PHYSICAL ACTIVITY TO IMPROVE HEALTH AND REDUCE CHRONIC DISEASE RISK IN FEMALE NIGHT SHIFT WORKERS

by

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ABSTRACT

There is growing evidence that shift workers are at increased risk of cancer and a number of chronic diseases. As the prevalence of shift work is unlikely to decrease, an understanding of the factors that contribute to, and strategies that can be used to mitigate this risk are needed. Physical activity is known to improve health, and reduce chronic disease risk. However, evidence suggests that women shift workers may be less likely than other women to be sufficiently physically active.

This dissertation aims to examine the effect that physical activity may have on improving health and reducing breast cancer risk in shift workers, by employing a variety of research methodologies. The first study is a systematic review of the literature on interventions aimed at improving the health of shift workers. This was conducted to understand what strategies have been most effective, as well as to identify gaps in the literature. The second study used cross-sectional data from the Canadian Health Measures Survey to understand patterns of physical activity and sedentary time in shift workers compared to day workers, as well as objective measures of physical fitness and obesity. The third and fourth studies aimed to understand women shift workers' perspectives on physical activity, particularly barriers to and preferences for physical activity programming, using quantitative and qualitative research methods respectively.

Findings from these four studies led to the development of a distance-based physical activity intervention, consisting of behavioural counselling sessions, and use of an activity tracker to encourage participants to meet Canada's physical activity guidelines of 150 minutes per week of moderate-vigorous physical activity. This intervention was found to be feasible to implement in women shift workers, with preliminary evidence of efficacy.

In summary, these studies highlight the important role that physical activity may play in improving health and reducing breast cancer risk in women shift workers. The intervention developed lays the groundwork for future randomized-controlled trials to determine the magnitude of the effect that regular physical activity may have on shift workers' risk of breast cancer and other chronic diseases.

PREFACE

This statement confirms that the work presented in this dissertation was conceived, conducted and written by Sarah Neil-Sztramko (SNS). The co-authors of the manuscripts, including Dr. Carolyn Gotay (CG), Dr. Kristin Campbell (KC), Dr. Paul Demers (PD), Manisha Pahwa (MP), and Carola Muñoz (CM) made contributions commensurate with supervisory committee, collegial, or co-author duties.

With substantive input from CG, SNS developed the research question and protocol for the systematic review described in Chapter 2. SNS developed the search strategy, conducted the literature search, identified and abstracted eligible papers in collaboration with MP. SNS was responsible for drafting the manuscript, with assistance from MP. CG and PD provided scientific input throughout the process, as well as editing and approval of the final manuscript. Chapter 2 has been published:

Neil–Sztramko SE, Pahwa M, Demers PA, Gotay CC. Health-related interventions among night shift workers: a critical review of the literature. *Scandinavian Journal of Work, Environment and Health*. 2014. 40(6):543-556.

The Canadian Health Measures Survey was developed and conducted by Statistics Canada under Health Canada's Research Ethics Board. SNS conceived and designed the research question, and led the application for data access through Statistics Canada with assistance from KC and CG. SNS conducted the data analysis, was responsible for interpretation and wrote the manuscript with scientific input, editing and final approval of the manuscript from CG, PD and KC. Chapter 3 has been accepted for publication:

Neil-Sztramko SE, Gotay CC, Demers PE, Campbell KC. Body composition, physical activity and physical fitness in Canadian shift workers: Data from the Canadian Health Measures Survey Cycle 1 and 2. Accepted to the *Journal of Occupational and Environmental Medicine*, August 2015.

The principal investigator of the larger research project (the ICOS study) from which the data from Chapter 4 were collected is CG. This study was conducted under the University of British Columbia Clinical Research Ethics Board (H12-00258). SNS conceived and designed the protocol for the sub-study related to barriers and preferences related to physical activity in shift workers. CM was responsible for recruiting participants and collecting the data. SNS analyzed the data and drafted the manuscript with scientific input, editing and approval of the final manuscript from CG, PD and KC. Chapter 4 has been submitted for publication, and is currently under review.

Neil-Sztramko SE, Gotay CC, Demers PA, Muñoz C, Campbell KC. Barriers to and preferences for physical activity in female shift workers: a mixed methods analysis. *(Under Review)*

The research in Chapter 5 was conducted under the University of British Columbia Behavioural Research Ethics Board (H14-01390). With substantive input from CG and KC, SNS designed the research protocol and created the focus group guide. SNS was present for all focus groups, transcribed, coded and analyzed all data and wrote the manuscript. CG, PD and KC provided scientific contribution to revision of the chapter.

The research in Chapter 6 was conducted under the University of British Columbia Clinical Research Ethics Board (H14-03408). SNS conceived the research question and designed the study protocol with supervisory committee input and guidance from KC, CG and PD. SNS led the research study, recruited and enrolled participants, collected data, conducted the behavioural counselling sessions, analyzed and interpreted the data and wrote the manuscript. CG, PD and KC provided scientific input and contributed to revision of the chapter.

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LIST OF ABBREVIATIONS

A:	Afternoon shift
ALPHA:	Alberta Physical Activity and Breast Cancer Prevention
aMT6-s :	6-sulfatoxymelatonin
APMHR:	Age-predicted max heart rate
BD:	Benign breast disease
BL:	Bright Light
BMI:	Body mass index
BP:	Blood Pressure
BW:	Body weight
Bwd:	Backward, refers to the direction of shift rotation
CI:	Confidence interval
CHMS:	Canadian Health Measures Survey
CRP:	C-reactive protein
CT:	Computerized tomography
CVD:	Cardiovascular Disease
D:	Day shift
DBP:	Diastolic Blood Pressure
DXA:	Dual energy X-Ray Absorptiometry
E:	Evening shift
EEG:	Electroencephalography
ESS:	Epworth Sleep Scale
F:	Female
FFQ:	Food Frequency Questionnaire

Fwd: Forward, refers to direction of shift rotation

Gl: Glucose

GLTEQ: Goodin Leisure Time Exercise Questionnaire

h: hours

HAPA: Health Action Process Approach

HbA1C: Hemoglobin A1C

HDL: High-density lipoprotein

HOMA-IR: Homeostasis model assessment – insulin resistance

HR: Hazard Ratio

HRR: Heart Rate Reserve

HRT: Hormone replacement therapy

IARC: International Agency for Research on Cancer

IGF: Insulin-like Growth Factor

IGF/BP: Insulin-like Growth Factor/Binding Protein

IL-6: Interleukin-6

IPAQ: International Physical Activity Questionnaire

KSQ: Karolinska Sleep Questionnaire

LDL: Low-density lipoprotein

LSHCI: Lund Subjective Health Complaints Inventory

M: Male

mCAFT: modified Canadian Aerobic Fitness Test

MeSH: Medical Subject Heading

MET: Metabolic Equivalent

MHR: Max Heart Rate

MVPA: Moderate to vigorous physical activity

N:	Night shift
NEW:	Nutrition and Exercise in Women trial
NHANES:	National Health and Nutrition Examination Survey
O:	On call
OC:	Oral contraceptives
OCRC:	Occupational Cancer Research Centre
OHE:	Hydroxyestrone
OR:	Odds ratio
PA:	Physical activity
PAR-Q:	Physical Activity Readiness Questionnaire
PATH:	Physical Activity for Total Health trial
PSG:	Polysomnography
PSQI:	Pittsburgh Sleep Quality Index
REM:	Rapid eye movement
RCT:	Randomized Controlled Trial
RPAQ:	Recent Physical Activity Questionnaire
RR:	Relative risk
S:	Swing shift
S&Y:	Shiftwork & You questionnaire
SBP:	Systolic Blood Pressure
SCN:	Suprachiasmatic nucleus
SES:	Socioecomonic status
SHAPE:	Sex Hormones and Physical Exercise trial
SHBG:	Sex Hormone Binding Globulin
SSI:	Standard Shiftwork Index

SSS: Stanford Sleepiness Scale

SW: Shift Work

T: Training/support

t_{max}: time of maximum, refers to cortisol or melatonin levels

t_{mid}: time of midpoint, refers to cortisol or melatonin levels

TG: Triglycerides

TNF-α: Tumour necrosis factor-alpha

VAS: Visual Analogue Scale

VO_2 max: Maximum oxygen consumption

W: Work

WC: Waist Circumference

WHO: World Health Organization

WHR: Waist-to-hip ratio

WISER: Women in Steady Exercise Research trial

- : off work

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To my family

1. CHAPTER 1: BACKGROUND AND LITERATURE REVIEW

In today's society, the nine to five workday is no longer considered typical for many in the workforce. As the demand for productivity, as well as access to goods and services at all hours of the day and night has increased, there are a growing number of individuals employed in occupations requiring a variety of work schedules to cover a 24-hour period. These individuals are known as shift workers.

1.1. SHIFT WORK IN CANADA AND AROUND THE WORLD

1.1.1. PREVALENCE AND PATTERNS OF SHIFT WORK

The definition of shift work varies by country, but most commonly refers to schedules that include work that is conducted between the hours of ten o'clock pm and five o'clock am[1]. Shift workers can be further classified as those who work permanent night shifts (the same overnight shift worked on each working day) or rotating night shifts (work hours change, often rotating through morning, afternoon and night shifts).

According to the most recent population estimates from the 2005 General Social Survey, 25.6% of Canadians work something other than regular day shifts[2]. A rotating shift schedule is the most common in Canada, compared to evening shifts, permanent nights, split shifts, or on-call/casual work[2]. In addition, shift work is becoming increasingly prevalent in Canadian society. Between 1992 and 2005, the percentage of shift workers in Canada increased by 3.5%[2]. Industries with the highest proportion of shift workers include protective services (e.g., police, security) (66%), accommodation and food (52.7%), health (45%), and transportation and warehousing (39.5%)[2]. While some employees do report choosing to work shift work to allow time for school (14.9%), based on personal preference (9.8%) or to accommodate family or childcare schedules (8.4%), the most common reason given for working shift work was the nature of the job (48.0%)[3]. Around the world, the prevalence of shift work is quite varied. Estimates from the European Union in 2000 suggest only 25% of individuals work exclusive day shifts[4]. Of those who do not work days, alternating morning and afternoon shifts, followed by alternating morning, afternoon and night shifts were most common[4].

Aside from a classification of rotating or permanent shift work, the number of hours worked, the speed and direction of shift rotation, and time off between shifts is highly variable. These factors, along with the number of years one engages in shift work, rest periods during or after shift, sleep patterns, and exposure to light at night are all important factors that contribute to the impact that shift work has on an individual and their health[5]. In Canada, guidelines currently exist for the maximum number of work hours over a day of work; particularly in relation to overtime pay[6]. There are currently no regulations or guidelines to govern how the shift schedule should be best organized for workers' health and safety or workplace productivity.

1.2. Shift Work and Health

There is emerging evidence that shift work has a number of adverse effects on the health of workers[7]. Of these, the relationship between shift work and breast cancer has received a great deal of attention in the research literature and the popular media. Internationally, the impact of shift work on breast cancer risk has been acknowledged. In 2009, Danish women who developed breast cancer after more than 20 years of shift work were awarded compensation through employment insurance[8]. In Canada, both employers and employees recognize the need for interventions to improve health in this population. In a recent cross-sectional survey of workers, union representatives, employers, researchers and policy-makers, conducted by the Occupational Cancer Research Centre (OCRC), 71% of respondents felt that they were 'moderately' or 'very aware' of the negative health effects of shift work[9]. When asked about the biggest concerns related to shift work, the most commonly reported was quality of life (81.6%), with 36% of respondents reporting cancer-risk as a concern related to shift work.

1.2.1. Shift Work and Cancer

In 2007 the International Agency for Research on Cancer (IARC) classified shift work as a Group 2A carcinogen, meaning it is probably carcinogenic to humans[10]. Despite the limited human epidemiologic evidence at the time, this classification was based on sufficient evidence from research linking exposure to light at night and circadian rhythm disruption to cancer in animal models. To date, the majority of observational human research on the health impacts of shift work has examined the relationship between shift work and breast cancer.

1.2.1.1. Breast Cancer

A summary of the observational studies on shift work and breast cancer (published prior to June 1, 2015) is provided in Table 1.1. Since 2013, five meta-analyses have been conducted on this topic, with varying conclusions. Kamdar et al. included fifteen studies published before March 1, 2012 and reported a pooled adjusted relative risk (RR) of breast cancer in those ever exposed to shift work, compared to those never exposed of 1.21 (95% confidence interval (CI): 1.00 – 1.47), however no significant dose response was found[11]. This paper should be interpreted with caution as a subsequent letter to the editor highlighted errors in the data abstracted from the papers, and questions about inclusion and exclusion of key papers[12]. A similar meta-analysis conducted by Ijaz et al. included twelve case-control and four cohort studies published before

October 10, 2012. They report a 5% increased risk of breast cancer for every five years of shift work (RR: 1.05, 95% CI: 1.01 – 1.10); however significant findings were limited to case-control and not cohort studies. Due to the low methodological quality of included studies, the authors determined there was insufficient evidence to conclude a relationship between shift work and breast cancer exists[13]. In the most rigorous review conducted to date, Jia et al, included thirteen studies published before September 2012, and found an increased risk of breast cancer for those who had ever worked shift work (pooled RR: 1.20, 95% CI: 1.08 – 1.30) and those who had worked greater than fifteen years of shift work (pooled RR: 1.15, 95% CI: 1.03 – 1.29)[14]. Of note, when the analysis was restricted to only studies that were deemed of high methodological quality, the pooled RR was 1.40 (95% CI: 1.13 – 1.73). Wang et al. also conducted a meta-analysis including ten studies published between 1971 and May 2013, and reported a pooled adjusted RR for breast cancer in those ever exposed to shift work, compared to those never exposed, of 1.19 (95% CI: 1.05 – 1.35) and an overall increased risk of breast cancer of 3% for every five years of shift work (pooled RR: 1.03, 95% CI: 1.01 – 1.05)[15]. In the most recently published meta-analysis He et al. included fifteen studies published up until January 2014 and reported an overall pooled RR of 1.19 (95% CI: 1.08 – 1.32) in those who had ever worked shift work, and a dose-response RR of 1.16 (95% CI: 1.06 – 1.27) for every ten years of shift work[16].

While the variation in these meta-analyses can partially be explained by the different studies included, the overall consistency of the results is reassuring despite lack of statistical significance in some. Each of these meta-analyses also highlights some of the methodological limitations that exist in the literature to date. The majority of studies conducted have been case-control studies, which may suffer from recall bias with respect to the degree of exposure to night shift work, as well as the measurement of important variables that may confound the relationship between shift work and breast cancer risk (such as age, menopausal status, and lifestyle factors). Of the cohort studies conducted, none were originally designed to examine the relationship between shift work and breast cancer, and thus are limited to varying degrees by the information collected on work schedule. Based on the literature to date, it appears that the risk of breast cancer increases with the duration of shift work, with many studies finding significant effects after 20 or 30 years of shift work[17-20]. Whether this is a dose-response relationship, or whether there is a threshold under which shift work results in no additional breast cancer risk remains to be determined.

In 2011, a working group convened by IARC published guidelines for classifying shift work in future studies. They highlight the importance of reporting three main factors related to the classification of shift work exposure that should be captured in future studies in order to fully clarify the relationship between shift work and cancer. These include: 1) the shift system (defined as the start and end time of shifts, speed and direction of rotating shifts, number of hours worked per day, and whether shifts were regular or irregular); 2) cumulative exposure to shift work (defined as number of years on a particular shift schedule); and 3) shift intensity (defined as the amount of time off between work days)[5].

Table 1.1 Observational studies examining the association between shift work and breast cancer risk

Study	Study Design	Exposure categories	Results	Adjusted for
		Risk of Breast Cancer Compared to Never Working Shift Work		
Davis 2001[21]	Case-control	Ever graveyard shift	1.6 (1.0, 2.5)	Parity, family history, OC, HRT, age
Hansen 2001[22]	Case-control	Job with mainly night work	1.5 (1.3, 1.7)	Age, SES, age at birth of first/last child, number of children
O'Leary 2006[23]	Nested case-control	Any evening shift work Any overnight shift work	1.08 (0.81, 1.44) 0.55 (0.32, 0.94)	Reference date, parity, family history, education, BD
Schwartzbaum 2007[24]	Cohort	Job/industry >40% shift work	0.97 (0.67, 1.40)	Age, SES, occupation, count
Pesch 2010[25]	Case-control	Ever any shift work Ever night shift	0.96 (0.67, 1.38) 0.91 (0.55, 1.49)	Age, family history, HRT, number of mammograms
Pronk 2010[26]	Cohort	Ever	0.9 (0.7, 1.1)	Age, SES, family history, age at first birth, occupational PA, number of pregnancies
Hansen 2012[18]	Nested case-control	Ever	1.4 (0.9, 2.1)	Age, HRT, number of births, menarche age, education, sunbathing frequency, smoking
Hansen 2012[27]	Case-control	Ever rotating (not permanent) Ever permanent	1.8 (1.2, 2.8) 2.9 (1.1, 8.0)	Age, weight regularity, HRT, menarche age, menstrual regularity, menopausal status, age at first birth, family history, duration of lactation
Fritschi 2013[28]	Case-control	Ever	1.16 (0.97, 1.38)	Age
Knutsson 2013[29]	Cohort	Shifts (no nights) Night shifts	1.23 (0.70, 2.17) 2.02 (1.03, 3.95)	Number of children, alcohol
Koppes 2014[30]	Cohort	Occasional Regular	1.04 (0.85, 1.27) 0.87 (0.72, 1.05)	Age, ethnicity, children, education, occupation, job tenure, work hours

Study	Study Design	Exposure categories	Results	Adjusted for
Want 2015[31]	Case-control	Ever	1.34 (1.05, 1.72)	Age, education, BMI, age at menarche, menopausal status, PA, breast feeding, family history, sleep
Åkerstedt 2015	Cohort	1-45 years	0.94 (0.73, 1.22)	Age, education, tobacco, BMI, children, coffee, previous cancer, hormone use
Risk of Breast Cancer by Duration of Shift Work (Years)				
Tynes 1996[32]	Nested case-control	*Women < 50 years old*		Duration of employment
		> 0 – 3.2	1.4 (0.3, 6.4)	
		> 3.2 – 14.6	1.1 (0.2, 6.1)	
		Women > 50 years old		
		> 0 – 3.2	0.7 (0.1, 10.0)	
		> 3.2 – 14.6	1.5 (0.1, 2.2)	
Davis 2001[21]	Case-control	Number of years > 1 shift/week	1.13 (1.01, 1.27)	Parity, family history, OC, HRT, age
Hansen 2001[22]	Case-control	> 6	1.7 (1.3, 1.7)	Age, SES, age at birth of first/last child, number of children
Schernhammer 2001[33]	Cohort	1 - 14	1.08 (0.99, 1.18)	Age, menarche, parity, age at first birth, BD, BW, BMI at 18, family history, OC, HRT, height, alcohol, menopause
		15 - 29	1.08 (0.90, 1.30)	
		≥ 30	1.36 (1.04, 1.78)	
Lie 2006[19]	Nested case-control	> 0 – 14	0.95 (0.67, 1.33)	Years of nursing, parity
		15 – 29	1.29 (0.82, 2.02)	
		30+	2.21 (1.10, 4.45)	
O'Leary 2006[23]	Nested case-control	≥ 1 shift/week, < 8 years	0.74 (0.32, 1.68)	Reference date, parity, family history, education, BD
		≥ 1 shift/week, ≥ 8 years	0.32 (0.12, 0.83)	
Schernhammer 2006[20]	Cohort	1 – 9	0.98 (0.87, 1.10)	Age, menarche age, age at first birth, menopause/age, parity, BMI, alcohol, OC, HRT, PA, smoking, BD, family history
		10 - 19	0.91 (0.72, 1.16)	
		20 +	1.79 (1.06, 3.01)	

Study	Study Design	Exposure categories	Results	Adjusted for
Pesch 2010[25]	Case-control	>0 - 4 5 – 9 10 – 19 ≥ 20	0.64 (0.34, 1.24) 0.93 (0.41, 2.15) 0.91 (0.38, 2.18) 2.49 (0.87, 7.18)	Age, family history, HRT, number of mammograms
Pronk 2010[26]	Cohort	>0 - ≤ 5 >5 - ≤ 17 >17	0.9 (0.6, 1.3) 0.9 (0.6, 1.4) 0.8 (0.5, 1.2)	Age, SES, family history, age at first birth, occupational PA, number of pregnancies
Lie 2011[34]	Nested case-control	1 - 11 ≥ 12	1.2 (0.9, 1.5) 1.3 (0.9, 1.8)	Age, period of diagnosis, parity, family history, alcohol
Hansen 2012[18]	Nested case-control	1 - 5.9 years 6 - 14.9 years ≥ 15 years	0.9 (0.4, 1.7) 1.7 (0.9, 3.2) 2.1 (1.0, 4.5)	Age, HRT, number of births, menarche age, education, sunbathing frequency, smoking
Hansen 2012[27]	Case-control	1 – 5 years 5 - 10 years 10 - 20 years ≥ 20 years	1.5 (0.99, 2.5) 2.3 (1.4, 3.5) 1.9 (1.1, 2.8) 2.1 (1.3, 3.2)	Age, weight regularity, HRT, menarche age, menstrual regularity, menopausal status, age at first birth, family history, duration of lactation
Fritschi 2013[28]	Case-control	< 10 years 10 - < 20 years ≥ 20 years	1.25 (1.00, 1.56) 1.09 (0.79, 1.50) 1.02 (0.71, 1.45)	Age
Grundy 2013[17]	Case-control	0 - 14 years 15 - 29 years ≥ 30 years	0.95 (0.79, 1.16) 0.93 (0.67, 1.30) 2.21 (1.14, 4.31)	Age, data collection centre
Menegaux 2013[35]	Case-control	< 4.5 years ≥ 4.5 years	1.12 (0.78, 1.60) 1.40 (1.01, 1.92)	Age, parity, family history, age at first pregnancy, alcohol, BMI, menarche age, HRT, smoking

Study	Study Design	Exposure categories	Results	Adjusted for
Li 2015[36]	Nested case-control	> 0 - 12.8 years	0.99 (0.83, 1.17)	Age
		> 12.8 - 19.92 years	0.97 (0.82, 1.15)	
		> 19.92 - 27.67 years	0.90 (0.76, 1.05)	
		> 27.67 years	0.88 (0.74, 1.05)	
Åkerstedt 2015	Cohort	1-5 years	0.94 (0.71, 1.24)	Age, education, tobacco, BMI, children, coffee, previous cancer, hormone use
		6-10 years	0.69 (0.42, 1.14)	
		11-20 years	0.81 (0.50, 1.30)	
		21-45 years	1.62 (1.01, 2.60)	
Risk of Breast Cancer with Cumulative Exposure to Shift Work (Number of night shifts)				
Davis 2001[21]	Case-control	Hours/week of nights	1.06 (1.01, 1.13)	Parity, family history, OC, HRT, age
Pesch 2010[25]	Case-control	< 807	0.66 (0.40, 1.11)	Age, family history, HRT, number of mammograms
		≥ 807	1.78 (0.89, 3.58)	
Pronk 2010[26]	Cohort	>0 - ≤ 576	0.9 (0.6, 1.3)	Age, SES, family history, age at first birth, occupational PA, number of pregnancies
		>576 - ≤ 1632	1.0 (0.7, 1.5)	
		>1632	0.7 (0.4, 1.1)	
Lie 2011[34]	Nested case-control	< 1007	1.2 (0.9, 1.6)	Age, period of diagnosis, parity, family history, alcohol
		≥ 1007	1.2 (0.9, 1.7)	
Hansen 2012[18]	Nested case-control	< 416	0.8 (0.4, 1.9)	Age, HRT, number of child births, menarche age, education, sunbathing frequency, smoking
		416 – 1560	1.4 (0.7, 2.9)	
		≥ 1560	2.3 (1.2, 4.6)	
Hansen 2012[27]	Case-control	< 468	1.6 (1.0, 2.6)	Age, BW, HRT, menarche age, menstrual regularity, menopause, age at birth of first child, family history, lactation
		468 – 1095	2.0 (1.3, 3.0)	
		≥ 1095	2.2 (1.5, 3.2)	

Study	Study Design	Exposure categories	Results	Adjusted for
Li 2015[36]	Nested case-control	>0 - 1316.79	0.96 (0.81, 1.14)	Age
		> 1315.79 - 2018.71	1.00 (0.84, 1.19)	
		> 2018.71 - 2880	0.88 (0.74, 1.04)	
		> 2880	0.89 (0.75, 1.07)	

Legend: BD: Benign Breast Disease; BMI: Body Mass Index; BW: Body weight; HRT: Hormone Replacement Therapy; OC: Oral Contraceptives; PA: Physical Activity; SES: Socioeconomic Status

1.2.1.2. Other Cancer Types

In addition to breast cancer, the relationship between shift work and other types of cancer has also been investigated. In relation to prostate cancer, five observational studies have been conducted to date. Three case-control studies[37-39] and one prospective cohort study[40] found a statistically significant increased risk of prostate cancer in individuals who had worked shifts, while two prospective cohort studies found no relationship between work schedule and prostate cancer mortality[41,42], although one of these was based on data from only 17 cases[42]. Three studies have examined the relationship between shift work and ovarian cancer. Data from one case-control study and from the American Cancer Society's Cancer Prevention Study-II found an increased risk of ovarian cancer in those with a history of shift work[43,44], while an analysis combining data from the Nurses' Health Study I and II cohorts found no increased risk[45]. Also using data from the Nurses' Health Study cohorts, female shift workers have been found to be at increased risk of colorectal[46], endometrial[47] and lung cancer[48], but a significantly decreased risk of skin cancer[48].

