- Meeting with the study team to learn about the study, complete a questionnaire on your own time (less than 35 minutes to complete) and collect testing materials. The questionnaire will ask you questions about your work environment to help us learn about the effect of noise on your health from other possible factors related to your job demands.
- Providing saliva samples on two work days (10 samples in total taken over 2 days)
- Keeping a short daily diary on the two work days (less than 10 minutes) to assess incidents of aggressive behaviour, your mood and perceived stress.
- Wearing a heart rate monitor during two work days
- Wearing a noise monitor during two work days
- Repeating the sampling procedures (cortisol, heart rate, and noise) a second time approximately two weeks after the initial sample collection

Even if you choose to take part in this study, you do not have to answer any questions in the questionnaire that you do not feel comfortable answering

No specific testing, other than the criteria outlined above, is required to determine eligibility.

If you agree to take part in this study, the procedures and visits you can expect will include the following:

<u>Scheduling meeting</u>
The research investigators will explain the goal of the study, display and demonstrate in a general meeting how to use the equipment, which consists of a vial filled with five (5) cotton swabs to collect the saliva samples, a heart rate monitor with its chest band. At the end of the meeting, and after reviewing the consent form, your working schedules and contact information will be collected to set up a time to complete the study. A questionnaire will be given to you to complete on your own time.

Part I:

- <u>Off-work (Day 1)</u>
  Once the scheduling is completed, the research coordinator or a research assistant will meet with you outside your workplace to give you your salivary samples for one day. The use of equipment will be explained, demonstrated and set up for you.

- Sampling in workplace (Days 2 and 3)

  Following your day off-work, you will be provided at the start of each shift for two consecutive days, with the same equipment and with a short questionnaire to complete at the end of shift. At the end of each day, the equipment will be retrieved as well as the salivary samples.

Part II: Sampling procedures for Part I will be repeated after two weeks.

9. WHAT ARE MY RESPONSIBILITIES?

Throughout the two days of sampling, you are asked to comply to the best of your ability with the instructions. The vial you will be provided with will track the time of each opening and closing in order to help us follow up your activities during the day and make sure we interpret the analysis result accurately.

10. WHAT ARE THE POSSIBLE HARMS AND SIDE EFFECTS OF PARTICIPATING?

There are no expected harms or side effects. However, some of the questions in the questionnaires are of a personal nature and some participants may find them upsetting. Participants are not required to answer any questions that they do not wish to answer.

11. WHAT ARE THE BENEFITS OF PARTICIPATING IN THIS STUDY?

There may or may not be direct benefits to you from taking part in this study. However, your personal cortisol and heart rate levels will be communicated and explained to you after collecting and analyzing the data.

12. WHAT IF NEW INFORMATION BECOMES AVAILABLE THAT MAY AFFECT MY DECISION TO PARTICIPATE?

Given the short time period of this project, it is unlikely that new information would arise.

13. WHAT HAPPENS IF I DECIDE TO WITHDRAW MY CONSENT TO PARTICIPATE?

Your participation in this research is entirely voluntary. You may withdraw from this study at any time. If you decide to enter the study and to withdraw at any time in the future, there will be no penalty or loss of benefits to which you are otherwise entitled, and your employment status will not be affected.

If you choose to enter the study and then decide to withdraw at a later time, all data collected about you during your enrolment in the study will be retained for analysis. By law, this data cannot be destroyed.

14. WHAT HAPPENS IF SOMETHING GOES WRONG?

Signing this consent form in no way limits your legal rights against the sponsor, investigators, or anyone else.

15. WHAT HAPPENS AFTER THE STUDY IS FINISHED?

Once your participation is concluded, we will send you a letter summarizing your heart rate results and cortisol levels, along with explanation of what your levels mean.

16. WHAT WILL THE STUDY COST ME?

This study will not incur any personal expenses.

You will be paid for your participation in our project. The honorarium for your participation will be in the form of a gift certificate of $40.

17. WILL MY TAKING PART IN THIS STUDY BE KEPT CONFIDENTIAL?

Your confidentiality will be respected. No information that discloses your identity will be released or published without your specific consent to the disclosure. However, research records identifying you may be inspected in the presence of the investigator and his or her designate by representatives of WorkSafe BC, and the UBC Research Ethics Board for the purpose of monitoring the research. No records which identify you by name or initials will be allowed to leave the Investigator's offices. Your date of birth will be collected using only month and year to reduce collection of identifying information and protect your confidentiality.

The list linking your personal information to data will be destroyed after all physiologic markers are gathered and questionnaires are completed, and all data is analyzed, summarized, and reported to you.

18. WHO DO I CONTACT IF I HAVE QUESTIONS ABOUT THE STUDY DURING MY PARTICIPATION?

If you have any questions, or desire further information with respect to this study, you may contact Dr. George Astrakianakis (Principal Investigator) at 604-827-5189, Dr. Murray Hodgson (co-investigator) at 604-822-3073, or Yat Chow (study coordinator) at 604-827-5791.

19. WHO DO I CONTACT IF I HAVE ANY QUESTION OR CONCERNS ABOUT MY RIGHTS AS A SUBJECT DURING THE STUDY?

If you have any concerns about your treatment or rights as a research subject, you may contact the Research Subject Information Line in the UBC Office of Research Services at 604-822-8598 or if long distance e-mail to RSIL@ors.ubc.ca.

20. SUBJECT CONSENT TO PARTICIPATE

Your signature below indicates that you have read this consent and agree to participate in this study.