1.2.2. Shift Work and Other Chronic Diseases

Shift work is also known to increase the risk of a number of other chronic diseases. A recent meta-analysis summarized 34 studies that reported on the risk of vascular events in shift workers compared to day workers[49]. They found a statistically significant increased risk of myocardial infarction (pooled RR: 1.23, 95% CI: 1.15 – 1.31), ischemic stroke (pooled RR: 1.05, 95% CI: 1.01 – 1.09) and all coronary events (pooled RR: 1.24, 95% CI: 1.10 – 1.39) in both unadjusted and adjusted analyses. Importantly, the authors also reported on the quality of evidence using the Downs and Black quality appraisal tool[50], and found the overall risk of bias to be unlikely. It is hypothesized that shift work increases the risk of cardiovascular disease by acting as a physiological, psychological and behavioural stressor to the body[51]. As a physiological stressor, shift work can cause inflammation[52] and impaired autonomic function[53]. As a psychosocial stressor, shift work can result in poor work-life balance, and recovery from work[54]. As a behavioural stressor shift work can lead to poor lifestyle habits such as low levels of physical activity, poor diet, and increased rates of smoking[55]. All of these physiological, psychological and behavioural factors are known risk factors for cardiovascular disease[51].

Two recent review papers have summarized the relationship between shift work and diabetes risk. A recent meta-analysis by Gan et al. included twelve observational studies examining the relationship between shift work and Type II diabetes[56], and reported a pooled adjusted odds ratio (OR) of 1.09 (95% CI: 1.05 – 1.12). A second review conducted by Knutsson and Kempe included only cohort studies[57]. While they did not conduct a meta-analysis, the authors did conclude that there was moderate evidence to support the relationship between shift work and diabetes risk, with three of the five studies included finding a statistically significant association[57]. Interestingly, they also identified two papers that reported that glucose control was impaired amongst individuals with both Type II[58] and Type I[59] diabetes who work shift work, compared to day workers. This could have potential implications for complications due to a diabetes diagnosis, and long-term health and quality of life.

1.2.3. Shift Work and Psychosocial Outcomes

Shift work is also hypothesized to have an effect on worker's mental health; however, these outcomes have not been assessed as thoroughly in the literature. Based on Vogel et al.'s 2012 review of the physical and mental health effects of shift work, no studies had examined the frequency of mental health disorders using standardized criteria in shift workers, or the relationship between shift work and mental health disorders[7]. One prospective cohort study reported shift workers were more likely to experience depressive mood, by asking: "Have you been feeling low every day over the last two weeks?"; however, responses to this question may not necessarily indicate the presence of true clinical depression[60]. In a cross-sectional study, nurses were also found to have higher symptoms of somatization, anxiety and paranoia, although whether this is related to shift work itself or to the nature of their occupation is unknown[61]. An updated literature search conducted to include literature from January 2012 to January 2015 using the keywords reported by Vogel et al. revealed no new literature in this area.

Outside of diagnosed mental health disorders, there is evidence that shift workers experience adverse psychosocial outcomes. Shift workers experience more work-family conflict that non-shift workers, regardless of the type of schedule worked[62]. However, new strategies are emerging which may help to assist shift workers achieve better work-life balance. A twelve-month self-rostering intervention (in which employees were involved in choosing their shift schedule through an employers' information technology software program) resulted in a decline in both work-family and marital conflict[63].

1.2.4. OTHER ADVERSE EFFECTS OF SHIFT WORK

One well-reported adverse outcome associated with shift work is the increased risk of occupational injury. Based on longitudinal Canadian data from the Survey of Labour and Income Dynamics, while overall rates of work injury declined over the ten years of study data, this pattern was not observed in shift workers; permanent shift work was associated with an increased risk of work injury in both men and women, and rotating shift work was associated with increased risk of work injury in women only[64]. In a 2011 systematic review, Wagstaff and Sigstad Lie examined the effect of shift work on safety in the workplace. Of the five studies included, all noted a significantly increased risk of workplace injury in shift workers compared to day workers, with the increase in injury rates ranging from 50 to 100%[65].

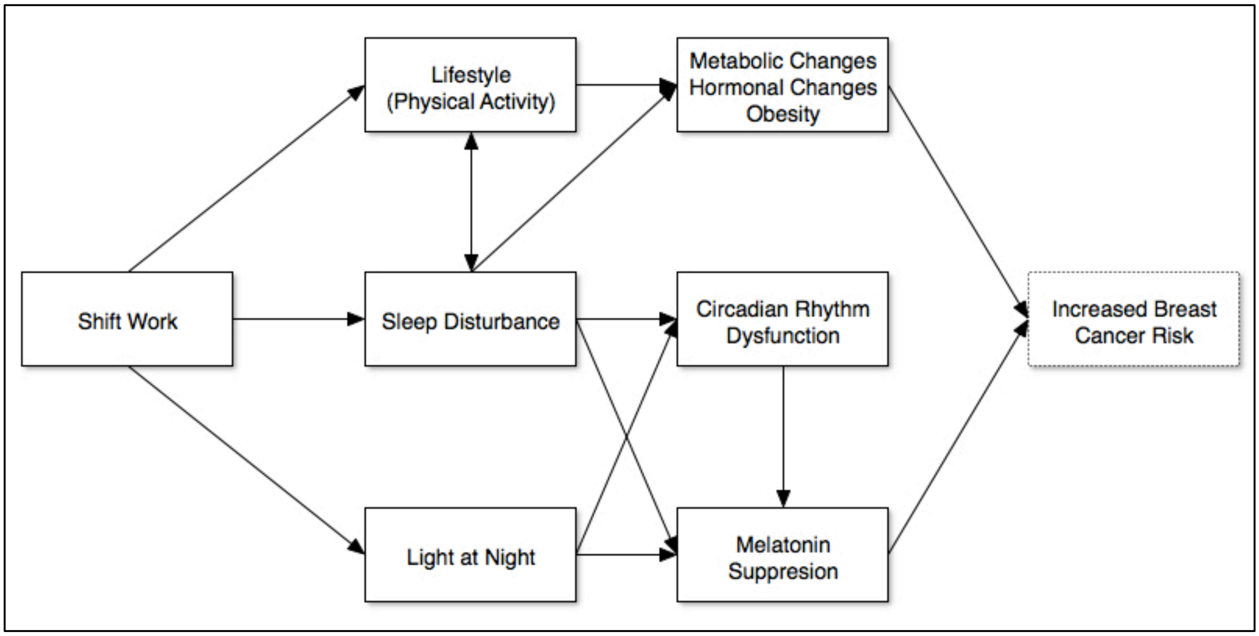
Another short-term negative impact of shift work is adverse reproductive outcomes in female shift workers. A 2013 meta-analysis including five observational studies found female shift workers to be at increased risk of miscarriage (pooled RR: 1.51, 95% CI 1.27 – 1.78)[66]. Female shift workers are also at increased risk for menstrual disruption (pooled OR: 1.22, 95% CI: 1.15 – 1.29) and infertility (pooled OR: 1.80, 95% CI: 1.01 – 3.20) based on another meta-analysis including four studies each[67].

Based on the cumulative evidence to date, shift workers clearly experience a number of adverse health effects related to their work schedule. Despite this knowledge, the exact biological mechanisms that underlie these risks are not entirely understood. The following discussion will focus on the published literature to date examining the mechanisms linking shift work to breast cancer; however, many of the mechanisms described may also underlie the relationship between shift work and other types of cancer, other chronic diseases and other health conditions.

1.3. Mechanisms Linking Shift Work and Breast Cancer

For the purposes of this thesis, the theoretical framework in Figure 1.1 will guide the discussion of the relationship between shift work and breast cancer.

Figure 1.1 Theoretical framework for the mechanisms linking shift work and breast cancer



1.3.1. Light at Night

The hypothesis that a relationship existed between exposure to light at night and the risk of breast cancer first appeared in the scientific literature in 1987, in a paper published by Dr. Richard G. Stevens in the American Journal of Epidemiology[68]. He presented data from a variety of sources, indicating that changes in the incidence of breast cancer over time and geographic variation in breast cancer incidence could not be entirely explained by known major risk factors for breast cancer (i.e., age at menarche, first birth, and menopause amongst others); thus he hypothesized that other factors must be contributing to breast cancer incidence. He outlined a biological rationale that linked exposure to the 60 Hertz electric light field to reduced melatonin production in the pineal gland, which would then result in increased mammary carcinogenicity, most likely due to the decreased suppressive effect of melatonin on estrogen from the ovary, and prolactin from the mammary gland[68]. At the time, there was limited animal research to support each of the steps in this proposed pathway. In the years since his original paper was published, a breadth of research has been conducted to support and refine his initial ideas, leading to an update to his original hypothesis published in 2014[69]. For the purposes of this thesis, the effects of exposure to light at night will be separated into two pillars: disruption in circadian rhythms and suppression of melatonin. While light at night also has an influence on sleep, sleep disruption will be discussed separately, as a direct effect of shift work.

1.3.1.1. Circadian Rhythms

The suprachiasmatic nucleus (SCN), located in the hypothalamus, is the body's central clock that is responsible for synchronizing many physiological processes to a 24-hour rhythm, also known as the circadian rhythm. This occurs through humoral, endocrine and neural signals[70]. Almost all of the body's systems are influenced by the body's circadian rhythms; these include but are not limited to, the endocrine, reproductive, immune, cardiovascular, and renal systems[71].

Light entering through the retina is the most powerful zeitgeber (an environmental cue that helps to set the internal body clock), that regulates the central clock to its cycle[71]. There is growing evidence that a number of other non-photic factors also play a role in regulating the body's circadian rhythms. These include physical activity, food timing, social stimuli, the sleep-wake cycle, and pharmacological agents, including both stimulants and hypnotics[72]. In addition to the central clock, human physiological processes are also governed by a number of peripheral clocks in a variety of other human tissues including muscles, adipose tissue, the liver, and pancreas. These peripheral clocks are influenced by both the central clock in the SCN, and the external factors listed above[73]. In response to an abrupt shift in the body's circadian rhythm (such as that experienced during travel across time zones, or by shift workers working a night shift), the central clock adapts more quickly than the peripheral clocks. This desynchronization has negative effects on the metabolizing and proliferating cells of the body[74].

Several circadian clock genes have been identified that regulate both cell proliferation and cell apoptosis. Variations in these genes, such as Period homolog 3[75] and Cryptochrome 2[76] are associated with increased risk of breast and prostate cancer, respectively. The function of the clock genes in many of the peripheral tissues, and the role of the circadian rhythm disruption and its relationship to cancer risk is complex, and currently not well understood. To date, most of the research examining the effect of light at night and circadian rhythm disruption has been focused on the effects on the hormone melatonin[77].

1.3.1.2. MELATONIN

Melatonin is a hormone that is primarily produced by the pineal gland in response to information from the SCN and the sympathetic nervous system. Exposure to light during the day suppresses melatonin production, with plasma melatonin levels almost undetectable during normal waking hours[78]. Melatonin is produced and released during the night, with typical peak melatonin levels occurring in the middle of the night, when no light is detected by the retina[78].

Shift workers are hypothesized to have a blunted melatonin peak during the night shift (due to their exposure to light at night), and overall lower levels of melatonin even on days off (due to the disruption of their circadian rhythms). Using data from female shift working nurses in the Nurses' Health Study cohorts, an inverse relationship was observed between the number of recent night shifts worked and urinary melatonin levels when measured during a morning spot urine sample seven to nine days before the start of their next menstrual cycle[79]. In another investigation, 172 night shift and 151 day working nurses were studied during work and sleep periods. Urinary melatonin levels were found to be 62% lower in night shift nurses compared to day nurses following a workday, and 42% lower on days off[80]. In a field-based study of thirteen male and female rotating shift workers, total urinary melatonin excretion over 24-hours was not significantly different when measured on day shifts and night shifts; this indicates that the effects of shift work on melatonin extend over the days of the rotating work schedule, and are not limited to days working overnight[81].

The relationship between lower levels of melatonin and increased cancer risk is thought to be related to both the tumour suppressive properties of melatonin, and the effect of melatonin on the estrogen pathway[69]. In a recent meta-analysis based on five nested case-control studies, Basler et al. found a protective effect against breast cancer for women in the highest quartile of urinary melatonin compared to women in the lowest quartile (pooled OR: 0.82, 95% CI: 0.71 - 0.95)[82]. In relation to the estrogen levels of shift workers, female rotating shift nurses (n = 60) were found to have higher 17-β-estradiol levels than day shift only nurses (n = 56) (rotating shift nurses: 50.5 pg/mL, 95% CI: 44.5 – 58.8 vs. day nurses: 41.9 pg/mL, 95% CI: 31.8 – 43.7) when samples were taken before a morning shift, after a day off with a regular night sleep[83]. In the same study, no statistically significant differences were found in melatonin levels (rotating shift nurses: 42.0 ng/mg, 95% CI: 34.1 – 54.8 vs. day shift nurses, 35.2 ng/mg 95% CI: 28.7 – 43.6)[83]. Again using female shift workers from the Nurses' Health Study cohort, a 23% difference in levels of bioavailable estradiol was found between women who were in the highest and lowest quartiles of melatonin levels, and levels of estradiol were higher (14%, $p = 0.04$) in women who had worked night work for at least fifteen years compared to women who had never worked night shifts[79].

In addition to light exposure, melatonin production is influenced by the timing and duration of sleep, as during sleep time, light is no longer suppressing melatonin production. The relationship between melatonin and sleep is bidirectional. Melatonin also acts as a hypnotic, and the melatonin peak in response to night time helps to aid sleep. Insufficient sleep has also been found to be associated with a number of adverse health effects; thus sleep may play an important role in the relationship between melatonin, circadian disruption and cancer risk in shift workers.

1.3.2. Sleep

There is a growing appreciation for the importance of sleep in the health and well-being of individuals. While there are current public health guidelines for physical activity and nutrition, there are no analogous guidelines for sleep[84]. Both quantity and quality of sleep have been found to be important to health. Using cross-sectional data from the National Health and Nutrition Examination Survey (NHANES) in the United States, sleep duration of less than four, five and six hours per night was associated with a significantly increased risk of obesity (OR: 2.34, 1.93 and 1.25 respectively for women and 2.51, 1.07 and 1.24 respectively for men) compared to those who slept seven hours per night[85]. Using longitudinal data from the NHANES I survey, short sleep duration (defined as less than five hours of sleep per night) was associated with significantly increased risk of type II diabetes (OR: 1.47, 95% CI: 1.03 – 2.09)[86] and high blood pressure (Hazard Ratio (HR): 2.10, 95% CI: 1.58 – 2.79)[87], after controlling for a number of socio-demographic characteristics as well as health conditions and other lifestyle behaviours. A longitudinal analysis using data from the Whitehall II study found that the joint effect of short sleep length (defined as less than or equal to six hours per night) and self-reported sleep disturbances resulted in the greatest risk of all-cause mortality (OR: 1.18), cardiovascular disease mortality (OR: 1.57), and other deaths (OR: 1.49) in men compared to short sleep (ORs: 1.13, 1.04, 1.17 respectively) or sleep disturbances (OR: 0.85, 0.82, 0.68, respectively) individually[88]. In women, short sleep duration resulted in the greatest risk of all-cause mortality (OR: 1.27) compared to sleep disturbances (OR: 1.03) or short sleep with sleep disturbance (1.03); however, the combination of short sleep and sleep disturbance resulted in the greatest risk of cardiovascular disease mortality (OR: 3.18), compared to disturbed sleep (OR: 2.36) or short sleep (OR: 1.85)[88].

To date, there is inconsistent evidence linking short sleep duration to cancer risk. A recent meta-analysis of ten prospective cohort studies found no relationship between short sleep duration and risk of cancer (pooled RR: 1.05, 95% CI: 0.90 – 1.24), with a high degree of heterogeneity observed across studies (I^2 = 57.6%)[89]. However, all studies used self-report questionnaires to capture sleep duration, and no measures of sleep quality were included. Therefore, more research is needed in this area, including objective measures of sleep quality and quantity to fully understand this relationship.

In addition to the long-term consequences, the acute physiological effects of sleep deprivation in humans have also been documented. Following six nights of restricted sleep (four hours between 0100-0500h), a group of healthy young men demonstrated impaired glucose tolerance, increased cortisol, and increased sympathetic nervous system activity compared to both baseline values, and values after seven nights of recovery sleep[90]. Sleep deprivation has also been shown to increase inflammatory markers including interleukin (IL)-6, tumour necrosis factor-alpha (TNF-α), and c-reactive protein (CRP) during simulated night shifts[91]. Higher levels of these biological markers have consistently been linked to higher risk of postmenopausal breast cancer[92].

Shift workers experience obvious disruptions to a regular sleep-wake schedule due to their work schedule, with variations dependent on the type of schedule worked. Permanent night shift workers were found to be less likely to experience insomnia after a night shift compared to rotating shift workers in a cross-sectional analysis (OR: 0.30, 95% CI: 0.19 – 0.47); however, permanent night shift workers were more likely to experience insomnia on days off compared to rotating shift workers (OR: 3.22, 95% CI: 1.54 – 6.71)[93]. There is also evidence that chronotype, an individual's natural preference to morning or evening times of day, can affect the relationship between shift work and sleep. When 238 shift workers working different shift schedules were surveyed, those who were identified to be morning-type individuals experienced shorter sleep duration and higher sleep disturbances after night shifts, while evening-type individuals experienced more sleep problems on days with early morning shifts[94]. While it is not understood how chronotype influences sleep at a physiological level, differences between chronotypes may partly explain some the variation in risk of other health effects across individuals; however, further investigation is needed into this relationship.

1.3.3. Lifestyle Factors

Lifestyle factors that are known to influence the risk of breast cancer and other chronic diseases may also be impacted by permanent or rotating shift schedules. In particular, the effects on vitamin D, diet, obesity, and physical activity will be discussed.

1.3.3.1. Vitamin D

Shift workers have been hypothesized to have lower levels of vitamin D due to less outdoor time that results from working during the night and sleeping during the day. This hypothesis is supported by the lower incidence of skin cancer that has been observed in a cohort of nurses who work shift work[48]. To date, only one cross-sectional study has compared vitamin D levels between shift workers and day workers and found no significance difference between fixed day workers (n = 6), rotating shift workers with no night shifts (n = 4) and rotating shift workers on night shifts (n = 4); however, this study was limited by inadequate statistical power[95].

The relationship between vitamin D and breast cancer incidence is less clear. Van der Rhee et al. reviewed the observational studies published on the relationship between sunlight exposure, vitamin D intake and cancer risk, and found mixed results for vitamin D and breast cancer[96]. While the majority of studies found a significant negative association between sunlight exposure and breast cancer risk, there was less consistent evidence for the relationship between vitamin D intake and breast cancer risk. The difficulties in assessing vitamin D exposure create limitations in the research conducted to date. The correlation between sunlight exposure and an individual's vitamin D status may vary by geographic location and also amongst individuals due to sunscreen use, skin pigmentation, obesity and the presence of certain diseases. Vitamin D intake may also not be an adequate predictor of vitamin D status depending on sunlight exposure[97]. Thus prospective studies assessing vitamin D status and breast cancer incidence in shift workers and non-shift workers are needed before the relationship can be fully understood.

1.3.3.2. DIET AND METABOLISM

Current evidence suggests that not only do shift workers have different patterns of dietary intake than day workers, but that energy metabolism may also be impacted by their shift schedules. Based on a 2010 review paper of dietary patterns in shift workers, self-reported total energy intake over a 24-hour period does not appear to be significantly different between shift workers and day workers, or across different days of the night shift[98]. However, diet composition and distribution of energy intake across the day does appear to differ. In a cross-sectional analysis of data from the NHANES, rotating shift workers reported diets that were higher on the dietary inflammatory index (indicating a pro-inflammatory, typical western diet) than day workers (1.07 vs. 0.86, p <0.01)[99]. When rotating shift workers were compared to day-only workers in the same workplace in another cross-sectional analysis, total energy expenditure did not differ between the two groups, but shift workers were more likely to consume calories in the afternoon or night, regardless of what shift they were working at the time[100].

Laboratory-based data from simulated night shift studies offer different insights. In one study, sixteen adults took part in a laboratory-based study that included five days of sleep restriction, equivalent to one week of shift work. Participants were required to stay in the lab throughout the course of the study. While total energy expenditure (assessed by direct calorimetery) increased by approximately 5%, mostly due to usual movements during the increased time awake, *ad libitum* energy intake also increased, particularly during the nighttime hours[101]. In another study, when sixteen individuals were exposed to both a simulated night shift and control condition in random order, participants were more likely to choose a high-fat breakfast over a healthy breakfast following a night shift (81%) compared to the control condition (31%)[102]. It is important to note that behaviours observed during simulated night shift work may not reflect actual behaviours of individuals who regularly work night shifts. However, laboratory based-studies that objectively record and measure both energy intake and expenditure may overcome many key limitations of self-report data. Future studies that include objective measures of food intake in shift workers in a field based setting are needed to fully understand the patterns of energy intake in shift workers.

Outside of shift work, different dietary patterns are known to be associated with increased risk of breast cancer. In a recent meta-analysis of eighteen observational studies, women who consumed a healthy dietary pattern (high in vegetables and fruits, poultry, fish, low-fat dairy and whole grains) had lower odds of breast cancer (pooled OR: 0.89, 95% CI: 0.82 – 0.99)[103]. In another meta-analysis, women in the highest quintile of vegetable intake had a lower risk of breast cancer (pooled RR: 0.82, 95%CI: 0.74 – 0.90) for estrogen receptor (ER) negative but not ER positive breast cancer[104]. While dietary fat is associated with increased breast cancer risk in observational studies, the two randomized controlled trials of reduced-fat dietary interventions that have been conducted to date have found no decrease in breast cancer risk after 8.1[105] and 10 years[106] of follow-up.

Independent of energy intake, sleep deprivation, with or without circadian rhythm disruption, has been found to cause changes in postprandial metabolic profiles. In a laboratory-based study using healthy subjects exposed to a simulated night shift, circulating glucose and insulin levels were found to be higher following a high-fat meal eaten following a nine-hour phase advance compared to measurement taken after a normal sleep[107]. When this study was repeated using a low-fat diet, there were no differences in postprandial glucose or insulin; however, triglycerides were significantly higher following a meal eaten on the simulated night shift[108]. Chronic hyperinsulinemia and insulin resistance is associated with increased risk of breast cancer[109]. Insulin acts as a stem cell proliferator and can inhibit cell apoptosis[110]. In addition, insulin also regulates the bioavailability of sex steroid hormones, such as estrogen, that have been linked to increased breast cancer risk[110]. The observed alterations in energy metabolism experienced by shift workers have been hypothesized to contribute to the increased rates of cardiovascular disease, diabetes and obesity that have been observed in shift workers[98].

1.3.3.3. Obesity

Obesity is a well-established risk factor for a number of chronic diseases that are prevalent in shift workers, including diabetes, cardiovascular disease, and certain cancers, as well as sleep apnea and other sleep disorders[111]. Shift workers have been found to have a greater prevalence of obesity than day workers across a variety of occupations. In a cross-sectional analysis from the Nurses' Health Study II, women who had ever worked night shifts were more likely to be obese (Body Mass Index (BMI) ≥ 30.0 kg/m^2) than women who had never worked night shifts (OR: 1.26, 95% CI: 1.20 – 1.32)[112]. In a cross-sectional survey, Brazilian truck drivers who worked irregular shifts had a BMI that was on average 2.0 kg/m^2 greater than drivers who worked day shifts only (28.4 ± 3.8 vs. 26.4 ± 3.6 kg/m2, $p = 0.04$)[113]. In a cross-sectional study of Italian employees enrolled in an occupational surveillance program, shift workers had increased odds of obesity compared to day workers (OR: 1.93, 95% CI: 1.01 – 3.71)[114]. In each of these studies, the relationship between shift work and obesity persisted even after controlling for known confounders including physical activity, diet, and sleep. Shift work is also associated with weight gain in prospective observational studies. In a retrospective cohort of male employees in Japan, over 27.5 years of observation, shift workers were more likely to become obese than day workers (RR: 1.14, 95% CI: 1.01 – 1.28)[115]. In a cross-sectional study of nurses and security personnel at one hospital, those who began working night shift work reported significantly greater weight gain (4.2 kg vs. 0.9 kg, $p = 0.02$) since starting their most recent job than those who continued to work day shifts[116].

Independent of shift work, sleep deprivation is associated with increased risk of obesity in adults. In a recent meta-analysis of 26 observational studies, short sleep duration was associated with a significant increase in the odds of obesity (pooled OR: 1.55, 95% CI: 1.43 –

1.68) with an estimated decrease of 0.35 kg/m^2 (95% CI: -0.57 to -0.12) with every one-hour increase in average sleep duration[117]. Controlled laboratory-based studies have investigated the acute effects of sleep deprivation on energy balance in healthy adults. During a fifteen day laboratory based study (described above), sixteen participants gained 0.82 ± 0.47 kg after only five-days of sleep restriction, despite a 5% increase in energy expenditure above baseline. This was primarily attributed to the observed increase in *ad libitum* energy intake[101].

It may difficult to distinguish between the independent effects of sleep and light at night on obesity risk, as the two may be highly correlated. There is evidence to suggest that light at night, independent of sleep, may contribute to obesity. In a United Kingdom-based cohort study of over 113 000 women aged 16-103, women with the lowest level of exposure to light at night had a lower odds of being obese compared to those with the highest exposure to light at night (OR: 0.83, 95% CI: 0.79 – 0.88), even after controlling for sleep duration[118]. Findings from this study should be taken with caution, as light at night was assessed by asking participants to estimate how dark their bedroom was, and asking them how often they were awake at 0100h, which may be insufficient to truly measure light exposure at night. In a cross-sectional study that enrolled 54 participants, light exposure, captured objectively using wrist actigraphy over seven days, was an independent predictor of BMI, also after controlling for other covariates including age, gender, overall activity, caloric intake, and sleep duration[119].

Adipose tissue produces estrogen, and is the main estrogen-producing tissue in postmenopausal women. This increase in circulating estrogen, as well as insulin resistance and hyperinsulinemia is common in obese individuals. Furthermore, increased levels of systemic circulating inflammatory cytokines are thought to be one of the main mechanistic contributors to the increased risk of breast cancer in obese individuals[120]. After convening an expert panel in

2001, the IARC concluded that there is sufficient evidence linking obesity and weight gain to increased risk of postmenopausal breast cancer, and other cancers including colon, endometrium, kidney and esophageal cancer[121]. In a recent meta-analysis of 89 observational studies, the increased risk of breast cancer in obese women (BMI $\geq$ 30 kg/m^2) compared to normal weight women (BMI < 25 kg/m^2) was limited to hormone-receptor positive cancers in postmenopausal women (pooled RR: 1.39, 95% CI: 1.14 – 1.70), with obese premenopausal women at decreased risk of breast cancer (pooled RR: 0.78, 95% CI: 0.67 – 0.92)[122]. The meta-analysis found no relationship between obesity and hormone-receptor negative breast cancer in either pre- or postmenopausal women. Overall, obesity is a complex phenomenon with many important contributing factors. Based on the evidence to date, it appears that both sleep deprivation and exposure to light at night may increase the risk of obesity in shift workers.

1.4. Physical Activity and Health

Physical activity also contributes to an individual's daily energy expenditure and can be an important contributor to energy balance and risk of obesity. The focus of this dissertation will be on the role of physical activity in the health of shift workers

1.4.1. General Benefits of Physical Activity

Physical activity is well known to have a number of health benefits, and insufficient physical activity is estimated to cause 9.4% of premature mortality worldwide, including 10.1% of breast cancer mortality, 7.2 % of colon cancer mortality, 7.2% of mortality from Type II diabetes, and 5.8% of mortality from coronary heart disease[123]. One of the first observational studies relating physical activity to health outcomes was published in the Lancet in 1953 by Morris et al. Data on the incidence of coronary heart disease were collected from male employees of the London Transport service between 1949 and 1950. It was found that bus drivers who worked a mainly sedentary job had an increased risk of coronary heart disease (RR: 1.42) compared to conductors, whose jobs involved more physical activity (walking)[124]. In a second landmark study, Paffenbarger et al., using longitudinal data from male Harvard University alumni, found an increased risk of fatal and non-fatal heart attacks in those with <2000 kcal per week of physical activity energy expenditure (RR: 1.64, p <0.001)[125], as well as an decreased risk of all-cause mortality with increasing physical activity energy expenditure (500 to 1999 kcal per week vs. <500 kcal per week, RR: 0.70, 95% CI: 0.54 – 0.88 and >2000 kcal per week vs. <500 kcal per week, RR: 0.68, 95% CI: 0.54 – 0.96)[126].

Since these studies were published, there has been a tremendous amount of research on the health benefits of physical activity. A 2013 systematic review of longitudinal studies of at least five years duration found consistent evidence for the role of physical activity in the prevention of weight gain, obesity, coronary heart disease, type II diabetes, Alzheimer's disease and dementia[127]. Based on the overwhelming evidence to date, the Canadian Society for Exercise Physiology's Canada's Physical Activity Guidelines for Adults recommend that adults aged 18 to 64 engage in 150 minutes per week of moderate to vigorous physical activity (MVPA) in bouts of ten minutes or more, as well as muscle and bone strengthening exercises two or more days per week in order to realize the various health benefits of physical activity[128]. Moderate-intensity physical activity is identified by an increased heart rate and heavier breathing; one would be able to carry on a conversation, but not sing. Vigorous intensity physical activity is characterized by a marked increase in heart rate, sweating and heavier breathing. While working at a vigorous intensity, one would need to catch his or her breath after a couple of words.

1.4.2. Physical Activity and Breast Cancer Risk

Participation in regular MVPA has been shown to have a protective effect against breast cancer in both cohort (pooled OR: 0.61, 95% CI: 0.59 – 0.63) and case-control (pooled OR: 0.84, 95% CI: 0.81 – 0.88) studies[129]. While increased duration of physical activity is associated with greater breast cancer risk reduction in dose response studies, a risk reduction begins to be observed with 120 to 180 minutes per week of MVPA[130]. This is consistent with Canada's Physical Activity Guidelines for Adults[128] and the American Cancer Society's Guidelines for Cancer Prevention[131] which recommend achieving 150 minutes per week of MVPA. Vigorous intensity physical activity appears to result in greater risk reduction compared to moderate activity[130].

To date, there have been four large-scale randomized controlled trials comparing physical activity to a control group for the primary prevention of breast cancer: in chronological order, the Physical Activity for Total Health (PATH) trial[132], the Sex Hormones and Physical Exercise (SHAPE) trial[133], the Alberta Physical Activity and Breast Cancer Prevention (ALPHA) trial[134], and the Women in Steady Exercise Research (WISER) trial[135]. The results of these trials are summarized in Table 1.2.

The PATH, SHAPE and ALPHA trials were all conducted over twelve months in sedentary, overweight, postmenopausal women. While all trials were successful in increasing overall physical activity levels in intervention groups compared to controls, changes in other outcomes varied, potentially due to the difference in the exercise interventions. The interventions prescribed varied from between 150 to 270 minutes per week of moderate to vigorous aerobic exercise, plus two or three sessions per week of resistance training in the PATH trial, to 225 minutes per week of moderate to vigorous aerobic exercise in the ALPHA trial, to only 60 minutes per week of moderate to vigorous aerobic activity plus 75 minutes of resistance training per week in the SHAPE trial. Overall, exercise in the ALPHA trial was shown to alter biomarkers linked to breast cancer risk including sex hormones[134], insulin resistance[136] and inflammatory markers[137], as well as mammographic density[138], but no change in insulin-like growth factor (IGF) axis proteins[136]. However, findings from the SHAPE and PATH trials suggest that weight loss, in addition to exercise, is needed in order to make meaningful improvements in biomarkers related to breast cancer risk; participants in the PATH trial who lost weight had significant declines in sex hormones[139], and while there were no significant effects on estrogens in women who did or did not lose weight, changes in body fat were significantly positively correlated with changes in estrogen levels[140]. The WISER study was a four-month intervention conducted in premenopausal women. While it was successful in improving fitness and body composition and reducing inflammation (as measured by CRP)[141], no changes in insulin or sex hormones were found[142,143], potentially due to the relatively short sixteen week duration of the intervention.

In response to these findings, a four-arm randomized controlled trial (consisting of diet, exercise, diet and exercise, and a control group) was conducted to help tease out the effects of physical activity and weight loss on biomarkers of breast cancer risk. The exercise component of the Nutrition and Exercise in Women (NEW) study consisted of 225 minutes per week of moderate to vigorous aerobic exercise (70 to 80% of maximal oxygen consumption (VO_2 max)) over the course of the twelve month intervention. Weight loss and changes in body composition were greatest in the combined diet and exercise group, followed by diet alone, with small but significant changes in the exercise only group compared to controls[144]. Participants in the diet or combined diet and exercise groups experienced the greatest changes in sex hormones[145], CRP[146], insulin, glucose and homeostasis model assessment – insulin resistance (HOMA-IR)[147] compared to controls and to exercise alone. In secondary analyses, regardless of intervention group assignment, changes in biomarkers were greatest in those who lost the most weight, although there was also a significant trend across tertiles of physical activity and change in fitness[145-147]. To further understand the unique contributions of reduced calorie diet and exercise on weight loss and biomarkers of breast cancer risk, a three-arm randomized controlled trial (SHAPE-2) is currently underway that will compare the individual effects of weight loss primarily via reduced calorie diet and weight loss via a combination of reduced calorie diet and an intensive aerobic and resistance exercise intervention, compared to a control group[148].

Overall, the results of randomized controlled trials suggest that weight loss in addition to exercise is what is most important for improving cancer-related biomarkers in healthy, overweight postmenopausal women, although there is still much more to be learned about how best to reduce breast cancer risk in premenopausal women. To date, no interventions have been conducted to examine the effects of physical activity on breast cancer risk that use breast cancer diagnosis as a primary outcome. While there has been a call for a randomized controlled trial to fully elucidate the effects of physical activity and energy balance on breast cancer risk, the estimated sample size for this type of trial ranges from 16 350 participants followed for a minimum of five years to detect an HR of 0.75 with 80% statistical power, to 50 874 participants followed over a minimum of three years to detect an HR of 0.85 with 90% statistical power[149]. Such trials are extremely expensive and unlikely to occur in the current period of reduced research funding.

Table 1.2 Randomized controlled trials of physical activity to reduce breast cancer risk

	Participants	Intervention	Significant Findings	No Change
PATH	Sedentary Overweight/obese Postmenopausal Age 55-75 years	12 months 3 mo supervised 9 mo home-based *Aerobic*: 5-6x/week 70-80% HRR 30-45min/ session Walking/cycling *Resistance*: 2-3x/week 20-30 min/session	*Physical Activity and Fitness* ↑ MVPA ↑ VO_2 max *Body Composition* ↓ Body weight, BMI, waist, hip ↓ % Body fat, total body fat kg (DXA) ↓ Total abdominal fat, subcutaneous fat (CT) *Biological Markers* ↓ Insulin, HOMA, Leptin, ↓ 2-OHE, Estrone, Estrodiol (in those who lost weight only) ↓ Testosterone, Free testosterone (in those who lost weight only)	*Biological Markers* Estone, estradiol, SHBG, free estradiol, androgens, IGF-1, IGFBP-3, IGF-1/IGFBP-3, glucose, Triglycerides, prolactin
SHAPE	Sedentary Postmenopausal Age 50-69 years	12 months 66% supervised 33% home-based 3x/week *Aerobic*: 60-85% APHRM 20 min/session *Resistance*: 25 min/session	*Physical Activity and Fitness* ↑ MVPA *Body Composition* ↓ % body fat *Biological Markers* ↓ Free testosterone, testosterone (in those who lost weight only)	*Biological Markers* Estrogens, androgens, SHBG

	Participants	Intervention	Significant Findings	No Change
ALPHA	Sedentary Postmenopausal Age 50-74 years	12 months 60% supervised 40% home-based 5x/week 70-80% HRR 45 min/session Aerobic exercise	*Physical activity and fitness* ↑ Total, recreational PA ↑ VO_2 max *Body Composition* ↓ Body weight, BMI, Waist, Hip ↓ Total body fat, % body fat (DXA) ↓ Abdominal fat, intra-abdominal fat and abdominal cross-sectional area, subcutaneous fat (CT) ↓ Mammographic density *Biological Markers* ↓ Estradiol, free estradiol, Insulin, HOMA-IR, Leptin, CRP *Other* ↑ Quality of Life	*Physical Activity and Fitness* Occupational PA, household PA *Body Composition* Lean body mass (CT) *Biological Markers* Estrone, androstenedione, free testosterone, testosterone Glucose, IGF-1, IGFBP-3, IGF-1/IGFBP-3, Adiponectin IL-6, TNF-α
WISER	Sedentary Weight-stable, Eumenorrheic Age 18-30 years	4 menstrual cycles (~ 16 weeks) 5x/week 80-85% MHR 30 min/session Aerobic exercise	*Physical Activity and Fitness* ↑ METs at 85% MHR Body Composition ↓ Fat mass, % body fat (DXA) ↑ Lean mass (DXA) *Biological Markers* ↑ IGFBP-3, 2-OHE/16α-OHE ↓ CRP	*Body Composition* Weight (kg), BMI *Biological Markers* Glucose, insulin, HOMA-index, QUICKI, IGF-1, IGFBP-1, Leptin, IGFBP-2, IGF-1/IGFBP-3, Adiponectin, Sex hormones (Estradiol, estrone, testosterone, Progesterone, SHBG), Melatonin, Cortisol, nor/epinephrine,

	Participants	Intervention	Significant Findings	No Change
NEW	Sedentary Overweight/obese Postmenopausal Age 50-75 years	12 months *Diet* 2 dietician visits Weekly group (up to 6 months) Monthly group (after 6 months) 1200-2000 kcal/day <30% kcal from fat *Exercise*: 60% supervised 40% home-based 5x/week 70-80% HRR 45 min/session Aerobic exercise	**Diet + Exercise (vs. exercise alone)** *Body Composition* ↓ Body weight, BMI, Waist (cm), body fat (kg, %) ↑ Lean mass (%) *Biological Markers* ↓ Insulin, C-peptide, CRP, glucose, HOMA-IR, estradiol, leptin, free estradiol, free testosterone, IL-6 ↑ SHBG *Other* ↓ Fat intake **Exercise (vs. control)** *Physical activity and fitness* ↑ Min/week, steps/week, VO_2 max *Body Composition* ↓ Waist (cm), body fat (%, kg) ↑ Lean mass (%), *Biological Markers* ↓ Estrone, leptin	**Diet + Exercise (vs. exercise alone)** *Physical activity and fitness* Min/week, steps/day, VO_2 max *Body Composition* Lean mass (kg) *Biological Markers* Vitamin D, estrone, testosterone, IGF-1, IGFBP-3 *Other* Total kcal/day **Exercise (vs. control)** *Body Composition* Body weight, BMI, Lean mass (kg) *Biological Markers* Insulin, C-peptide, CRP, glucose, HOMA-IR, Vitamin D, estradiol, testosterone, androstenedione, SHBG, free estradiol, free testosterone, IL-6, IGF-1, IGFBP-3 *Other* Quality of Life, Dietary intake

Legend: APMHR: Age-predicted max heart rate, CRP: C-reactive protein, CT: Computerized tomography, DXA: Dual energy X-Ray Absorptiometry, HRR: Heart Rate Reserve, IGF/BP: Insulin-like Growth Factor/Binding Protein, IL-6: Interleukin-6; MHR: Max Heart Rate, MET: Metabolic Equivalent, MVPA: Moderate-vigorous Physical Activity, OHE: hydroxyestrone, SHBG: Sex Hormone Binding Globulin; VO_2 max: Maximum O_2 consumption

1.4.3. PHYSICAL ACTIVITY AND CIRCADIAN RHYTHMS

It has been hypothesized that physical activity may act as a zeitgeber assisting with synchronizing the central and peripheral clocks to regulate circadian rhythms[72]. However, inconsistent results have been found, partially due to the confounding effects of light, timing of food intake, and social cues. Most studies have focused on acute exercise bouts, and have not investigated the effects of regular, sustained exercise participation. In a series of early animal studies by Redlin and Mrosovsky, physical activity produced large phase-shifting effects in rodents during the body-clock day of the circadian cycle[150]. Several laboratory-based studies have been conducted in humans to examine the effect that acute exercise bouts may have on circadian rhythms. In a quasi-experimental study, Eastman et al. found that eight, fifteen-minute bouts of moderate intensity exercise spaced throughout a simulated night shift produced larger phase shifts compared with controls who remained sedentary while exposed to the same night shift[151]. Using a two-by-two factorial design of bright light vs. dim light, with or without exercise, Baehr et al. found that fifteen-minute bouts of cycling once per hour over six hours during a night shift resulted in greater phase shift than no exercise, regardless of whether exercise was combined with bright light exposure[152]. In an attempt to determine the longer term effects of exercise on adaptation to night shift, a group of participants were exposed to nine-hour delayed simulated night shifts for fifteen days and asked to complete three, 45-minute bouts of cycling each night. Compared to non-exercising controls who were exposed to the same simulated night shifts, those who exercised during the night shift showed a greater shift in their melatonin profiles, suggesting better adaptation to the night shift[153]. In summary, based on the most recent review of the literature, published in 2007, Atkinson et al. concluded that in laboratory conditions, under a constant routine, exercise can mediate phase delays in circadian rhythms and alter hormonal secretions; however, there is currently insufficient evidence in human subjects on long term effects, or on the best exercise prescription, to provide evidence-based advice to shift workers or travelers who cross time-zones[154].

Outside of laboratory-based experiments, there is conflicting evidence for the relationship between physical activity and melatonin levels. In healthy young adults, physical activity was positively correlated with levels of 6-sulfatoxymelatonin (aMT6-s), measured by a morning urine sample[155]. Knight et al. also found a positive relationship between physical activity and melatonin in 213 healthy female volunteers who did not work night shifts. Interestingly, this relationship was stronger for physical activity completed later in the day, and the relationship was similar for moderate and vigorous activity[156]. To date, only one intervention study has examined the effects of regular physical activity on melatonin levels in healthy women. The WISER study, described previously, found no effect of sixteen weeks of physical activity on melatonin[157]. However, this study was conducted in healthy, premenopausal women with no evidence of circadian disruption. The effect of exercise on melatonin levels of shift workers who are exposed to light at night and have low baseline levels of melatonin has not been investigated.