- I have read and understood the subject information and consent form.
- I have had sufficient time to consider the information provided and to ask for advice if necessary.
- I have had the opportunity to ask questions and have had satisfactory responses to my questions.
- I understand that all of the information collected will be kept confidential and that the results will only be used for scientific objectives.
- I understand that my participation in this study is voluntary and that I am completely free to refuse to participate or to withdraw from this study at any time without any effect on my employment status.
- I understand that I am not waiving any of my legal rights as a result of signing this consent form.
- I have read this form and I freely consent to participate in this study.
- I have been told that I will receive a dated and signed copy of this form.

SIGNATURES

_____	_____	_____
Printed name of subject	Signature	Date

_____	_____	_____
Printed name of witness	Signature	Date

_____	_____	_____
Printed name of principal investigator/ designated representative	Signature	Date

Appendix D

Perceived Stress Scale

The questions in this scale ask you about your feelings and thoughts during the **last 24 hours**.

Please indicate with a check how often you felt or thought a certain way.

1. How often have you felt that you were unable to control the important things in your life?

   ___ 0 = Never ___ 1 = Almost never

   ___ 2 = Sometimes ___ 3 = Fairly often

   ___ 4 = Very often

2. How often have you felt confident about your ability to handle your personal problems?

   ___ 0 = Never ___ 1 = Almost never

   ___ 2 = Sometimes ___ 3 = Fairly often

   ___ 4 = Very often

3. How often have you felt that things were going your way?

   ___ 0 = Never ___ 1 = Almost never

   ___ 2 = Sometimes ___ 3 = Fairly often

   ___ 4 = Very often

4. How often have you felt difficulties were piling up so high that you could not overcome them?

   ___ 0 = Never ___ 1 = Almost never

   ___ 2 = Sometimes ___ 3 = Fairly often

   ___ 4 = Very often

Appendix E

Data Collection Schedule

Sampling Day	Tasks
0 (Off day)	Researchers deliver the necessary equipment for salivary cortisol collection in a smaller cooler and the survey questionnaire to the participants. Researchers obtain informed consent from the participants.
1 (Work day #1)	Researchers conduct noise measurements (dosimetry) and HRV monitoring on site with the participants. All instruments are removed at the end of the shift.
2 (Work day #2)	Researchers conduct noise measurements (dosimetry) and HRV monitoring on site with the participants. All instruments are removed at the end of the shift.
3 (Off day)	Researchers retrieve the cooler containing the salivary cortisol samples and the completed survey questionnaire.

Appendix F

Cortisol Log

Participant ID#_____

You are kindly asked to check all that apply and indicate the time each time you take a cotton swab for the salivary sampling.

Sample ID #	**Number of Samples**	**Time**	**Did you have some alcohol?**		**Did you drink fluids before your sample?**		**Did you smoke before your sample?**	
			Yes	**No**	**Yes**	**No**	**Yes**	**No**
Day 1								
_____	1	_____	Yes	No	Yes	No	Yes	No
_____	2	_____	Yes	No	Yes	No	Yes	No
_____	3	_____	Yes	No	Yes	No	Yes	No
_____	4	_____	Yes	No	Yes	No	Yes	No
_____	5	_____	Yes	No	Yes	No	Yes	No
Day 2								
_____	1	_____	Yes	No	Yes	No	Yes	No
_____	2	_____	Yes	No	Yes	No	Yes	No
_____	3	_____	Yes	No	Yes	No	Yes	No
_____	4	_____	Yes	No	Yes	No	Yes	No
_____	5	_____	Yes	No	Yes	No	Yes	No

Appendix G

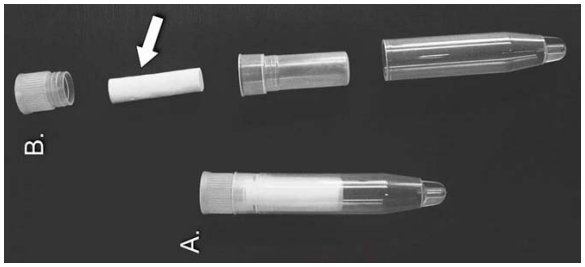
Participation Instruction Sheet

Instructions

SALIVA COLLECTION

If possible, please refrain from smoking, brushing your teeth or using mouth wash, eating or drinking anything but water **at least 30 minutes** before taking a saliva sample.

1. Wash hands and rinse mouth twice with cool water (if desired)
2. Remove a cotton swab from the sample container
3. Put the cotton swab in your mouth and chew gently for 40-60 seconds
4. Return the cotton swab back into the **top** cylinder and back inside the tube.



5. Write (a) the time on the label; and (b) circle indicate if you have eaten, smoked and drunk by circling Yes or No
6. If you accidentally ate, smoked, took medications, or drank prior to saliva collection, continue sample collection as usual according to the schedule, simply mark it down on the test tube and the cortisol log by circling YES or NO
7. Adhere the label to the tube and put into the sealed bag, do so for all **five** swabs

SCHEDULE

First day of workblock – DAY 1

- Start saliva collection x 5 times
    - Immediately after waking; 30 minutes after waking; + 4 hours after waking; + 8 hours after waking; before bed. Please mark time of collection on label and adhere on the tube and keep saliva tubes refrigerated.
- **Daily diary questionnaire**: Please complete **only day 1 of the daily diary** at the end of your saliva collection, heart rate monitoring, and noise measurements.

Second day of workblock – Day 2

- **Continue saliva collection.** 5 times per day with the same schedule.

- **Daily diary questionnaire:** Please complete **only day 2** of the daily diary at the end of your saliva collection, heart rate monitoring, and noise measurements.

COMPLETED SHIFT QUESTIONNAIRE will be collected at the end of day 2.