1.4.4. Physical Activity in Shift Workers

Shift workers have been hypothesized to participate in less MVPA than day workers, due to their irregular work schedules. In a cross-sectional study of 376 health care workers, permanent night shift workers were more likely to report that their shift schedule interfered with regular exercise than permanent day shift workers, and were also less likely to report feeling physically fit compared to others[158]. A cross-sectional survey of 1194 workers surveyed by telephone in Queensland, Australia found that those who reported working shifts were more likely to report low physical activity (as captured via self-report using the International Physical Activity Questionnaire (IPAQ)) than day workers (pooled OR: 1.86, 95% CI: 1.21 – 2.88)[159]. In another study of 26 442 workers at a chemical and coatings manufacturer, compared to eight-hour day shift workers, rotating shift workers were more likely to report never participating in exercise (8h rotating shift RR: 1.18, 95% CI: 1.08 – 1.28, 10h rotating shift RR: 1.25, 95% CI: 1.02 – 1.51 and 12h rotating shift RR: 1.33, 95% CI: 1.22 – 1.46)[160]. Surprisingly, while permanent night shift workers working 8h and 10h were also more likely to report no exercise than day workers (8h permanent night shift RR: 1.10, 95% CI: 0.96 – 1.26, 10h permanent night shift RR: 1.46, 95% CI: 1.11 – 1.92), permanent night workers on 12h shifts were less likely than day workers to report no exercise (RR: 0.61, 95% CI: 0.40 – 0.92). The greater number of days off per week that commonly correspond with schedules that include longer shift duration may allow for more opportunities or motivation to exercise[160]. Rotating shift workers may experience differences in physical activity levels between the days when working day shifts and those when working night shifts. When a group of nurses wore an accelerometer for 24-hours on days where they completed a day shift and again on days when completing a night shift, MVPA was non-significantly lower on night shift compared to day shift days (206 ± 530, vs. 284 ± 649 minutes, $p = 0.09$)[161]. However, in another cross-sectional study using self-report data, while day shift and rotating shift nurses had similar levels of weekly household and transportation physical activity, occupational physical activity was higher for rotating shift workers (83.2 vs. 130.8 MET hours per week, $p < 0.001$) and leisure-time physical activity was lower (7.1 vs. 8.6 MET hours per week)[162]. While collecting data using accelerometers reduces the possibility of recall and reporting bias related to physical activity compared to self-report data, accelerometers are unable to distinguish between physical activities across different domains (e.g., occupational, transportation, and household activity vs. purposeful exercise) unless accompanied by a detailed log or diary. Therefore, more research is needed to understand patterns of activity in shift workers.

In line with the evidence from laboratory-based studies on the effects of physical activity on circadian adaptation, physical activity may also be related to an individual's tolerance to shift work. Harma et al. found that years of shift work was negatively correlated to maximal aerobic fitness (VO_2max) (r = -0.29) and muscular strength (r = -0.31), and that VO_2max had a large effect on fatigue in a stepwise multivariable regression analysis of data from female nurses[163]. In another study of 95 male and female shift workers, leisure time energy expenditure was positively correlated to coping scores from the Standard Shiftwork Index[164].

To date, only one physical activity intervention has been conducted in shift workers. In this study, 119 nurses were randomized to a four month supervised physical activity intervention of two to six sessions per week, or no-intervention control group[165,166]. In those who completed follow-up (n=75), the intervention group experienced improvements in VO_2max and muscular strength, as well as decreased fatigue and musculoskeletal symptoms from baseline compared to the control group. A trend towards improved circadian adaptation to shift work (measured using body temperature over 24-hours) was also reported. However, the authors reported low adherence (17% of participants missed >25% of scheduled sessions) and a large loss to follow-up (37%), perhaps due to the requirement for supervised scheduled exercise sessions. Promotion of physical activity behaviour change is well understood to be a challenge that requires targeted efforts for individuals to reach physical activity levels linked to cancer risk reduction and other positive health outcomes[167]. The limitations of this study in retention and adherence highlight the need for a better understanding of factors related to physical activity participation in shift workers, as traditional supervised physical activity programming with face-to-face behavioural support is unlikely to be feasible in this population.

1.5. Dissertation Objectives

The overall purpose of this dissertation is to examine the role that physical activity may play in reducing breast cancer risk, and improving overall health and quality of life of shift workers. The aim is to fill some of the gaps in the literature to date, particularly in the context of Canadian shift workers, as much of the research to date has been conducted in Scandinavian countries. Understanding the relationship between physical activity and cancer risk in shift workers in Canada will help in the development of future programs and policies to improve the health of Canadian shift workers.

The primary objectives of this research are:

1. To critically review the literature on health-related interventions that have been conducted in shift workers to identify evidence-based strategies that may be implemented to improve the health of shift workers (Chapter 2).
2. To compare physical activity patterns and correlates of physical activity (namely physical fitness and body composition) in shift workers to day workers, in the Canadian context (Chapter 3).
3. To understand specific barriers to physical activity that shift workers experience and identify preferences for physical activity programming that would be important to integrate into the design of a physical activity intervention (Chapter 4 and 5).
4. To test the feasibility of a physical activity program in shift workers (Chapter 6).

2. Chapter 2: Health-Related Interventions Among Night Shift Workers: A Critical Review of the Literature

2.1. Synopsis

Associations between shift work and chronic disease have been observed, but relatively little is known about how to mitigate these adverse health effects. This critical review primarily aimed to synthesize interventions that have been implemented in shift workers to reduce the chronic health effects of shift work, followed by an overall evaluation of study quality. MeSH terms and keywords were created and used to conduct a rigorous search of MEDLINE, CINAHL, and EMBASE for studies published on or before August 13, 2012. Study quality was assessed using a checklist adapted from Downs and Black. Of the 5053 articles retrieved, 44 met the inclusion and exclusion criteria. Over 2354 male and female rotating and permanent night shift workers were included, mostly from the manufacturing, health care, and public safety industries. Studies were grouped into four intervention types: 1) shift schedule; 2) controlled light exposure; 3) behavioural; and, 4) pharmacological. Results generally support the benefits of fast-forward rotating shifts; simultaneous use of timed bright light and light-blocking glasses; physical activity, healthy diet, and health promotion. Mixed results were observed for hypnotics. Study quality varied and numerous deficiencies were identified. Except for hypnotics, several types of interventions reviewed had positive overall effects on chronic disease risk outcomes. There was substantial heterogeneity among studies with respect to study sample, interventions, and outcomes. There is a need for further high-quality, workplace-based prevention research conducted in shift workers.

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2.2. Introduction

Shift work may be defined as the organization of working time to cover more than the usual eight-hour workday, up to a 24-hour period[5]. Some epidemiological studies have used three night shifts per month to classify exposure to night shift work[5], although no standard definition exists. Shift work is prevalent in health care, emergency services, manufacturing, retail, and hospitality. Some jobs require regular work on the same night shift (i.e., permanent night shift), while others are employed on rotating shift schedules involving days and nights. Approximately 15 to 20% of the working population in Europe and North America is employed in either a permanent night or rotating shift schedule[10].

Shift work, particularly work at night, has been found to disrupt endogenous circadian rhythms involved in melatonin expression, sleep patterns, food digestion, and other physiological processes[10]. Work at night is associated with a range of known and potential adverse health effects. In 2007, the International Agency for Research on Cancer (IARC) classified shift work involving circadian disruption as a probable human carcinogen (group 2A) based on sufficient animal evidence and limited human evidence[10]. The epidemiological studies considered in IARC's evaluation showed increased risks of breast cancer among long-term rotating shift workers and emerging evidence for other cancer types, such as prostate and colorectal[10]. Since the IARC decision, several meta-analyses have been published, three supporting the association between shift work and breast cancer[14-16] and two reporting inconclusive evidence[11,13]. Aside from potential cancer risks, shift workers also experience increased incidence of chronic illnesses including cardiovascular disease, diabetes and metabolic syndrome (a combination of obesity, dyslipidemia, high cholesterol, and insulin resistance)[168], as well as gastrointestinal disorders[169], workplace injuries[64], and disruption of family and social life[170].

The short- and long-term effects of shift work on sleep have also been studied. Night work has been shown to reduce sleep quantity and quality on workdays and days off. While shift workers tend to fall asleep rapidly in the morning immediately following a night shift, sleep tends to be shorter due to the natural awakening effects of circadian rhythms during the daytime, as well as social cues and daytime commitments. Objective assessments using electroencephalography (EEG) readings show a decrease in rapid eye movement (REM) sleep and stage two sleep[171]. Sleep questionnaires completed by shift workers show reduced sleep length and higher frequencies of sleep difficulties, intermittent sleep, and early waking[172]. Poor sleep quality and quantity have been shown to be related to various chronic diseases[84] including diabetes[173], cardiovascular disease[88], and obesity[85,174]. Thus, sleep quantity and quality are important outcomes of interventions aimed at improving long-term health in shift workers.

There is a need for interventions that can be implemented in workplaces, or by workers outside of work hours, to mitigate the harmful effects of shift work. Laboratory and field-based studies have been conducted to evaluate preventive approaches and interventions that promote health. To date, studies have assessed: 1) shift schedule changes (e.g. direction of rotation, speed of rotation, shift length, and self-rostering); 2) controlled exposure to light and dark (e.g. exposure to bright light in the workplace, use of goggles to minimize bright light exposure after night shift work and before sleep); 3) behavioural or lifestyle interventions (e.g. dietary changes, physical activity, scheduled napping); and, 4) pharmacological aids or other substances to facilitate sleep (e.g. exogenous melatonin) or to enhance alertness (e.g. Modafinil, caffeine).

Reviews have summarized the effects of specific intervention types such as caffeine[175], bright light and melatonin[176], and changes in shift schedules[177], however these reviews included laboratory-based studies that were conducted in non-shift workers in simulated night shift environments and findings may not be generalizable. They also included studies that examined outcomes likely irrelevant to long-term health, such as productivity and absenteeism. To our knowledge, there is currently no comprehensive review focused exclusively on data collected from prospective interventions conducted in shift workers with the aim of improving long-term health. A summary of this evidence would help to identify potentially effective interventions and gaps for further research.

The primary objective of this review was to synthesize the research reporting interventions that have been implemented in shift workers designed to prevent the long-term, adverse health effects of shift work. The secondary aim was to evaluate the overall quality of included studies. Based on the findings, future directions for intervention research are suggested.

2.3. METHODS

2.3.1. SEARCH STRATEGY

A comprehensive list of MeSH terms related to shift workers, health-based interventions, and long-term health outcomes were developed (Figure 2.1) and used to search MEDLINE, CINAHL, and EMBASE for studies published on or before August 13, 2012. The search was limited to studies that were conducted on human subjects and published as English-language articles in peer-reviewed journals. Reference lists of relevant review papers and studies identified in the literature search were hand searched for other potentially eligible articles.

Figure 2.1 Search strategy

Medline • Shift work$.mp. shiftwork$.mp, night work$.mp, night shift.mp., evening work$.mp, split shift work$.mp, rotating shift work$.mp, non-day shift work$.mp, health worker.mp., healthcare worker.mp., paramedic$.mp. or exp Allied Health Personnel, emergency medical tech$.mp., Physicians/, Nurses/, Manufacturing work$.mp., Hospitality work$.mp, armed forces, mp., armed personnel.mp, Military Personnel/, Police$.mp. or exp Police/, Astronauht.mp. or exp Astronauts/, flight attendant$.mp. , steward$.mp., air crew.mp., or pilots.mp. AND • *Light/ bright light.mp, dim light.mp, exp Lighting/, controlled light exposure, mp., light intensity.mp, blue light.mp, phototherapy.mp. or exp Phototherapy/, light exposure.mp., Darkness/, goggles.mp, dark goggles.mp, sunglasses.mp, blue blockers.mp, short wavelength.mp, light exposure.mp., Modafanil.mp., adrafinil.mp, armodafinil.mp, Melatonin/ad, tu [Administration & Dosage, Therapeutic Use], Caffeine/ad, ae, ct, sd, tu, th [Administration & Dosage, Adverse Effects, Contraindications, Supply & Distribution, Therapeutic Use, Therapy], stimulants.mp., Exp Relaxation Therapy/ or stress management.mp, Exp Counsling/ or counseling.mp, physical activity.mp., exp Exercise/ or exp Exercise Therapy, Diet.mp or exp Diet/, meal.mp, weight loss.mp. or exp Weight Loss/, Low energy emission therapy.mp, Nap$.mp, Exp "Personnel staffing and scheduling"/ or work schedule.mp, schedule change.mp., schedule modification.mp., shift system.mp., shift change.mp., shift rotation.mp, shift length.mp, work schedule flexibility.mp,. , Working conditions.mp, workload/or working time directive.mp, exp Primary Prevention/ or prevention.mp; health promotion.mp. or exp health promotion/ AND • Work schedule tolerance.mp. or exp Work Schedule Tolerance/, circadian adaptation.mp., circadian rhythm adaptation.mp., circadian alignment.mp., circadian adjust$.mp., phase shift.mp., phase delay.mp., Exp Sleep/ or sleep.mp., sleep-wake cycle.mp., rest-activity cycle.mp., Melatonin.mp. or exp Melatonin/, dim light melatonin onset.mp., urinary 6-sulfatoxymelatonin.mp., Cortisol.mp., Cancer.mp. or exp Neoplasms/, diabetes.mp. or exp Diabetes Mellitus/, cardiovascular disease.mp. or exp Cardiovascular Diseases/, heart disease.mp. or exp Heart Diseases/, exp Metabolic Syndrome X/ or metabolic syndrome.mp.
EMBASE • Shift work$.mp. or exp shift worker/, shiftwork$.mp., exp night work/ or night work$.mp., night shift work$.mp., evening work$.mp., split shift work$.mp., rotating shift work$.mp., alternating shift work$.mp., non-day work$.mp., Healthcare worker.mp.; emergency medical tech$.mp., paramedical personnel/ or paramedic$.mp.; *physician/ or *nurse, Manufacturing worker.mp. or exp industrial worker/, Hospitality worker.mp., Armed forces.mp.; military personnel.mp. or exp soldier/; armed personnel.mp; police$.mp. or exp police/, Astronaut.mp. or exp cosmonaut/; flight attendant$.mp. or exp airplane crew/; airplane pilot/ or pilots.mp. AND • Exp phototherapy/ or exp light exposure/ or bright light.mp. or light/; dim light.mp; lighting.mp. or exp illumination/; darkness/; controlled light exposure.mp.; light intensity.mp. or exp light intensity; blue light.mp. or exp blue light/, Goggles.mp.; dark goggles.mp; sunglasses.mp.; blue-blockers.mp; short wavelength.mp., exp melatonin/ct, ad, dv, do, dt, po [Clinical Trial, Drug Administration, Drug Development, Drug Dose, Drug Therapy, Oral Drug Administration], exp caffeine/ct, ad, do, dt, po, th [Clinical Trial, Drug Administration, Drug Dose, Drug Therapy, Oral Drug Administration, Therapy]; stimulants.mp., exp Modafinil/ or modafanil.mp; Armodafinil.mp. or exp armodafinil/; adrafinil.mp. or exp adrafinil/, Stress management.mp. or exp stress management/; counseling.mp. or exp counseling/, Exercise.mp. or exercise/; physical activity.mp. or exp physical activity/, Diet.mp. or exp diet/; Meal.mp. or meal/, Weight loss.mp. or exp weight reduction/, Low

energy emission therapy.mp., Nap$.mp., Exp Work schedule/ or schedule change.mp.; schedule modification.mp.; shift system.mp.; shift change.mp.; shift length.mp. or exp working time/; work schedule flexibility.mp., shift rotation.mp. Workload/ or working time directive.mp.; exp work environment/ or working conditions.mp., *health promotion/ or *health program or *prevention AND • circadian adaptation.mp.; circadian rhythm adaptation.mp.; circadian alignment.mp.; circadian adjust$.mp.; phase shift.mp.; phase delay.mp., Sleep-wake cycle.mp. or exp sleep waking cycle/; rest-activity cycle.mp.; *sleep/, Melatonin.mp. or exp melatonin/; dim light melatonin onset.mp.; urinary 6-sulfatoxymelatonin.mp. or exp 6 hydroxymelatonin o sulfate/, Cortisol.mp, Cancer.mp. or exp Neoplasms/, diabetes.mp. or exp Diabetes Mellitus/, cardiovascular disease.mp. or exp Cardiovascular Diseases/, heart disease.mp. or exp Heart Diseases/, exp Metabolic Syndrome X/ or metabolic syndrome.mp.
CINAHL • (MH “Shiftwork”) or “shiftwork” or (MH “Shift workers”) or “shift work” or “night work’ or “night shift work” or “evening work” or “split shift work” or “rotating shift work” or “alternating shift work” or “non-day work”, (MH “Health personnel”) or “health worker” or “healthcare worker” or (MH “Nurses”) or (MH “Emergency medical technicians”) or “emergency medical tech$” (MH “Physicians”) or “paramedic”, “Manufacturing worker” or “industrial worker”, “Hospitality worker”, “Armed forces” or (MH “military personnel”) or “soldier” or (MH “police”) or “police” , “Astronaut” or “flight attendant” or “airplane crew” or (MH “Pilots”) AND • (MH “Phototherapy”) or “phototherapy” or (MH “Lighting”) or “light exposure” or “bright light” or (MH “light”) or “dim light” or “ darkness” or “controlled light exposure” or “light intensity” or “blue light”, “Goggles” or “dark goggles” or “sunglasses” or “blue-blockers” or “short wavelength”, (MH “melatonin”) or “melatonin”, (MH “Caffeine”) or “caffeine” or “stimulant”, (MH “Modafinil”) or “modafanil” or “armodafinil” or “adrafinil”, (MH “Stress management”) or “stress management” or (MH “counseling”)or “counseling”, (MH “Exercise”) or “exercise” or (MH “physical activity”) or “physical activity”, (MH “Diet”) or “diet”; (MH “meal planning”) or “Meal”, (MH “Weight loss”) or “weight loss”, “Low energy emission therapy”, “Nap$”, “Work schedule” or “schedule change” or “schedule modification” or (MH “Personnel staffing and scheduling”) or (MH “Flexible scheduling”) or “shift system” or “shift change” or “shift length” or “working time” or (MH “Work environment”) or “shift rotation” or (MH “ Workload”) or “working time directive”, (MH “Health promotion”) or “health promotion” or “prevention” AND • (MM “Circadian Rhythm”) or “circadian adaptation”; “circadian rhythm adaptation”; “circadian alignment”; (MH “Phase Angle”) OR “phase shift”; “phase delay”, “Sleep-wake cycle” or ‘rest-activity cycle”; (MH “sleep”) or “sleep”, (MM “Melatonin”) or “melatonin”; “dim light melatonin onset”; “urinary 6-sulfatoxymelatonin”, “Cortisol”, (MH “Neoplasms”) or “Cancer”; (MH "Diabetes Mellitus, Type 2") OR (MH "Diabetes Mellitus") OR "diabetes"; (MM "Cardiovascular Diseases") OR (MM "Cardiovascular Risk Factors") OR "cardiovascular disease", (MM "Metabolic Syndrome X") OR "Metabolic syndrome"

2.3.2. Study Eligibility and Selection

Two reviewers (SENS, MP) independently inspected the title and abstract of each study identified to determine eligibility for inclusion. Eligibility was based on a pre-determined set of criteria (Figure 2.2). Studies were included if the intervention aimed to improve one or more chronic disease-related health outcomes in shift workers. Participants must have been working permanent or rotating night shifts at the time of intervention. Interventions that were implemented in simulated work environments or non-shift workers (e.g., healthy volunteers) were excluded. Interventions that were conducted in workers with extreme work schedules (e.g., greater than 24 hours of continuous work) or in workers who cross time zones (e.g., astronauts, aircrew, military workers) were excluded because of potential confounding from factors such as cosmic radiation and jet lag.

Figure 2.2 Inclusion and exclusion criteria

Inclusion criteria
• All workers on permanent night or rotating shifts at the time of intervention AND • Implemented an intervention for 7 or more consecutive days and evaluated it AND • Designed to improve one or more health outcomes related to chronic disease: o Sleep quantity and quality (objective and subjective measurement tools) o Markers of circadian disruption/adaptation (melatonin, cortisol, body temperature, uric acid, norepinephrine, epinephrine) o Markers of chronic disease risk (cholesterol, triglycerides, glucose, hemoglobin A1C, C-reactive protein, blood pressure) o Risk factors for chronic disease (physical activity, unhealthy diet, tobacco use, alcohol consumption, overweight or obesity)
Exclusion criteria
• Interventions conducted among non-shift workers (e.g. healthy volunteers) OR • Interventions conducted among workers with extreme work schedules or workers who cross time zones (e.g. astronauts, pilots, flight attendants, air crew, military/soldiers) OR • Interventions conducted in simulated work environments and conditions OR • Literature reviews, commentaries, editorials, opinion pieces, policy document, consensus statement OR • Absence of both pre- and post-intervention main outcome measures OR • Designed to improve any one or more of the following outcomes: o Organizational-related (e.g. profit, turnover, absenteeism, job satisfaction, productivity, performance, alertness, vigilance) o Workplace injuries o Sleepiness o Fatigue o Mental health, mood, well-being, work-life balance, psychological stress, burnout o Attitudes towards intervention

The intervention must have been implemented for seven or more consecutive days since this review focused on interventions with implications on long-term health. Before-and-after studies, or natural interventions (defined as studies involving an intervention not initiated by researchers) were included if there was at least one main outcome measure both pre- and post-intervention in order to determine the effect of the intervention itself. We included non-pharmacological and pharmacological interventions. Randomized and non-randomized study designs were included, as well as case-control, and cohort studies if the exposure was an intervention.

Eligible studies were required to report on outcomes related to chronic disease risk as defined by the World Health Organization (WHO): "diseases of long duration and generally slow progression"[178]. The related health outcomes included were: 1) sleep quantity and quality; 2) markers of circadian disruption/adaptation; 3) biological markers of chronic disease; and 4) common modifiable risk factors for chronic disease as identified by the WHO[178]. Studies only reporting organizational outcomes (e.g., productivity, absenteeism) were excluded because they were beyond the scope of this review's focus on shift workers' health. Similarly, studies that only measured work-related injuries were excluded because this outcome has a different etiology than chronic disease. Although the experience of sleepiness and fatigue are part of the diagnosis of Shift Work Sleep Disorder[179], these outcomes were excluded in this review since they are more strongly related to work-related injuries and productivity than to chronic disease risk, which is linked with the measures of sleep quality and quantity that are included here. Mental health and psychosocial outcomes such as psychological stress, work-life balance, burnout, mood, and well-being were also excluded. Although these are interesting and important outcomes, they represent a distinct set of health effects that have different risk factors and etiologies compared to chronic disease as defined in this review. Outcomes such as "attitudes towards intervention" were omitted since these were primarily concerned with the intervention itself and not shift workers' health.

The two lists of eligible studies generated by each reviewer were compared and eligibility of any paper in question was resolved by consensus. Included papers were obtained in full and further reviewed for data extraction and quality assessment.

2.3.3. Quality Assessment

Study quality was assessed using a 28-point checklist adapted from Downs and Black, with reported test-retest and inter-rater reliability of 0.88 and 0.75, respectively[50]. The original checklist has been widely used in systematic reviews of both randomized and non-randomized studies. Of the various quality assessment tools available, this was the most appropriate tool as it has been validated and it was not possible to randomize workers in many of the included studies. The checklist encompasses four key areas with the following number of points available: 1) reporting of objectives, outcomes, study subjects, interventions, confounders, results, adverse events, loss to follow-up, and probability values (eleven points); 2) external validity (three points); 3) internal validity: a) bias in the measurement of the intervention and the outcome (seven points), and b) confounding related to the selection of study subjects (six points); and 4) statistical power (one point). The checklist was independently completed by two reviewers (SENS, MP) who gave each study a score for each section, and an overall score. Scores assigned by each reviewer were compared and discrepancies were resolved by consensus. Individual and aggregate scores for intervention types are presented for different intervention types or sub-types in order to identify areas for improvement in subsequent research.

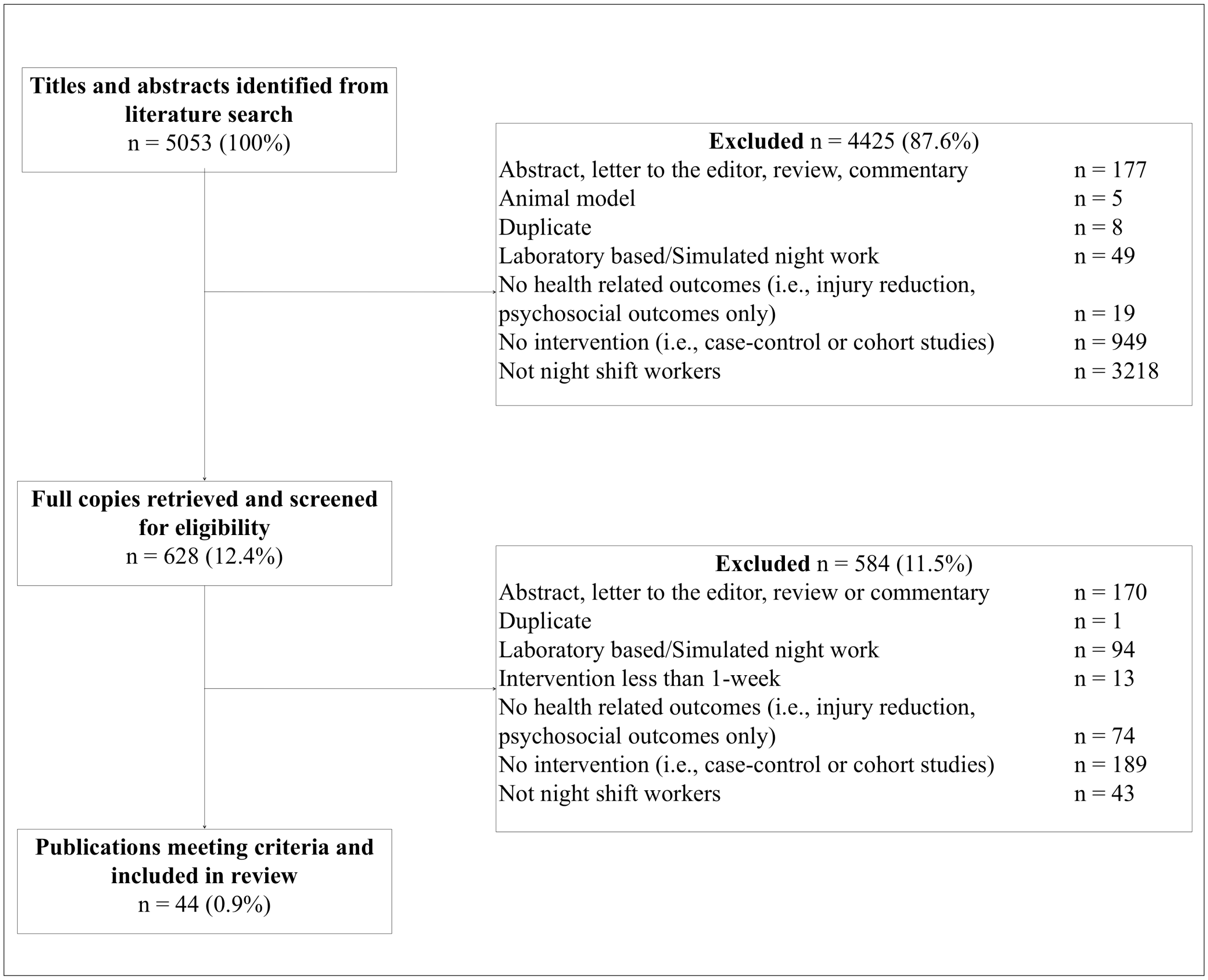
2.3.4. Data Extraction and Synthesis

Included studies were grouped as one of four intervention types: controlled light exposure, shift schedule, behavioural, and pharmacological. Detailed information about the objective, design, sample, intervention, comparison group, and outcomes were extracted from each publication and tabulated independently by SENS and MP. Only health outcomes that met eligibility criteria were extracted. Adverse events and funding sources were noted. It was not possible to conduct a meta-analysis due to the heterogeneity of study designs, populations, interventions, and outcomes. Authors were not contacted for additional information about their studies. Missing information was noted.

2.4. Results

The literature search generated 5053 search results. Of these, 4425 titles and abstracts did not meet inclusion criteria and were excluded (Figure 2.3). Full text articles were obtained for the remaining 628 search results. Of these, 584 were excluded. The most common reason for exclusion was laboratory or simulated interventions conducted in non-shift working volunteers. Hence, this review included 44 articles describing results from 38 different interventions published between 1982 and 2012.

Figure 2.3 Search strategy and study selection



2.4.1. DEMOGRAPHIC CHARACTERISTICS

Studies included a total of 2354 workers (Table 2.1). One-third (36.6%) were industrial or manufacturing workers, followed by health care workers (18.4%), police officers and security workers (7.7%), and workers in other occupations and industries (37.4%). Most worked rotating shifts (60.7%); only 2.7% worked permanent night shifts (remainder, not reported). Studies that assessed changes in shift schedules recruited the largest number of workers (N=1023) compared to studies of controlled light exposure (N=243), behavioural interventions (N=203), and pharmacological interventions (N=902). Reports included more men (54.0%) than women (30.4%). Shift workers’ age ranged from 20-58 years.

Table 2.1 Characteristics of participants included in studies

	Total (N = 2354)		Controlled light (n = 228)		Shift schedule (n = 1023)		Behavioural (n = 203)		Pharmacological (n = 902)	
Age (range)	20.0 – 58.0		25.0-55.0		23.8-56.0		20.0-49.0		24.0-58.0	
	N	%	Workers (N)	Studies (N)	Workers (N)	Studies (N)	Workers (N)	Studies (N)	Workers (N)	Studies (N)
Occupation/industry										
Industrial, manufacturing, maintenance	861	36.6	35	3	651	10	122	2	53	1
Nurse, resident, physician	433	18.4	131	4	176	2	81	2	45	1
Police officer, security	181	7.7	15	1	120	2	0	0	46	2
Oil rig, mine	92	3.9	34	3	58	1	0	0	17	1
Mail room, computer operators	46	2.0	28	1	18	1	0	0	0	0
Various	741	31.5	0	0	0	0	0	0	741	3
Shift schedule										
Permanent nights	64	2.7	64	3	0	0	0	0	0	0
Rotating	1429	60.7	169	8	1023	15	93	3	161	5
Not reported	861	36.6	10	1	0	0	110	1	741	3
Sex										
Male	524	22.3	21	3	375	6	128	3	0	0
Female	191	8.1	116	3	0	0	75	1	0	0
Both male and female	1348	57.3	106	6	386	6	0	0	873	7
Not reported	291	12.4	0	0	262	3	0	0	29	1

Note: Percentages across study types may exceed 100% due to one study[180] that included both controlled light exposure and pharmacological interventions

2.4.2. Quality Assessment

The average rating across all studies was 15.9 out of a possible 28 points (range: 8-27) (Table 2.2). For reporting, scores ranged from 2-11 (mean = 7.0) out of a possible eleven. Information was most frequently missing for the distribution of principal confounding factors in study groups, adverse events, and *p*-values for statistical tests. External validity scores ranged from 0-3 (mean = 1.2) out of a possible three, with reviewers frequently unable to determine whether participants were representative of shift workers as a whole or of workers in specific industries under investigation. Internal validity (bias) scores ranged from 3-7 (mean = 4.4) out of a possible seven. Particular concerns were insufficient information about compliance and lack of blinding of subjects and assessors. Scores for internal validity (confounding) ranged from 1-6 (mean = 3.2) out of a possible six. Deficiencies were most common regarding randomization, concealment of group allocation until complete baseline assessment, and reporting loss to follow-up. Only three interventions reported a sample size calculation, which provided a score of one rather than zero.

Table 2.2 Quality assessment by study type

	Controlled Light Exposure		Changes in Shift Scheduling		Behavioural Interventions		Pharmacological Interventions		Overall	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	**Mean**	**Possible**
Reporting	7.1	2-10	6.5	3-10	7.4	4-11	7.5	5-11	**7.0**	**11**
External Validity	0.9	0-2	1.4	1-3	2.2	1-3	0.8	0-2	**1.2**	**3**
Internal Validity										
Bias	4.1	3-6	4.1	3-5	4.4	3-6	5.6	3-7	**4.4**	**7**
Confounding	2.9	1-5	3.0	2-4	3.8	2-6	4.1	2-6	**3.2**	**6**
Power	0.1	0-1	0	0	0.2	0-1	0.1	0-1	**0.1**	**1**
Total	15.1	8-21	14.9	9-20	18.0	10-27	18.1	11-24	**15.9**	**28**

2.4.3. Controlled Light Exposure

The literature search yielded sixteen papers that described twelve interventions of controlled light exposure in shift workers[180-195] (Table 2.3). Mean study quality was 15.1 (range: 9–21). Seven evaluated the use of intermittent bright light[180,181,186,187,189,190,193,195], four used a combination of bright light and light-blocking goggles[182-185,188,192,194], and one evaluated glasses that filtered blue light wavelengths[191]. Across all interventions, light intensity ranged from 200-10,000 lux, and cumulative exposure times per shift ranged from ten minutes to six hours. Follow-up ranged from seven to 96 days (mean = 23.7 days, median = 14.0 days). The most common outcomes were sleep (n = 9)[180-182,186,190-194] and markers of circadian rhythm: melatonin (n = 7)[183-186,189,190,192,194,195], cortisol (n = 2)[188,189,195], and body temperature (n = 3)[184,185,187,189,195].

Controlled light exposure had different effects on health. Two brief periods of bright light significantly affected 24-hour total sleep time (including naps) in truck plant workers, but did not change sleep efficiency or quality[190]. In oil workers, bright light at the rig and on days off improved sleep latency and total sleep time[181], and oil workers who also wore sunglasses improved sleep efficiency[194]. Nurses who were exposed to bright light before the midpoint of peak melatonin concentration and who wore goggles during the commute home increased total sleep time after night shifts[182]. There was also some indication that phase shift, an indicator of circadian adaptation to night shift work, had occurred, as evidenced by significant body temperature and melatonin changes. Nurses who exposed themselves to bright light for ten minutes on workday mornings reported significant improvements in quality of night sleep on day shifts compared to non-bright light exposure periods[193]. Wearing blue-blocking goggles while commuting improved total sleep time[191] and sleep efficiency[192] in two studies. The two remaining studies found no significant effect of bright light on sleep parameters[180,186].

Of the studies that used a bright light intervention (with or without goggles), four successfully altered melatonin levels[183-185,189,190,195] and three did not[186,192,194], with no difference in quality scores between the two groups of studies (means 14.2 and 14.3 respectively). Cortisol was measured as an indicator of circadian rhythms in two studies; one was successful in shifting the usual release pattern of salivary cortisol[188], and the second increased plasma cortisol levels over the night shift[189,195]. Body temperature also follows the circadian rhythm and was used to assess circadian adaptation to night shift work in three studies; two effectively altered body temperature[184,185,189,195], while one found no change[187]. Other health outcomes evaluated are summarized in Table 2.3.

Table 2.3 Controlled light exposure interventions

Author/Year	N	Sample	Shift system	Study Design	Intervention	Duration	Outcome Measures (Tool)	Results: Intervention		Results: Control	Quality
Bjorvatn 1999[181]	7	M oil rig workers, age 29-47	12H shifts One-week rotation DD---NN ----	Single-arm pre-post	30 min BL (10 000 lux) 3h < wake time	14 night shifts	*During night shifts*				17
							- Time in bed (min)	+8.0		n/a	
							- Sleep latency (min)	+1.2			
							- Total sleep time (min)	+7.8			
							- Sleep quality (Likert, 1-5)	+0.0			
							Days off				
							- Time in bed (min)	+25.9			
							- Sleep latency (min)	+6.5			
							- Total sleep time (min)	+20.3			
							- Sleep quality (Likert, 1-5)	+0.4			
Bjorvatn 2007[180]	17	M=16, F=1, oil rig workers, mean age 42, report problems adjusting to SW	12H shifts One week N One week D 3-4 weeks off	3-arm randomized cross-over	1) 30 min BL (10 000 lux), < nadir 2) 3 mg melatonin 3) Placebo	14 work days	*During night shifts*	BL	Melatonin	Placebo	
							Subjective sleep (diary)				20
							- Sleep onset latency (min)	9[a]	13[b]	14	
							- Total sleep time (min)	392	405[b]	386	
							- Sleep efficiency (%)	86	87	86	
							- Sleep quality (1-5)	3.1	3.1	3.1	
							Objective sleep (Actiwatch)				
							- Sleep onset latency (min)	6	9[b]	6	
							- Total sleep time (min)	419[a]	416	403	
							- Sleep efficiency (%)	88	87	86	
							Days off				
							Subjective sleep (diary)				
							- Sleep onset latency (min)	17	19	19	
							- Total sleep time (min)	318	355[b]	340	
							- Sleep efficiency (%)	80	87[b]	83	
							- Sleep quality (1-5)	2.8	2.8	2.7	
							Objective sleep (Actiwatch)				
							- Sleep onset latency (min)	7	15[b]	6	
							- Total sleep time (min)	367	355	348	
							- Sleep efficiency (%)	87	86	85	
Boivin 2002, 2004[184,185]	15	M=6, F=9 nurses, mean age 41.7	8H shifts ≥ 8 shifts/15 days	2-arm RCT with cross-over (n=4)	1) BL exposure (~2000 lux) 2) Neutral gray density lens goggles (commute)	12 shifts (mean 19 days)	Phase angle (hours)				15
							- Core body temp. (°C)	-0.06[a, b]		+5.31	
							- Salivary melatonin (pg/mL)	-2.05[a, b]		+4.31	
							Phase shift				
							- Core body temp. (t_{min}, h)	+9.32[a, b]		+4.09	
							- Salivary melatonin (t_{mid}, h)	+11.31[a, b]		+5.08	
James 2004[188]							Salivary cortisol				12
							- Phase angle (h)	-1:47[b]		+7:17[a]	
							- t_{mas} (h)	+10:04[a, b]		+3:03	
							- t_{min} (h)	-12:34[a, b]		+3:41	
							- 24h mean (ug/dL)	+0.03		+0.02	

Author/Year	N	Sample	Shift system	Study Design	Intervention	Duration	Outcome Measures (Tool)	Results		Quality
								Intervention	Control	
Boivin 2012a[182]							*After night shift* - Time in bed (h, Actigraph) - Total sleep time (h, PSG) - Sleep efficiency (h, PSG)	 -0:37 7:06 [b] 92%	 -1:37 6:36 88%	17
Boivin 2012b[183]	15	M=7, F=8 police officers, mean age 29.8	EEE--DD DD--NNN NNNN--- ---EEEE --DD---	2-arm RCT with cross-over (n = 2)	1) Intermittent BL 2) Orange-tinted goggles (sunrise to day sleep)	7 night shifts	*Before/After night shift* - UaMT6s t_{mid} (h) - UaMT6s total (ng) - Salivary melatonin acrophase (h) - Salivary melatonin amplitude (pg/mL) *During night shift* - Daytime mean uaMT6s	 -7.07 [a] +1671 -5.93 -2.13 + [b]	 -5.75 [a] +268 -4.52 -2.03 x	18
Budnick 1995[186]	13	M=11, F=2 industrial techs, median age 35	12H shifts 16-day rotation DDDD---- NNNN----	Single-arm, pre-post	1) ↑ Ambient light (1500 lux) 2) BL (4000-8000 lux) > 50% of shift	96 days	Hours of sleep (log book) Urinary melatonin	x x	n/a	13
Figueiro 2001[187]	21	F day (n=12) and night (n=9) NICU nurses, age 25-38	12H permanent D or N	Single-arm, pre-post	1) 15 min BL (2300-4000 lux) start/middle/end of shift 2) BL + dark goggles (sham)	2 weeks	Tympanic temperature throughout night shift	x	n/a	9
Kakooei 2010, Zamanian 2010[189,195]	34	F nurses, mean age 27	Irregular 3-shift system, day, evening and night	Single-arm, pre-post	BL (4500 lux) 2x 45-min	30 days	Plasma melatonin (pg/mL) Body temperature t_{peak} (h) Plasma cortisol (ug/dL)	-7.29 [a] +3:00 [a] +1.75 [a]	n/a	12, 8
Lowden 2004[190]	18	M=17, F=1 industrial operators, mean age 36.2	MEN-- 4 week rotation	2-arm RCT with cross-over	BL (2500 lux) 2 self-chosen breaks	4 weeks	Sleep (Actiwatch) - Bed time (h) - Sleep time (h) - 24-total sleep (h) - Sleep efficiency (%) Melatonin ,(pg/mL)	 07:44 6:43 6:53 [b] 90.4 15.02 [b]	 07:44 6:28 x 89.5 18.10	18
Sasseville 2009[191]	28	M=13, F=15 mail center workers, 25-55y	NNNNN--	Single-arm pre-post	Blue-blocker goggles during night shift commute	2 weeks	Sleep (Actiwatch) - Time before bedtime (min) - Time in bed (h) - Total sleep time (h) - Sleep efficiency (%) - Movement Fragmentation Index (%)	 -9 +0:17 +0:32 [a] +2.0 [a] -1.7 [a]	n/a	16
Sasseville 2010[192]	4	M sawmill workers, mean age 44.8	DDDDD-- NNNNN-- EEEEE--	Single-arm, pre-post	1) Environment supplemented with blue-green light (200 lux) 2) Blue-blockers on commute when outside < 1600h	1 week	Phase shift of salivary melatonin (h) Bed time (h) Time in Bed (h) Total Slept Time (h) Sleep efficiency (%) Sleep latency (h)	-2:02 +0:14 +0:05 +0:40 [a] +3.7 -0:18 [a]	n/a	12

Author/Year	N	Sample	Shift system	Study Design	Intervention	Duration	Outcome Measures (Tool)	Results		Quality
								Intervention	Control	
Tanaka 2011[193]	61	F nurses, mean age 29.7	DDD-NN-	2-arm RCT with crossover	10 min BL (5444-8826 lux) on day-shift mornings	One month	Night sleep (VAS) Alcohol consumption	6.30 [b] x	5.94	21
Thorne 2010[194]	10	M oil rig workers, mean age 46x49, BMI >28	1900-0700h 14 or 21 days (summer) 1800-0600h 14 days (winter)	2-arm intervention	1) 1h BL (~3000 lux) 2) Sunglasses from wake to BL exposure	21 days	Rate of aMT6s adaptation (h/day) *Objective sleep (Actigraphy)* - Sleep onset (h) - Sleep offset (h) - Sleep duration (h) - Sleep efficiency (%) - Fragmentation index - Sleep latency (h) *Subjective sleep (Diary)* - Sleep onset (h) - Sleep offset (h) - Sleep duration (h) - Sleep efficiency (%) - Fragmentation index - Sleep latency (h) - Sleep quality (1-9 Likert)	2.16 22.85 5.78 6.18 86.7 [a] 27.2 0.21 22.92 6.51 6.99 0.14 1.3 0.31 4.6	2.00 23.45 6.19 5.95 79.4 30.7 0.38 22.91 6.66 7.26 0.13 1.5 0.32 5.1	18

[a] Significant difference before-after intervention, $p < 0.05$
[b] Significant between groups
Note: + = positive change - = detrimental change, x = no change
Legend: BL, Bright Light; BMI, Body Mass Index; D, Day shift; E, Evening shift; F, Female; h, hours; M, Male; N, Night shift; PSG, Polysomnography; RCT, Randomized Controlled Trial; SSS, Stanford Sleepiness Scale; - , off work; t_{mid}, time of midpoint; t_{max}, time of maximum; VAS, Visual Analogue Scale

2.4.4. SHIFT SCHEDULE CHANGE

Fifteen interventions evaluated a change in shift schedule[196-211] (Table 2.4). Mean study quality was 14.9 (range: 9–20). Interventions involved changes from a backward (counter-clockwise) to forward (clockwise) rotating shift (n = 6)[197-199,202,205,206,210] and vice versa (n = 1)[201], switching from eight- to ten- or twelve-hour shifts (n = 6)[200,203,204,207,208,211], adjusting the shift schedule based on ergonomic principles[196], flexible shift scheduling[210], and delaying shift start time[209]. Many changes from backward to forward rotating shifts also increased rotation speed (n = 4)[197,199,202,210]. Follow-up ranged from four weeks to one year (mean = 8.3 months, median = 9 months). The three most frequently evaluated outcomes were sleep (n = 15)[196-211], behaviours related to chronic disease risk (e.g., diet, physical activity levels and alcohol intake) (n = 7)[196,197,202,205-208,210], and chronic disease risk factors (e.g., cholesterol, triglycerides and blood pressure)[196,205-207,210].

Three studies found that sleep quantity or quality was significantly positively affected by changing from backward to forward rotation[197-199], but this effect was not observed in three other reports, which found no significant effects on sleep[202,205,206,210]. In one study, this change was associated with significant decreases in triglycerides, glucose, and systolic blood pressure[205,206]. However, overall study quality was worse in studies that found a significant effect on sleep (mean scores 14.3 and 17.0, respectively). Of interventions that changed from eight- to ten- or twelve-hour shifts, three improved sleep[204,207,211], one significantly improved physical fitness[207], and three resulted in no significant or negative changes in sleep after the night shift[200,203,208]. Those who found no change were of higher quality (mean score = 14.0) than those who found a significant effect (mean score = 13.3). Another intervention took a multi-faceted approach to shift scheduling based on four ergonomic principles: regularity, fewer consecutive night shifts, more weekends off, and two different types of shifts. This resulted in a significant decline in low-density lipoprotein (LDL) and total to high-density lipoprotein (HDL) ratio; however, sleep quality was unaffected[196]. Airline maintenance workers given individual flexibility and control over work hours experienced no significant improvement of any health parameters[210]. A one-hour delay in start time at a steel plant resulted in increased sleep on morning shift days, but decreased sleep on evening and night shift days[209].

Table 2.4 Change in shift schedule interventions

Author/ Year	N	Sample	Shift system	Study Design	Intervention	Length	Outcome Measures (Tool)	Results: Intervention		Results: Control	Quality
								I4	I3		
Boggild 2001[196]	101	Nurses, median age 35-42	2-3 shift rotation, flexible/ irregular schedule	3-arm, quasi-experimental	1) I4 (regularity; ↓consecutive shifts; ↑ weekends off; 2 types of shifts) 2) I3 (any three of above)	6 months	TChol (mmol/L)	-0.1	+0.2	0.0	17
							TG (mmol/L)	-0.1	0.0	0.0	
							HDL (mmol/L)	+0.1 [b]	0.0	-0.1	
							LDL (mmol/L)	-0.2 [b]	0.0	+0.1	
							Total:HDL ratio	-0.3 [b]	-0.3	+0.1	
							Sleep quality (Subjective)	x	x	x	
							Lifestyle (questionnaire)	x	x	x	
Hakola 2001[197]	16	M steel factory workers, young (30-39y) and old (44-56y)	Slow bwd rotating EEE-MMMNNN-----	Single-arm pre-post	Fast fwd rotation MMEENN----	1-year	Sleep quality (SSI)				9
							- Morning shift	+ [a]		n/a	
							- Evening shift	x			
							- Night shift	x			
							Sleep Length (Actigraph)	x			
							Sleep Efficiency (Actigraph)	+			
Hakola 2010[198]	75	M=4, F=71 nurses, mean age 46	-EMEMNN-	Single-arm, pre-post	1) ↓ Quick transitions 2) Fwd shift rotation	1-year	Sleep length (SSI, h)	+ [a]		n/a	18
							Leisure-time activity (SSI)	+ [a]			
Harma 2006[199]	140	M maintenance workers; mean age 36 (<45y) and 50 (>45y);	Bwd rotating EEE--MMM--NNN--	2-arm, non-randomized	Rapid fwd rotation MEN--	6 months	Sleep (Actigraph)				16
							- Sleep length	+ [b]		n/a	
							- Sleep efficiency	+ [b]			
							- Sleep fragmentation	- [b]			
Hossain 2004[200]	58	M=56, F=2 miners, mean age 40.3	Bwd rotating, 8H NNNNN--EEEEE--DDDDD--	Single-arm, pre-post	10H Bwd rotation DDDD---NNN---	1 year	*During night shift (PSG)*			n/a	17
							- Sleep duration (h)	-0.2			
							- Sleep quality (1-5)	-1.2 [a]			
							During day shift (PSG)				
							- Sleep duration (h)	-1.1 [a]			
							- Sleep quality (1-5)	+0.4			
							Days off (PSG)				
							- Sleep duration (h)	-0.2			
							- Sleep quality (1-5)	+0.4 [a]			
Karlson 2009[201]	118	M=98, F=20 manufacturing workers, mean age 44.6	Fast fwd rotating MMAANN----	2-arm, non-randomized	Slower, bwd rotation MMM---NNN---AAA---	9 months	Sleep disturbances (KSQ)	-0.3 [a, b]		+0.05	15
							Health				
							- Self-rated (single-item)	+0.6 [a, b]		+0.05	
							- Symptom Checklisk-35	-0.15 [a, b]		-0.10	
							- LSHCI	-0.14 [a, b]		-0.07	
Knauth 1998[202]	143	Steel manufacturing workers, mean age 35.6-39.8	Bwd rotating 1) Discontinuous NNNNNN-EEEEEE-MMMMMM- 2) Continuous NNNNNNN--EEEEEEE--MMMMMMM---	Two-arm, non-randomized	Quick, fwd rotation 1) Discontinuous ---MMM-MMMEEE-NNN----EEENNN- 2) continuous MEENN---	10 months	Subjective Health	x		x	13
							Sleep time/disturbances	x		x	
							Leisure time	x		x	

Author/ Year	N	Sample	Shift system	Study Design	Intervention	Length	Outcome Measures (Tool)	Results		Quality
								Intervention	Control	
Lowden 1998[203]	14	M= 12, F=2 chemical plant workers, mean age 37	8H 35 day rotation -AMMMM--- NNNNAA--- AAMMM---- NNNAA---	Single-arm pre-post	Fast rotating 12H NN-----DD--NN---- DDD--NN-----DD---	10 months	Subjective sleep (diary) - Bed time - Time of rising - Sleep length	 x x x	n/a	12
Mitchell 2000[204]	15	M power station workers, mean age 44	8H 4-week rotation AAAAAAA-- DDDDDDD- NNNNNNNN----	Single-arm pre-post	12H 16-week rotation	10 months	Sleep (diary) - After day shift (h) - After night shift (h) - Day off (h) Sleep quality (VAS)	 +0.55 +1.50 +0.05 + [a]	n/a	17
Orth-Gomer 1982, 83[205,206]	45	M police officers, mean age 30	Bwd rotating	2-arm intervention with cross-over	Fwd rotation	4 weeks (no wash-out)	Fasting cholesterol TG Gl Uric acid Epinephrine/Norepinephrine SBP (mmHg) DBP (mmHg) Cigarettes (#/8h shift) Sleep length at night (h) Day sleep after night work (h)	+ + [b] + [b] + x 111.6 [b] 75.2 4.7 -0.2 -0.2	+ + + + - 115.6 75.8 4.4 +0.1 -0.2	18
Peacock 1983[207]	75	M police officers, mean age 32.8	8H 12 day rotation NNNEEEMMM-----	Single-arm pre-post	12H 8 day rotation NN-DD---	6 months	Fitness (W170 test, J/min) Resting Blood Pressure Body temperature Urinary catecholamines Sleep quality (1-7 scale)	+12.03 [a] x x NR + [a]	n/a	10
Rosa 1989[208]	53	M=45, F=4 (4=?) control room officers at processing plant, age 25+	8H DDDDD---- SSSSSSS-- TDDTTT-- NNNNNNN--	Single arm, pre-post	12H rotation TTTTooo NNNNooo DDD---- --oNNNo oo--DDD	7 months	*After night shift (Diary)* - Total sleep time (h) - Sleep latency (min) - Sleep quality (1-9) - Exercise bouts (%) *After day shift (Diary)* - Total sleep time (h) - Sleep latency (min) - Sleep quality (1-9) - Exercise bouts (%)	 + 0.24 + 0.34 + 0.15 -15 + 0.20 + 4.22 - 0.07 -13	n/a	13
Rosa 1996[209]	68	M=63, F=2 steel plant operators, Young: mean age 31, Old: mean age 50	10H, bwd rotating EEEE-MMMM-NNNN---	Single arm, pre-post	1h delay in start time	4 months	*Morning shift sleep* - Subjective (SSI) - Actigraph (h) - Sleep diary *Evening shift sleep* - Subjective (SSI) - Actigraph (h) - Sleep diary *Night shift sleep* - Subjective (SSI) - Actigraph (h) - Sleep diary	 x + [a] + [a] - [a] x x x - -*	n/a	16

Author/ Year	N	Sample	Shift system	Study Design	Intervention	Length	Outcome Measures (Tool)	Results			Quality
								Intervention		Control	
Viitasalo 2008[210]	84	M airline maintenance workers, mean age 37-47	8H EEE--MMM-- NNN--	3-arm, non-randomized	1) Rapid fwd rotation MEN-- 2) Flexible shift (typically EEE---MMM---NNN---) ↓ work hours	7-8 months		Fwd	Flex		20
							Cholesterol (mmol/L)	+0.3	0.0	+0.1	
							HDL (mmol/L)	0.0	+0.1	+0.1	
							LDL (mmol/L)	+0.1	-0.1	+0.1	
							TG (mmol/L)	+0.2	0.0	+0.1	
							Gl (mmol/L)	-0.1	-0.2	-0.2	
							HbA1c (%)	-0.2	-0.2	-0.1	
							CRP (mg/L)	+0.3	+0.3	+0.3	
							Resting SBP (mmHg)	+2.5	-6	x	
							Resting DBP (mmHg)	x	+	x	
							BMI (kg/m^2)	0	0	0	
							Waist (cm)	+2	+3	+1	
							Waist/hip ratio	+0.2	+0.2	0	
							Dietary Fibre (g/day)	-2	+1	0	
							Quality of fat intake	+1	+1	0	
							Alcohol (g/day)	-1	+2	-1	
							Physical Activity (h/week)	0	-0.1	-0.3	
							Sleep disturbance (ESS)	+	+	-	
Williamson 1994[211]	18	Computer operators, mean age 23.8	8 week rotation 8H D, A and N 12H D, N	Single-arm, pre-post	Rotating 12H, 3-shift system DDNN----	12 months	*Hours of sleep (Diary)*			n/a	13
							- Day shift	+ [a]			
							- Night shift	+ [a]			
							- Rest day	- [a]			
							# of sleep periods (Diary)				
							- Day shift	-			
							- Night shift	+ [a]			
							- Rest day	+ [a]			

Note: + = positive change - = detrimental change, x = no change,
[a] Significant difference before-after intervention, $p < 0.05$
[b] Significant between groups, $p < 0.05$
ref Reference/comparison group
Legend: M, male; F, female; A, Afternoon shift; BL, Bright Light; BMI, Body Mass Index; Bwd, Backward; CRP, C-Reactive Protein; CVD, Cardiovascular Disease; D, Day shift; DBP, Diastolic Blood Pressure; E, Evening shift; ESS, Epworth Sleep Scale; Fwd, Forward; Gl, Glucose; HbA1C, Hemoglobin A1C; HDL, High Density Lipoprotein; KSQ, Karolinska Sleep Questionnaire; LDL, Low Density Lipoprotein; LSHCI, Lund Subjective Health Complaints Inventory; M, morning shift; N, night shift; o, on call; PA, Physical Activity; S&Y, Shiftwork and You questionnaire; S, Swing shift; SBP, Systolic Blood Pressure; SW, Shiftwork; SSI, Standard Shiftwork Index; T, training/support; TG, Triglycerides; VAS, Visual Analog Scale; W, work; - , off work;

2.4.5. Behavioural Interventions

Four interventions were implemented to modify behavior (Table 2.5): a one-hour rest period for electric power plant workers on the night shift[212], a physical activity program for nurses and nursing aides[165,166], a weight loss program in aluminum plant workers[213,214], and an educational program about strategies to enhance adaptation to shift work for emergency department attending physicians[215]. The number of workers in these studies ranged from 6-110 (mean = 50.8, median = 43.5). Follow-up ranged from three weeks to one year (mean = 21.3 weeks, median = 15 weeks). Sleep was reported in three of four studies[166,212,215]. Mean study quality was 18.0 (range: 10–27).

Physical activity improved sleep length with variable results on subjective sleep quality[166], and education about sleep hygiene strategies resulted in significantly improved REM sleep time[215]. A one-hour rest period during the night resulted in no significant change in sleep duration following the night shift[212]. Other outcomes were also evaluated (Table 2.5). Exercise significantly increased maximal aerobic capacity and strength, although circadian phase did not differ between groups, as measured by body temperature[165,166]. A group-based lifestyle intervention for weight loss was associated with significantly decreased body mass index and blood pressure and significantly improved physical activity and fruit intake[213].

Table 2.5 Behavioural interventions

Author/ Year	N	Sample	Shift system	Study Design	Intervention	Length	Outcome Measures (Tool)	Results: Intervention	Results: Control	Quality
Bonnefond 2001[212]	12	M power plant workers, mean age 37	5-shift rotation	Single arm, pre-post	1-h rest (23:30-03:30h)	1 year	Sleep duration after night shift (min, Diary)	-13.8	n/a	10
Harma 1988a[163]	75	F nurses, age 20-49	Irregular rotation of 8-10H D, E, N shifts	2-arm RCT	Physical training program targeting circulatory and muscular systems (jogging, running, swimming, skiing, walking and gymnastics); 2-6x/week, 60-70% maximum heart rate	4 months	VO_2 max (ml/kg/min)	+1.9 [a, b]	-0.3	18
							Strength (# sit-ups/30s)	+2.9 [a, b]	+0.5	
							Body Weight (kg)	-0.6 [a]	-0.5	
							Body composition (skinfolds, mm)	-2.5 [a]	-0.4	
							Subjective Sleep (Diary)			
							Sleep Length – Morning (h)	+0.2 [a]	0.0	
							Sleep Length – Evening (h)	+0.3 [a, b]	0.0	
							Sleep Length – Night (h)	+0.4 [a]	+0.1	
							Sleep Quality – Morning	-0.3 [a]	-0.4	
							Sleep Quality – Evening	0.0	+0.2	
							Sleep Quality - Night	-0.4	-0.5	
Harma 1988b[166]							Body Temperature Mesor (° C) - day	-0.11 [a]	-0.05 [a]	18
							Body Temperature Mesor (° C) - night	- 0.09 [a]	-0.06 [a]	
							Body Temperature Amplitude (° C) - day	-0.08 [a]	-0.01 [a]	
							Body Temperature Amplitude (° C) - night	+0.03 [a]	+0.05 [a]	
							Body Temperature Acrophase (h/min) - day	+1:11 [a]	+1:46 [a]	
							Body Temperature Acrophase (h/min) - night	+0:57	-0:06	
Morgan 2011[213,214]	110	M aluminum plant workers mean age 44.4; BMI 25-40	Four shifts (schedule not reported)	2-arm RCT	Group-based weight loss lifestyle intervention, one-on-one information session, study website, resource booklet, pedometer, financial incentive	14 weeks	Body weight (kg)	-4.0 [a, b]	+0.3	27
							Waist circumference (cm)	-4.4 [a, b]	+1.5	
							BMI (kg/m^2)	-1.3 [a, b]	+0.1	
							SBP (mmHg)	-7.3 [a]	-1.3	
							DBP (mmHg)	-3.7 [a]	-2.5	
							Physical Activity (MET minutes)	+0.4 [a, b]	+0.1	
							Current PA Level (GLTEQ)	+0.4 [a, b]	-0.2	
							Workday PA (GLTEQ)	+0.8 [a]	+0.4	
							Dietary Intake (FFQ)			
							- Fruit	+ 0.5 [a]	+0.1	
							- Vegetables	0.0	-0.1	
							- Bread	-0.8 [a]	-0.2	
							- Milk	-0.6	-0.1	
							- Cola	+0.4 [b]	-0.	
							- Diet drinks	+0.7	-0.1	
							- Soda drink	+0.4 [b]	-1.1	
							Alcohol risk score	+0.1	-0.1	
Smith-Coggins 1997[215]	6	M emergency physicians, mean age 34	10-16 shifts/month 8-9H D/E/N	2-arm, RCT with cross-over, 1 month washout	2-hour sleep physiology/hygiene education session	3-4 weeks	Subjective sleep (Log)	x	x	17
							Total sleep time (h, PSG)	+0:42	+1:08 [a]	
							REM sleep time (min, PSG)	+21.74 [a]	NR	

[a] Significant difference before-after intervention, $p < 0.05$, [b] Significant between groups, Note: x = no change,
Legend: BMI, Body Mass Index; BP, Blood Pressure; F, Female; FFQ, Food Frequency Questionnaire; GLTEQ, Goodin Leisure Time Exercise Questionnaire; HR, Heart Rate; M, Male; MET, Metabolic Equivalent; PA, Physical Activity; PSG, Polysomnography; RCT, Randomized Controlled Trial; VO_2max, Maximal oxygen consumption;

2.4.6. Pharmacological Interventions

Eight pharmacological interventions met inclusion criteria[180,216-222] (Table 2.6). Mean study quality score was 18.1 (range: 11-24). Two pharmacological agents were found to aid sleep following the night shift: melatonin and Zopiclone. Dosages of 3.0mg[180,217] or 5.0mg[221] of exogenous melatonin were administered to workers in three studies. This resulted in significant sleep improvements after 14[180] and 28 days[221] in two of three studies. Zopiclone (7.5mg) was administered in two different study groups who reported insomnia: workers at a security company, and at a car manufacturing plant. Zopiclone had positive effects on total sleep time[216,222] and quality[222], as well as sleep efficacy[216] and induction[222].

Three studies evaluated the use of Modafinil or Armodafinil as stimulants before night shifts in workers who met defined criteria for Shift work Sleep Disorder[218-220]. Administration of 200mg and 300mg of Modafinil did not significantly change endogenous melatonin levels or sleep quantity before or after night shifts[218,220]. Armodafinil (150mg) resulted in a small but statistically significant improvement in nighttime sleep latency, but had no effect on daytime sleep[219].

Table 2.6 Pharmacological interventions

Author/ Year	N	Sample	Shift system	Study Design	Intervention	Length	Outcome Measures (Tool)	Results: Intervention		Control	Quality
Bjorvatn 2007[180]	17	M=16, F=1, oil rig workers, mean age 42	12H shifts One week N One week D 3-4 weeks off	3-arm randomized cross-over	1) 30 min BL (10 000 lux), < nadir 2) 3 mg melatonin 3) Placebo	14 work days	*During night shifts*	BL	Melatonin	Placebo	20
							Subjective sleep (diary)				
							- Sleep onset latency (min)	9[a]	13[b]	14	
							- Total sleep time (min)	392	405[b]	386	
							- Sleep efficiency (%)	86	87	86	
							- Sleep quality (1-5)	3.1	86	3.1	
							Objective sleep (Actiwatch)				
							- Sleep onset latency (min)	6	9[b]	6	
							- Total sleep time (min)	419[a]	416	403	
							- Sleep efficiency (%)	88	87	86	
							Days off				
							Subjective sleep (diary)				
							- Sleep onset latency (min)	17	19	19	
							- Total sleep time (min)	318	355[b]	340	
							- Sleep efficiency (%)	80	87[b]	83	
							- Sleep quality (1-5)	2.8	2.8	2.7	
							Objective sleep (Actiwatch)				
							- Sleep onset latency (min)	7	15[b]	6	
							- Total sleep time (min)	367	355	348	
							- Sleep efficiency (%)	87	86	85	
Bozin-Juracic[c] 1996[216]	29	Security workers, age 24-58, insomnia	Slow rotation, 7 N, off, M, A	3-arm RCT	1) 7.5mg Zoplicone 2) 5mg nitrazepam 3) Placebo (after night shift)	7 days	*Main Sleep (sleep diary)*				11
							- Time in bed	x			
							- Length of sleep episode	x			
							- Total sleep time	treatment x day effect[a]			
							- Sleep efficacy	treatment x day effect[a]			
							- Sleep latency	x			
							- Sleep quality (VAS)	x			
							All Sleeps (sleep diary)				
							- Time in bed	x			
							- Sleep episode	x			
							- Total sleep time	x			
							- Sleep efficacy	treatment x day effect[a]			
							- Number of sleeps	x			
Cavallo 2005[217]	45	M=16, F= 29 pediatric residents, mean age 28.6	Night float 2-week rotation with 3 off	2-arm randomized cross-over trial	Melatonin (3mg) after night shift before sleep in dark room	2 weeks	*All days*				22
							- Sleep duration (h)	6.4		6.3	
							- Sleep quality (VAS)	64.1		62.0	
							- Number of awakenings	2.2		2.3	
							Days taking melatonin				
							- Sleep duration (h)	6.5		6.3	
							- Sleep quality (VAS)	62.6		60.8	
							- Number of awakenings	2.3		2.3	

Author/ Year	N	Sample	Shift system	Study Design	Intervention	Length	Outcome Measures (Tool)	Results		Quality
								Intervention	Control	
Czeisler[c] 2005[218]	209	M=122, F=87, mean age 38, SW disorder	≥5 night shifts per month (≥3 consecutive) ≤12h with ≥6h between 2200 and 0800h)	2-arm RCT	Modafinil (200mg) 30-60 min prior to night shift	3 months	Sleep efficiency - night shift (%) Sleep measures (PSG) - Time in bed (min) - Time awake (min) - Time asleep (min) - Sleep latency (min) - Sleep efficiency (%) - REM sleep (min) Melatonin phase (change in hours)	+7.3 -3.0 -11.7 +1.4 +2.9 +1.4 +0.5 -0.4	+9.5 -1.7 -8.8 +4.6 +1.3 +1.2 +2.3 -0.1	24
Czeisler[c] 2009[219]	254	M=135, F=119, mean age 39, SW disorder	≥5 night shifts per month (≥3 consecutive) ≤12h with ≥6h between 2200 and 0800h)	2-arm RCT	Armodafinil (150 mg) 30-60 prior to night shift	12 weeks	Night sleep latency (min, diary) Systolic BP (mm Hg) Diatsolic BP (mm Hg) Heart rate (bpm) Daytime Sleep (PSG) - Sleep latency (min) - Sleep efficiency (%) - Total sleep time (min) - Wake after sleep onset (min)	+3.1[a] +0.8 +0.4 +2.7 +2.9 -3.3 -19.0 +12.4	+0.4 -1.5 -0.7 +0.7 +0.2 +1.3 -2.0 -3.3	22
Erman[c] 2007[220]	278	M=111, F=167, mean age 40, SW sleep disorder	≥5 night shifts per month (≥3 consecutive) ≤12h with ≥6h between 2200 and 0800h)	3-arm RCT	1) Modafinil (200 mg) 2) Modafinil (300 mg) 3) Placebo 30-60 min prior to night shift	12 weeks	Sleep (diary) - Nighttime sleep - Daytime sleep	 x x	 x x	16
Folkard 1993[221]	17	M=15, F=2 police officers, mean age 29	28-day rotation ---- NNNNNNN-- AAAAAAA- MMMMMMM	2-arm RCT	1) Melatonin (5mg) 2) Placebo Prior to day sleep/first four night sleeps	28 days	Sleep (Diary) - Time of sleep onset (h) - Time of sleep offset (h) - Sleep duration (h) - Sleep latency (min) - Sleep quality (VAS)	 0 +0:30 +0.51[a] -2.35 +10.4[a]	 +0:07 +0:11 +0.07 -1.30 -0.2	13
Monchesky 1989[222]	53	M=47, F=6 auto plant workers; mean age 34.9	Alternating 2-week days, 2-week nights	2-arm RCT	1) Zopiclone (7.5 mg) 2) Placebo 30 min before bed during night shifts	14 days	Sleep (Self-reported) - Sleep induction - Sleep duration - Sleep quality	 +[a] + +	 x x x	17

Note: + = positive change - = detrimental change, x = no change,
[a] Significant difference before-after intervention, $p < 0.05$
[b] Significant between groups, $p < 0.05$
[c] Industry-sponsored study
Legend: M, male; F, female; BL, Bright Light; BP: Blood pressure; PSG, Polysomnography; SW, Shiftwork; VAS, Visual Analogue Scale

2.5. DISCUSSION

The main objective of this review was to synthesize intervention studies designed to mitigate the adverse health effects of shift work. Overall, interventions were complex and highly variable, which was reflected in the results. For example, studies of controlled light exposure used bright light, light-blocking goggles or glasses, and combinations of the two. Even within studies of intermittent bright light, patterns of exposure differed greatly with regards to timing, duration, frequency, and intensity. Therefore, it was difficult to draw direct comparisons across interventions or amongst outcomes, or to recommend one intervention to best improve the health of shift workers. We were also unable to conduct a meta-analysis to estimate magnitudes of effects for each intervention type due to study heterogeneity. Nevertheless, the main strength of this review was that all studies were conducted in participants who were engaged in night shift work. While laboratory-based studies are important for understanding the mechanisms underlying the link between shift work and adverse health outcomes, conducting workplace-based research is a key step in translating findings to real-world settings.

The aim of interventions that control light exposure is to shift circadian rhythms and subsequently promote adaptation to work at night, thereby minimizing health effects. In our review, a combination of timed bright light and light-blocking goggles appeared to promote adaptation to shift work as primarily measured by changes in sleep and melatonin. A previous review by Burgess et al.[176] similarly found that timed exposure to high intensity light during night shifts and wearing goggles during the commute home can increase circadian adaptation. Although many of the studies included in the latter review were performed in simulated night shift environments, the general consistency with our review, which included more variable workplace conditions, suggests that multi-pronged interventions to control light exposure may be more effective than using bright light or light-blocking goggles alone. Due to the nature of the interventions, most studies were not blinded or randomized, resulting in a loss of quality scores for internal validity. However, scores for reporting were generally high.

Fast-forward rotating shifts tended to report more favorable results for sleep. However, findings were inconsistent for changes in shift length or start time. Shift scheduling has been attempted to improve healthy lifestyle behaviours with positive effects reported in one of the studies reviewed[198] but not in five others[196,202,205,206,210]. Shift workers may be less likely to engage in regular physical activity, smoking cessation, and healthy diet, which may contribute to increased risks of adverse health outcomes[55]. Objective outcomes that may be the result of improved lifestyle habits, such as low-density lipoprotein cholesterol[196]; triglycerides, fasting glucose, and blood pressure[205,206]; cardiorespiratory fitness[207]; and blood pressure[210], did show improvement in association with a change in shift schedule. However, improvements were not universal or consistent in magnitude across studies and studies with higher quality scores appeared to find less favourable changes. Again, because shift-scheduling changes were generally implemented across workplaces, randomization and blinding were not possible, but selection bias was of less concern because a large percentage of workers were included in each study.

Interventions directed at physical activity[165,166] and weight loss[213,214] improved cardiorespiratory fitness and strength[165,166], body composition, blood pressure, and physical activity[213,214]. This suggests that lifestyle habits may not improve spontaneously in shift workers as a result of shift schedule changes, and that interventions specifically targeted at improving lifestyle behaviours may be necessary.

Studies of melatonin, hypnotics, and stimulants showed mixed results, potentially due to different doses administered to workers, compliance, shift schedule variation, and other factors. Pharmacological studies were more commonly randomized controlled trials (RCTs) and often double blinded, resulting in higher scores for quality. However external validity and generalizability, as well as prevalence of adverse events should be investigated in future studies. Some adverse effects were reported, including insomnia and headache from Modafinil[218,220], and nausea, anxiety, low back pain, and other effects from Armodafinil[219]. Adverse events were also reported across other intervention types such as headaches or feelings of heat/cold in response to bright light exposure[186,187], and difficulty scheduling social or family activities as a result of a shift schedule change[196,198]. Several studies stated that no significant adverse events resulted from the interventions[192,193,203,216,217], but most did not report on adverse events at all. Since participants were not monitored for adverse health effects beyond the study period in all articles, we could not evaluate potential long-term negative health consequences of the interventions.

These findings are particularly relevant to younger rotating shift workers in the manufacturing, health care, and public safety sectors in Europe and North America, as these populations were most commonly represented in the studies included. Approximately one-third of shift workers studied were in manufacturing, which may partly explain the greater proportion of male compared to female shift workers in this review. Future studies should be conducted in underrepresented groups. For example, although this review identified workers between the ages of 24 and 58 years (most years of working life), only three studies specifically examined age effects by stratifying results by older and younger workers[197,199,209]. The health effects of shift work may be more pronounced for older workers or those who have worked shifts for numerous years. Correspondingly, interventions to reduce the chronic health effects of shift work might have different effects on older and younger workers, warranting separate analyses.

As a secondary objective of this review, we presented aggregate quality assessments in order to help identify general areas for improvement in future research. While many studies received low scores overall, and within specific sections, this may partly attributed to the inherent limitations of the checklist selected for evaluating the quality of studies of this type. Low individual scores are not necessarily indicative of a poorly done study. The design and outcomes of these studies reflect real life workplace settings, and the information presented is useful for developing evidence informed interventions. Nevertheless, there are some changes that can be made to improve future study quality.

Reporting and external validity are areas for continued development; studies published after 2002 tended to receive higher scores (mean = 17.6) than studies published before 2002 (mean = 14.0), primarily due to improvements in these areas. Follow-up was quite short for many of the studies reviewed, with the longest mean follow-up observed for studies that altered shift schedules (8.2 months) and the shortest for studies of controlled light exposure (23.7 days). Since short-term changes in health outcomes may not persist in the long term, longer follow-up is needed to determine whether the interventions reviewed resulted in clinically meaningful effects on the development of chronic disease in shift workers. Sample size is another area for improvement. In this review, only three studies reported sample sizes with adequate power to detect a statistically significant difference in primary outcomes of interest[193,213,214,218].

RCTs are almost never feasible to implement in the workplace where an intervention affects all workers (e.g., change in shift schedule) or when it is difficult to prevent contamination of study groups. Studies of shift scheduling and controlled light exposure scored particularly low on internal validity for this reason. A cluster RCT that involves randomly assigning groups of workers (e.g. wards in a hospital) to an intervention may be more practical than randomizing individual workers and should be considered in future studies. Ensuring and reporting on adequate compliance, particularly in the context of controlled light exposure or behavior change interventions, is also difficult but should be urged in future studies. Lack of compliance may decrease the likelihood of finding significant health improvements and limits interpretation, reproducibility, and translation into the workplace.

Different methods used to assess similar outcomes may have also contributed to inconsistent results observed between studies of the same intervention type. For example, sleep outcomes reported using actigraphy or polysomnography (PSG), compared to sleep diaries, logs or questionnaires, more frequently found improvements in sleep. Of the five studies reporting both subjective and objective measures, two showed improvements only in objective measures[194,215] two showed improvements only in subjective measures[180,219], while one showed improvements in both[197]. While logs or questionnaires may have lacked adequate sensitivity to detect sleep pattern changes, actigraphy or PSG were limited by technical issues or poor compliance. Future studies should consider using both objective and self-reported measures to enhance validity, and standard methods for measuring sleep-related outcomes.

We excluded self-reported sleepiness as an outcome, as it is more closely related to workplace safety than chronic disease risk[193,200]. However, of included interventions that reported on sleepiness, findings were aligned with sleep quality and quantity results[180,181,190,193,199,210,215,219]. One exception was a study of Modafinil, which significantly reduced sleepiness during the commute home from a night shift, but had no effects on sleep[218].

While sleepiness while commuting is an important problem for shift workers, this indicator is not related to chronic disease risk, the focus of our review. We also excluded absenteeism as an outcome, as it is most closely related to productivity and work-related outcomes. However, it is possible that disease-specific sickness absence could provide an indication of chronic disease diagnosis and severity and should be considered in future studies.

Following our systematic search, we briefly scanned the literature for articles published between August 14, 2012 and May 1, 2014, and identified four that may have met our inclusion criteria[223-226]. Järnefelt et al. conducted a randomized controlled trial of a cognitive behavioural therapy intervention, which resulted in improved sleep in shift workers[223]. Lee et al. also used a cognitive behavioural therapy approach in a home-based sleep intervention in nurses[225]. This intervention improved self-reported sleep outcomes, but did not result in changes in objectively measured sleep using wrist actigraphy. Jarvelin-Pasanen et al. implemented an ergonomic shift scheduling system which improved heart rate variability[224]. Rahman et al. used filtered wave light on nights which resulted in improved sleep quantity and quality, as well as increased melatonin[226]. Findings from these four studies are generally consistent with the findings from the included studies. As more literature is published, future reviews that integrate newer studies would be a valuable addition to the state of the science as synthesized here.

Evaluating preventive strategies in shift workers is a relatively new and evolving area of research. This critical review highlights the range of practical interventions conducted in "real life" workplace settings. Previous reviews have been limited by considering either a single intervention type or outcome, or by including studies conducted in laboratory settings, worksite and home-based interventions, and by including both shift workers and healthy volunteers. The scope of our search on multiple databases enabled us to include 38 interventions representing four general intervention types. Our search was rigorous, spanning three large databases for all years up to August 13, 2012. This allowed us to minimize publication bias and identify most of the relevant studies for the aim of this review. This review also illuminates important gaps in shift work intervention research.

Combinations of intervention types and personalized interventions offer promising ways to improve the health of shift workers, but were not identified in our search. Comprehensive, evidence-based approaches that include best practices in shift scheduling, a range of options to control exposure to light and dark, support for physical activity and healthy eating, as well as pharmacological agents, may be the best ways to improve health. There is also a need to develop and test novel approaches, like social support, possibly using new technologies such as smart phones to help with sleep or other adverse effects.

As shift work becomes increasingly prevalent, relevant and high-quality research conducted on large numbers of shift workers in their normal working conditions and workplaces to test the effectiveness of different interventions is required. There is no “one size fits all” solution, and individual shift workers may have different responses to interventions as the result of chronobiology, personal preferences that affect compliance, or other factors that remain to be assessed. Intervention research should account for potential biases and other lifestyle, work, and environmental confounding factors that might be related to shift work and chronic disease. Innovative, evidence-based prevention efforts should be developed and evaluated to simultaneously meet the unique health needs of shift workers and the mandates of the organizations and industries in which they work. This is a promising area with many potential areas for further investigation.

2.6. CONCLUSION

This critical review, as a summary of health-related interventions that have been conducted in shift workers to date, serves as the basis of the remainder of this dissertation, and provides an understanding of the common methodological limitations and potential difficulties of implementing a variety of types of interventions aimed at improving health in this occupational group. Most relevant to this dissertation, only one intervention to date has specifically focused on physical activity and found a positive effect, despite low retention and adherence. Other interventions that measured changes physical activity or physical fitness in response to changes in shift scheduling, for example, were not successful in promoting behaviour change. This suggests that targeted behaviour change interventions are needed to alter lifestyle behaviours, such as physical activity, in shift workers.

3. Chapter 3: Physical Activity, Physical Fitness and Body Composition of Canadian Shift Workers. Cross-Sectional Data from the Canadian Health Measures Survey Cycles 1 and 2

3.1. Synopsis

Shift workers have an increased risk of cancer and other chronic diseases, likely due to a combination of biological and behavioural factors that are a consequence of their exposure to shift work. Literature to date suggests shift workers may be more likely to be overweight and less likely to exercise than day workers; however, physical fitness and sedentary time have not been examined in this population. Using cross-sectional data from the Canadian Health Measures Survey cycles 1 and 2 (n = 4323), relationships between work schedule and objective measures of physical activity, physical fitness and body composition were examined. Univariate and multivariate linear and logistic regression models were used to compare outcomes between day workers and rotating and permanent shift workers. In unweighted analyses, shift workers (n = 566) were more likely to be obese, and classified in high-risk categories for waist-hip ratio and waist circumference, although they reported fewer minutes per week of sedentary time. Despite no significant differences in physical activity, shift workers had lower measured aerobic capacity compared to day workers. In weighted analyses, only differences in aerobic capacity were observed between shift workers and day workers. These findings confirm previous findings that shift workers have poorer body composition than day workers, and suggest that shift workers may need to engage in more physical activity to achieve the same aerobic capacity as day workers. Further investigation taking into account shiftwork history is needed to fully understand these relationships.

A version of this work has been accepted for publication in the Journal of Occupational and Environmental Medicine. It was also presented as an oral presentation at the Canadian Public Health Association Conference, in Vancouver, BC on May 26, 2015.

3.2. INTRODUCTION

Work outside of daytime hours (i.e., 0900-1700h) is prevalent in today's society, particularly in health care, manufacturing, and hospitality and retail[227,228]. Growing evidence suggests that shift work has many negative health implications including increased risk of chronic diseases such as cancer, cardiovascular disease, diabetes, gastrointestinal disorders, and metabolic syndrome[168]; increased risk of workplace injuries[64]; and disruption of family and social life[7].

While the precise biological mechanism linking shift work to chronic disease is not entirely understood, the main working hypotheses involve a combination of circadian rhythm disruption related to exposure to light at night, as well as behavioural factors, such as decreased physical activity, and higher prevalence of obesity[229]. Estimates suggest that a lack of physical activity causes 9% of premature mortality worldwide[123] and a recent meta-analysis found that compared to individuals of normal weight (Body Mass Index (BMI) 18.5 to < 25.0 kg/m^2), those with a BMI >30 had higher all-cause mortality (Hazard Ratio (HR): 1.18, 95% Confidence Interval (CI): 1.12 –1.25)[230]. Both physical activity and obesity are independently associated with increased risk of diabetes, many cancers, cardiovascular disease, and a number of other chronic diseases[231,232].

Shift workers may be unlikely to engage in regular physical activity, perhaps the result of decreased free time and scheduling demands due to irregular shift schedules. In one longitudinal survey, shift workers were less likely to become physically active over two years of follow up than day workers[55], and in a cross-sectional survey, shift workers were more likely than day workers to report low leisure-time physical activity (Odds Ratio (OR): 1.86, 95% CI: 1.21 – 2.88)[159]. Shift workers are also at higher risk for obesity compared to day workers (Relative Risk (RR): 1.14, 95% CI: 1.01 –1.28 over ten years of follow up)[115], and shift work increased the odds of major weight gain in a five to seven year follow-up period among women (OR: 1.37, 95% CI: 1.08 – 1.74) but not men (OR: 1.25, 95% CI: 0.81 – 1.82)[233]. It is possible that lower levels of physical activity and increased body weight in shift workers may also be accompanied by increased sedentary time, and lower levels of physical fitness; however, this has not been examined.

The observational studies of health behaviours in shift workers to date have been primarily based on convenience sampling limited to one occupational group or workplace, and may be limited by selection bias, where those who participate may differ from those not enrolled. To our knowledge, there has been no exploration of the relationship between shift work and physical activity, physical fitness and body composition in the Canadian context. The aim of this analysis was to explore whether Canadian shift workers: 1) engage in less physical activity and more sedentary time; 2) are less physically fit; and 3) have poorer body composition than Canadians who work regular day work. We hypothesized that shift workers will be less physically active and more sedentary, less physically fit and have poorer body composition than day workers.

3.3. Methods

3.3.1. Data Source

Data from the Canadian Health Measures Survey (CHMS) cycles one (2007-9, n = 5604) and two (2009-11, n = 5874), were used for this analysis. This national cross-sectional survey, conducted by Statistics Canada, targets individuals 6-79 years of age, excluding those living on reserves or Crown land and in certain remote regions, full-time members of the Canadian Forces and residents of institutions[234]. The survey involves completion of an in-home health questionnaire, a visit to a mobile clinic for direct physical measurements, and wearing of an activity monitor. More information on the multi-stage sampling strategy[235] and detailed data collection methods have been published previously[236]. Ethical approval was obtained from Health Canada's Research Ethics Board, and all participants provided written informed consent.

3.3.2. Study Sample

Eligible participants for this analysis were greater than eighteen years old and had either worked in the last week, or if absent due to sickness or vacation, had held a regular job over the last year. Pregnant women were excluded as they were not eligible for the physical fitness or physical activity assessment, and measurement of body weight and circumferences would not accurately reflect body composition. The study sample was divided into two groups by shift schedule: day workers (self-reported "regular daytime schedule or day shift"), and shift workers (self-reported "regular night shift" or "rotating night shift"). Regular and rotating night shift schedules were pooled due to sample size. Individuals who reported irregular, split shifts, on call or unknown work schedules were excluded due to small sample sizes in accordance with Statistics Canada's guidelines for use of CHMS data[237]. Only participants with valid accelerometer data (greater than or equal to four days with at least ten hours of wear time) were included in the physical activity analysis, and only individuals <70 years old who responded "no" to all questions on the Physical Activity Readiness Questionnaire were eligible for physical fitness measurements, resulting in a smaller sample size for physical activity and fitness variables.

3.3.3. Variables

Physical activity data were collected using a waist-worn Actical accelerometer (Philips - Respironics, Oregon, USA) worn during waking hours for seven days. Moderate-vigorous physical activity (MVPA) was calculated in minutes per day where activity occurred at an intensity greater than 3.0 Metabolic Equivalents (METs), in bouts of more than ten minutes (aligned with Canada's Physical Activity Guidelines for Adults[128]). Because not all participants provided seven days of useable data, participants were classified as meeting physical activity guidelines if mean daily MVPA was ≥21.4 minutes (150÷7). Mean daily sedentary time (minutes per day) was calculated as activity at an intensity of less than 1.0 MET, such as riding in a car, reading or sitting[238].

Physical fitness and anthropometric assessments were conducted by trained assessors using published protocols[236]. The modified Canadian Aerobic Fitness Test (mCAFT), a submaximal step test, was used to measure aerobic capacity with a corresponding equation to predict maximal oxygen consumption (VO_2max, mL/kg/minute). Predicted values from the mCAFT have been shown to be highly correlated to objectively measured VO_2max[239]. Musculoskeletal fitness was quantified using a handgrip dynamometer for isometric handgrip strength. The sum of the higher of two measurements using the left and right hand was recorded as total handgrip strength (kg). Standing height (m) was measured using a fixed stadiometer with moveable headboard. Body weight (kg) was measured on a Mettler Toledo digital scale (Mississauga, Canada). Waist and hip circumference (cm) were measured following World Health Organization (WHO) protocols[240], with measurements taken halfway between the top of the iliac crest and the lowest palpable rib and at the widest point of the hip/buttocks region respectively. Waist-to-hip ratio (WHR) was calculated by dividing measured waist and hip circumferences. Participants were classified as overweight or obese if they had a BMI >25.0 or 30.0 kg/m^2 respectively. Men were classified as high risk if their WHR was > 0.9 or waist circumference was > 102 cm respectively. Women were classified as high risk if their WHR was > 0.85 and waist circumference was > 88 cm respectively, based WHO cut points[240].

Demographic information including age, gender, marital status, ethnicity, education, and number of children less than sixteen years old in the household were collected via self-report. Work characteristics including job status (full- or part-time), number of jobs held, and work hours per week were also collected via self-report.

3.3.4. Statistical Analysis

Data analyses were conducted using SAS 9.3 (SAS, Carey, NC) for Windows. Descriptive statistics were calculated as means or frequencies, with 95% confidence intervals using PROC SURVEYMEANS and SURVEYFREQ commands to account for the multi-stage sampling survey design, using sample and bootstrap weights created by Statistics Canada in accordance with CHMS guidelines to adjust for non-response and ensure population-representativeness[237]. Those with missing data for outcomes of interest (physical activity, physical fitness and body composition) and important confounders that were included in the final multivariable models were excluded from descriptive statistics. This limited the study sample to 98.9% of eligible individuals for physical activity analysis, using activity monitor subsample (n = 3513), 97.3% for body composition analysis (n = 4323) and 99.1% for physical fitness (n = 3410).

Univariate linear and logistic regression analyses were used to examine the relationships between work schedule and physical activity, physical fitness and body composition. PROC SURVEYREG and SURVEYLOGISTIC commands were used to account for the multi-stage sampling survey design, and the domain analyses option was used to incorporate participants with missing data, for proper estimation of variance. Due to the skewed distribution of MVPA and body composition, only regression analyses for binary variables are presented. Possible confounders that were related to work schedule and/or the outcome of interest during exploratory data analysis, or were known to be potential confounders of the relationship between shift work the outcome of interest based on previous studies, were retained in the final model if adding them resulted in a change of >10% in the parameter estimate for work schedule. Study cycle, gender, age, marital status, ethnicity, education, children in the household, smoking status, self-reported sleep, and work characteristics (full or part time, multiple jobs, and total hours worked per week) were examined as potential confounders. Interactions between work schedule and age and gender were examined, but were not significant.

The primary results reported take into account the complex sampling design of the CHMS, but not sample weights. Sample and bootstrap weights were developed for the CHMS by Statistics Canada to adjust for non-response and to ensure estimates are representative of the Canadian population using demographic variables available from the Canadian census. Work schedule was not taken into account when creating the sample and bootstrap weights; therefore application of these weights to our regression analysis may result in biased estimates when comparing shift workers to day workers[241]. Unweighted analysis may be biased by non-response to the invitation to participate or because of over-sampling, therefore we present findings both with and without sample weights, a technique that has been reported previously using data from similar national health surveys[242].

We hypothesized *a priori* that differences between groups might be more pronounced in older workers, as they may have a longer duration of shift work. As a sensitivity analysis, the same multivariable models were fit to a restricted study sample, including only those >50 years old. However, due to restrictions on release of CHMS data with small sample size, we are only able to present our analysis of body composition variables.

3.4. RESULTS

In the full sample (n = 4323), the majority of participants worked regular days (86.9%) followed by rotating (10.3%) and regular night shifts (2.8%) (Table 3.1). Compared to day workers, shift workers were younger ($p < 0.001$), more commonly single ($p < 0.001$), had lower education ($p <0.001$), and were more likely to work part-time ($p = 0.01$) or report multiple jobs ($p = 0.01$). Characteristics of the accelerometer or physical fitness subsamples did not differ from the full analytical sample (data not shown).

Table 3.1 Weighted demographic characteristics of the full study sample

	Overall Study Sample (n = 4323)		Shift Workers (n = 568)		Day Workers (n = 3755)		*p*
	Mean	95% CI	Mean	95% CI	Mean	95% CI	
Age (years)	41.0	(40.6, 41.5)	36.5	(34.9, 38.1)	41.7	(41.3, 42.2)	**<0.001**
	%	95% CI	%	95% CI	%	95% CI	
Work							
Regular Night	2.8	(1.8, 3.9)					
Rotating Shift	10.3	(7.8, 12.8)					
Regular Days	86.9	(84.0, 89.7)					
Cycle							
1	46.6	(44.4, 48.7)	43.2	(31.4, 54.9)	47.1	(44.7, 49.5)	0.68
2	53.4	(51.3, 55.6)	56.8	(45.1, 68.6)	52.9	(50.5, 55.3)	
Sex							
Male	53.3	(51.9, 54.7)	53.9	(45.6, 62.3)	53.2	(51.6, 54.9)	0.77
Female	46.7	(45.3, 48.1)	46.1	(37.7, 54.4)	46.8	(45.1, 48.4)	
Marital Status							
Married/Common-Law	65.4	(62.5, 68.2)	53.4	(45.2, 61.6)	67.5	(63.9, 70.4)	**<0.001**
Widowed/Separated/Divorced	8.4	(7.2, 9.6)	8.2	(5.0, 11.4)	8.4	(7.1, 9.7)	
Single	26.2	(23.8, 28.7)	38.4	(30.2, 46.6)	24.4	(21.7, 27.1)	
Ethnicity							0.10
White	80.6	(74.6, 86.6)	77.4	(68.6, 86.2)	81.1	(75.2, 87.0)	
Other	19.4	(13.4, 25.4)	22.6	(13.8, 31.4)	18.9	(13.0, 24.8)	
Education							
< Secondary school graduate	8.4	(6.5, 10.3)	11.8	(7.3, 16.4)	7.9	(6.1, 9.7)	**<0.001**
Secondary graduate/some post-secondary	27.0	(23.0, 31.1)	35.8	(27.4, 44.3)	25.7	(21.7, 29.7)	
Post-secondary graduate	64.6	(59.6, 69.5)	52.4	(44.0, 60.8)	66.4	(61.7, 71.2)	
Children < 16 years in the household							
Yes	63.5	(61.1, 65.8)	64.1	(58.0, 70.2)	63.4	(60.7, 66.1)	0.75
No	36.5	(34.2, 38.9)	35.9	(29.8, 42.0)	36.6	(33.9, 39.3)	
Multiple Jobs (Self-reported)							
No	90.3	(88.7, 92.0)	85.2	(79.1, 91.3)	91.1	(89.5, 92.7)	**0.01**
Yes	9.7	(8.0, 11.3)	14.8	(8.7, 20.9)	8.9	(7.3, 10.5)	
Job Status (Self-report)							
Full-time	84.3	(82.5, 85.8)	78.5	(70.9, 85.9)	85.2	(83.3, 86.8)	**0.01**
Part-time	15.7	(14.1, 17.3)	21.5	(14.0, 29.0)	14.8	(13.1, 16.5)	

Unadjusted mean daily MVPA in bouts of ten minutes or more was similar between shift workers and day workers, as was daily sedentary time (Table 3.2). Shift workers were no more likely than day workers to not meet physical activity guidelines after adjustment for age, sex, children in the household, education and number of hours worked per week in both weighted and unweighted analyses (Table 3.3). In the unweighted analysis, shift workers spent less time sedentary than day workers after adjusting for confounders; however no significant differences were found in the weighted analysis (Table 3.3). Similar results were seen with and without adjustment for daily MVPA (data not shown).

Table 3.2 Weighted physical activity descriptive data

	Overall Study Sample (n = 3513)		**Shift Workers (n = 452)**		**Day Workers (n = 3061)**		***p***
	Mean	95% CI	Mean	95% CI	Mean	95% CI	
MVPA (min/day)	10.2	(8.7, 11.8)	10.1	(6.2, 13.9)	10.2	(8.7, 11.8)	0.92
Sedentary (min/day)	575.7	(568.5, 582.9)	568.8	(553.7, 583.9)	576.7	(569.7, 583.6)	0.24
	%	95% CI	%	95% CI	%	95% CI	
Meets Guidelines							
No	84.4	(81.4, 87.4)	84.1	(75.8, 90.4)	84.5	(81.4, 87.5)	0.41
Yes	15.6	(12.6, 18.6)	15.9	(9.6, 22.2)	15.5	(12.5, 18.6)	

Legend: MVPA: Moderate-vigorous physical activity;
Note: Meeting physical activity guidelines was defined as those achieving >(150/7) minutes per day of moderate-vigorous physical activity in bouts of ten minutes or more.

Table 3.3 Univariate and multivariate regression results for physical activity levels and sedentary time (Accelerometer subsample, n = 3513)

		Unadjusted OR (95% CI)	Adjusted* OR (95% CI)	Weighted Unadjusted OR (95% CI)	Weighted Adjusted* OR (95% CI)
Does not meet PA Guidelines	Day work	1.0	1.0	1.0	1.0
	Shift work	0.96 (0.80, 1.15)	1.11 (0.90, 1.37)	0.97 (0.62, 1.52)	1.16 (0.73, 1.85)
		Unadjusted Mean Difference (95% CI)	**Adjusted* Mean Difference (95% CI)**	**Weighted Unadjusted Mean Difference (95% CI)**	**Weighted Adjusted* Mean Difference (95% CI)**
Sedentary time (min/day)	Day work	Ref	Ref	Ref	Ref
	Shift work	**-20.6 (-29.6, -11.7)**	**-14.5 (-22.1, -6.9)**	-7.9 (-22.7, 5.6)	-2.9 (-16.9, 11.1)

Legend: PA: Physical activity

* Adjusted for age, sex, children in the household, education and number of hours worked per week.

Unadjusted aerobic capacity and handgrip strength did not differ statistically between shift workers and day workers (Table 3.4). In both unweighted and weighted analyses, shift workers had a lower predicted VO_2 max than day workers after adjustment for confounders, but no differences were found in handgrip strength (Table 3.5).

Table 3.4 Weighted physical fitness descriptive data

	Overall Study Sample (n = 3410)		Shift Workers (n = 439)		Day Workers (n = 2971)		*p*
	Mean	**95% CI**	**Mean**	**95% CI**	**Mean**	**95% CI**	
VO_2 max (ml/kg/min)	26.4	(26.1, 26.7)	26.5	(25.8, 27.3)	26.4	(26.1, 26.8)	0.80
Hand grip strength (kg)	74.9	(73.3, 76.5)	72.0	(67.4, 76.7)	75.3	(73.7, 76.9)	0.15

Table 3.5 Univariate and multivariate linear regression results for physical fitness assessments (Fitness assessment subsample, n = 3410)

		Unadjusted Mean Difference (95% CI)	Adjusted* Mean Difference (95% CI)	Weighted Unadjusted Mean Difference (95% CI)	Weighted Adjusted* Mean Difference (95% CI)
Predicted VO_2 Max (mL/kg/min)	Day work	Ref	Ref	Ref	Ref
	Shift work	0.5 (-0.1, 1.1)	**-0.5 (-0.9, -0.04)**	0.1 (-0.7, 0.9)	**-0.6 (-1.1, -0.1)**
Hand Grip Strength (kg)	Day work	Ref	Ref	Ref	Ref
	Shift work	1.0 (-2.7, 4.7)	-1.3 (-3.0, 0.3)	-3.3 (-7.8, 1.3)	-2.3 (-5.1, 0.5)

* Adjusted for age, sex and education.

No statistically significant differences were found for any anthropometric variables before adjustment for important confounders (Table 3.6). In the unweighted analysis adjusting for confounders, shift workers were more likely to be obese, and classified in high-risk categories for WHR and waist circumference (Table 3.7). However, differences were not seen after applying sample weights. In sensitivity analyses restricted to those >50 years old, the magnitude of the odds ratios increased, however none were statistically significant (Table 3.7).

Table 3.6 Weighted body composition descriptive data

	Overall Study Sample (n = 4323)		Shift Workers (n = 568)		Day Workers (n = 3755)		*p*
	Mean	**95% CI**	**Mean**	**95% CI**	**Mean**	95% CI	
BMI (kg/m^2)	27.1	(26.7, 27.4)	26.6	(25.9, 27.3)	27.1	(26.7, 27.5)	0.10
Body Weight (kg)	78.1	(76.8, 79.4)	77.7	(74.9, 80.5)	78.5	(76.9, 79.5)	0.70
Waist Circumference (cm)	90.6	(89.5, 91.7)	89.6	(87.5, 91.6)	90.8	(89.7, 91.9)	0.14
Hip Circumference (cm)	103.5	(102.7, 104.2)	103.1	(102.1, 104.2)	103.5	(102.7, 104.3)	0.70
Waist-Hip Ratio	0.87	(0.87, 0.88)	0.87	(0.85, 0.88)	0.87	(0.87, 0.88)	0.23
	%	**95% CI**	**%**	**95% CI**	**%**	**95% CI**	
Overweight							
BMI ≤ 25.0	41.1	(37.5, 44.8)	44.0	(35.7, 52.3)	40.7	(36.9, 44.5)	0.23
BMI >25.0	58.9	(55.2, 62.5)	56.0	(47.7, 64.3)	59.3	(55.5, 63.1)	
Obese							
BMI ≤ 30.0	75.7	(72.9, 78.6)	77.2	(72.0, 82.4)	75.5	(72.6, 78.5)	0.40
BMI >30.0	24.3	(21.4, 27.1)	22.8	(17.6, 28.0)	24.5	(21.5, 27.4)	
Waist-Hip Ratio							
Low Risk	53.3	(50.0, 56.5)	56.6	(47.6, 65.5)	52.8	(49.5, 56.0)	0.25
High Risk	46.7	(43.5, 50.0)	43.4	(34.5, 52.4)	47.2	(44.0, 50.5)	

	Overall Study Sample (n = 4323)		Shift Workers (n = 568)		Day Workers (n = 3755)		*p*
Waist Circumference							
Low Risk	46.6	(43.6, 49.6)	51.0	(44.8, 57.3)	45.9	(42.8, 49.1)	0.06
High Risk	53.4	(50.4, 56.4)	49.0	(42.7, 55.2)	54.1	(50.9, 57.3)	

Legend: BMI: Body Mass Index

Note: Risk categories for Waist-Hip and Waist Circumference based on established cut points from the World Health Organization[240].

Table 3.7 Univariate and multivariate logistic regression for body composition variables (full study sample and restricted to those > 50 years old)

		Full Study Sample (n = 4323)			
		Unadjusted OR (95% CI)	**Adjusted* OR (95% CI)**	**Weighted, Unadjusted OR (95% CI)**	**Weighted, Adjusted* OR (95% CI)**
Obese	Day work	1.0	1.0	1.0	1.0
	Shift work	1.13 (0.98, 1.31)	**1.39 (1.09, 1.53)**	0.91 (0.71, 1.18)	1.05 (0.80 1.38)
High Risk WHR	Day work	1.0	1.0	1.0	1.0
	Shift work	1.02 (0.83, 1.25)	**1.37 (1.18, 1.60)**	0.86 (0.61, 1.21)	1.22 (0.84, 1.77)
High Risk WC	Day work	1.0	1.0	1.0	1.0
	Shift work	0.99 (0.87, 1.12)	**1.31 (1.14, 1.51)**	0.82 (0.64, 1.04)	1.09 (0.82, 1.45)
		Restricted Study Sample, Greater than age 50 (n = 1169)			
		Unadjusted OR (95% CI)	**Adjusted* OR (95% CI)**	**Weighted, Unadjusted OR (95% CI)**	**Weighted, Adjusted* OR (95% CI)**
Obese	Day work	1.0	1.0	1.0	1.0
	Shift work	1.41 (0.86, 2.32)	1.44 (0.87, 2.38)	1.68 (0.96, 2.94)	1.78 (0.99, 3.22)
High Risk WHR	Day work	1.0	1.0	1.0	1.0
	Shift work	1.33 (0.88, 2.01)	1.45 (0.91, 2.31)	1.30 (0.56, 3.00)	1.51 (0.62, 3.69)
High Risk WC	Day work	1.0	1.0	1.0	1.0
	Shift work	1.32 (0.87, 2.00)	1.44 (0.94, 2.20)	1.33 (0.59, 2.99)	1.38 (0.61, 3.32)

Legend: WC: Waist Circumference; WHR: Waist-Hip Ratio

* Adjusted for age, sex, and children in the household.

3.5. Discussion

Contrary to our hypothesis, no differences in MVPA between groups were found, and shift workers actually spent less time sedentary than day workers. While objective physical activity measures overcome the recall and social desirability biases of self-report, they fail to differentiate between purposeful exercise and occupational, transportation or household activity. As well, certain types of activity such water-based activities and bicycling, are not captured well by accelerometers. Future studies may consider the use of objective accelerometer data supplemented with a weekly physical activity log or diary to overcome some of these limitations.

While it is encouraging that shift workers were no less likely to meet physical activity guidelines, overall low levels of physical activity were observed in both groups, with only 15.6% of participants meeting physical activity guidelines. These estimates are comparable to a previous estimate of 15.4% (95% CI: 10.9 – 19.8%) of working and non-working Canadians age 20-79[243]. As lack of physical activity is associated with a number of negative health effects, this points to the importance of physical inactivity as a major public health issue both in shift workers and the general population.

While MVPA is known to play an important role in the prevention of chronic disease[244], aerobic capacity, independent of MVPA, is also associated with lower all-cause, cardiovascular and cancer mortality[245]. In both weighted and unweighted analyses, shift workers had a lower aerobic capacity. VO_2max is known to decrease with age, and the multivariate model found a mean decrease of 0.2 mL/kg/minute for every one-year increase in age. Thus, the difference in predicted VO_2max between shift workers and day workers corresponds to a difference of approximately three years.

It is interesting to note the significant difference in predicted VO_2max, despite no difference in MVPA. While VO_2max does have a genetic component, it is largely based on an individual's MVPA[246]. It may be possible that shift workers may not reap the same health benefits of MVPA, or may need to engage in higher intensity physical activity to achieve the same aerobic capacity as day workers. Another possible explanation could be the misclassification of physical activity due to the cut points used to classify physical activity. A cut point of >1535 counts/minute was used to define MVPA. It could be that while shift workers and day workers do not differ in the number of minutes above this cut point, the overall intensity of activity may be higher in day workers, resulting in a greater exercise stimulus and thus higher VO_2max.

In unweighted analyses, shift workers were more likely to be obese and in high-risk categories for WHR and waist circumference, consistent with previous findings[115,233]. No significant differences were observed when sample weights were applied. The CHMS was designed to be a nationally-representative source of data on the prevalence of various health conditions and behaviours. Sample weights were created to minimize selection bias from non-response and missing data and to account for oversampling of population subgroups. Estimates of the prevalence of shiftwork in Canada vary, from 13[247]-25%[2] suggesting shift workers may be underrepresented in our study sample. This could bias our results towards the null, particularly if those who are most burdened by shift work are less likely to participate. Because sample weights did not account for work schedule, non-response by work schedule is not accounted for using the sample weights that accompany the CHMS. For a robust analysis, we present both weighted and unweighted results, adjusted for important confounders, acknowledging that results may not be generalizable to all shift workers.

Based on evidence suggesting that long duration shift work (more than 20 years) is most hazardous to health,[33] we hypothesized *a priori* that a greater difference between groups would be observed in older workers with the longest work history. In analyses restricted to only those greater than 50 years old, the ORs comparing shift workers to day workers were greater than in the full study sample, however none reached statistical significance. In this analysis, age may act as a surrogate measure for duration of shift work or there may be true biological interaction between age and shift work with older workers being at higher risk for adverse body composition outcomes. Without data for shift work history, we are unable to explore these questions.

A major limitation to this analysis is the crude definition of shift work used and the heterogeneity of workers within each category. Based on the available data, we were only able to create a binary variable for shift work as those who self-reported working regular nights and rotating shifts. The survey did not capture the number of night shifts worked per month or history of shift work. Different types of shift schedules may impact health in different ways. While permanent night shift work may adversely impact social, work and family life, they may be less disruptive to the circadian system than rotating shift work, especially if the sleep-wake schedule is maintained on days off[5]. To truly separate these effects, different schedules (i.e., rotating and permanent night shift schedules) should be examined separately in future studies.

Despite these limitations, there are several strengths that make this analysis an important contribution to the literature. This population-based study included a large number of individuals across varying geographic regions, with a wide variety of demographic characteristics, and is not limited to a specific occupational group or workplace. Objectively measured data were collected by trained assessors, reducing the potential for information bias due to inaccurate recall and social desirability in the study sample.

Based on these findings, shift workers have a lower predicted VO_2max than day workers, and may spend less time in sedentary activities, despite no observed differences in MVPA. Shift workers are also more likely to be classified as high risk for a number of health outcomes based on body composition. These findings, in the context of the existing literature linking shift work to a variety of adverse health outcomes, support the further investigation into the mechanisms underlying these risks and the development of targeted lifestyle interventions to encourage shift workers to engage in regular MVPA, perhaps in combination with dietary or other lifestyle counseling, in order to improve aerobic capacity, and maintain a healthy body weight.

3.6. CONCLUSION

The critical review conducted in Chapter 2 suggests that interventions targeted at specific behaviour changes are most effective for improving lifestyle behaviours. The findings from the CHMS support the need for the development of lifestyle interventions with an aim to increase physical activity and physical fitness in shift workers. In order to fully understand patterns of physical activity across different domains, and the changes that may occur during an intervention, a combination of objective and subjective measures of physical activity may be most informative. The critical review in Chapter 2 also highlights lack of retention and adherence to interventions as a limitation in the literature to date. Therefore, interventions should be carefully designed based not only on the best available evidence, but also with input and feedback from shift workers themselves, to ensure the intervention is feasible and acceptable to this population.

4. Chapter 4: Barriers To, and Preferences For Physical Activity In Women Shift Workers

4.1. Synopsis

Shift workers are at increased risk for a number of chronic diseases. Physical activity may mitigate this risk, but shift workers are unlikely to be sufficiently active. Understanding shift workers' perspectives on physical activity programs is important for developing targeted interventions in this high-risk population. The purpose of this study was to identify major barriers to and preferences for physical activity programs in women shift workers. Women shift workers completed questionnaires to assess barriers to, and preferences for physical activity programming, and wore an accelerometer to measure physical activity. Participants (n = 46) were primarily health care professionals (73.8%), working rotating shifts. No differences were found between individuals who did and did not meet physical activity guidelines. The most common barriers to activity were work schedule, time, and self-discipline. The most important components of a physical activity program were flexible hours, that exercise not be boring, and that individuals see results. Participants preferred a combination of aerobic and resistance training activities outside the home, with face-to-face advice in flexible or drop-in sessions, on days off. Work schedule and timing are the primary barriers to physical activity in women shift workers. Future programs should consider flexible scheduling on days off to promote adherence.

A version of this chapter is currently under review. This work was also presented as an oral presentation at the Annual Symposium on Occupational, Environmental, and Public Health in Semiahmoo, WA in January 2014 and as a poster presentation at the International Symposium on Shift Work and Working Time in Salvador, Brazil in November 2013.

4.2. INTRODUCTION

There is growing evidence to support the association between shift work and long term risk of a number of chronic diseases[168], as well as short-term effects including adverse reproductive outcomes in women[67], adverse psychological impacts[248] and impairments in family and social life and work-life balance[7]. Lifestyle factors, such as physical activity, may play a large role in an individual's risk of developing many chronic diseases[249], and also positively influence current states of health and well-being. Shift workers have been shown to be less likely than the general population to engage in regular physical activity in some studies[55,159,160], and also to have lower levels of physical fitness (Chapter 3). Because shift workers are at an already increased risk for negative health outcomes, they potentially have even more to gain from participating in regular physical activity. To date, only one intervention has been conducted that aimed to increase physical activity in individuals working night shifts[165,166]. A total of 119 nurses or nursing aides were randomized to either a four-month exercise intervention consisting of two to six training sessions per week, or a control group. Despite poor adherence to the intervention, and large loss to follow up (37%), a number of positive outcomes were observed including statistically significant improvements in aerobic fitness, fatigue, and sleep. This study provides support for the role that physical activity may play in improving the health of shift workers; it also draws attention to the importance of understanding shift workers' needs and preferences for physical activity programs in order to encourage intervention adherence and maximize health benefits.

Physical activity has been shown to be a safe, cost-effective intervention that can improve cardiovascular and metabolic health, decrease cancer risk, and have beneficial effects on sleep and mental health in a variety of populations[127,250]. Increasing physical activity levels and achieving long-term behaviour change is difficult, and a number of health promotion theories exist to guide the development and implementation of effective interventions[251]. Self-efficacy for exercise[252], and outcome expectancies related to physical activity participation[253] have been shown to predict current physical activity levels. These may also represent constructs that could be targeted by a physical activity intervention to promote and sustain behaviour change. Combining behaviour change theory with input from individuals who are the target of these interventions may be the best approach for developing effective and sustainable interventions[254]. Identifying barriers to physical activity at the individual, social and environmental levels, and preferences for specific components of a health promotion program have been previously used to design interventions aimed at increasing physical activity implemented within the workplace[255]. However, barriers and preferences for physical activity that may be specific to shift workers have not been identified.

The primary objective of this study was to identify the main barriers to participating in regular physical activity, and preferences for structured exercise programming specific to woman shift workers who do and do not meet physical activity guidelines, in order to inform the development of future physical activity interventions in this population. The secondary objective was to examine factors that may predict current physical activity behaviour (e.g., self-efficacy, and outcome expectancies) to identify theoretical constructs that may be appropriate targets for a behaviour change intervention.

4.3. METHODS

4.3.1. PARTICIPANTS

Data for this analysis come from a larger intervention study conducted in English-speaking women shift workers aged 40 to 65 years old who had been employed in occupations with high circadian disruption (at least three night shifts per month for the past two years)[256]. Women were ineligible for the parent study if they reported a history of breast cancer or diabetes requiring pharmacological treatment or were pregnant or planning to become pregnant. Ethical approval was received from the University of British Columbia's Clinical Research Ethics Board, and all participants provided written informed consent.

4.3.2. DATA COLLECTION

Participants completed all measures related to this analysis prior to taking part in the parent intervention study. Participants were asked to wear a wrist-worn accelerometer (Actiwatch 2, Philips Respironics, Oregon, USA) during all sleep and wake times. The Actiwatch 2 captures activity in counts per minute, sleep and wake time, and light intensity. Cut points to classify activity as sedentary, light, moderate and vigorous have been previously developed[257] and were used to calculate minutes per day of moderate-vigorous physical activity (MVPA), and hours per day of sedentary time for each participant. In accordance with accepted accelerometer best practices, both MVPA and sedentary time were calculated when they occurred in bouts of ten minutes or more, allowing for one-minute interruptions[258]. Participants were classified as meeting physical activity guidelines if they took part in greater than 150 minutes per week of MVPA in bouts of ten minutes or more[128].

Barriers to participation in exercise and physical activity were assessed using a modified version of the Physical Activity for Risk Reduction Barriers Instrument[259], with one additional item (work schedule interference). Participants were asked: "*Which of the following do you experience as barriers to participation in exercise?*" with responses provided on a Likert scale, with one being never and five being very often. Preferences for exercise programming were assessed using a previously developed checklist[260] in which participants were asked to: "*Indicate how important each component is to you as a part of an exercise program, while also enjoying it"*. Responses ranged from one (not important) to ten (very important). Specific questions related to a proposed physical activity intervention were also asked.

Self-efficacy was assessed across three different domains, task self-efficacy[252], exercise self-efficacy[261] and scheduling self-efficacy (on day shifts, night shifts and days off) by asking: "*How confident are you that you could exercise three times per week for at least 30 minutes if…"*, with responses ranging from zero (not confident) to ten (very confident). Both affective outcome and health outcome expectancies were also measured using a previously developed tool[253] with responses ranging from one (strongly agree) to five (strongly disagree). These were reported to test the hypothesis that increased self-efficacy or higher outcome expectancy would be positively correlated with higher levels of physical activity.

Finally, all participants completed a health and lifestyle questionnaire, including demographic information, questions on health status and health behaviours, and information on work history and work schedule to describe the study sample.

4.3.3. Data Analysis

Data analysis was completed using R version 3.1.1 (R Foundation for Statistical Computing, Vienna, Austria). Descriptive data were summarized as mean and standard deviation, or frequency and percentage where appropriate. Median and interquartile range was calculated for variables that were heavily skewed. Non-parametric Wilcoxon rank-sum test (for continuous variables) and Fisher's exact test (for categorical variables) were used to test for differences between those did and did not meet physical activity guidelines.

The most common barriers to regular physical activity and the importance of components of an activity program were identified as the highest average scores for each component. Then the number and percent of participants reporting "often" or "very often" for most common barriers was calculated, along with number and percent reporting greater than seven out of ten for most important preferences. Preferences for specific components of a physical activity program were calculated as counts and percentages. Fisher's exact test was used to test for differences between those who did and did not meet physical activity guidelines for each barrier and program component, as well as the total number of barriers.

Self-efficacy and outcome expectancies scores were summarized as medians and interquartile ranges due to their skewed distribution. Wilcoxon rank-sum tests were used to test for differences between those who did and did not meet physical activity guidelines for each domain of self-efficacy and outcome expectancy, and to test for differences across self-efficacy and outcome expectancy domains.

4.4. RESULTS

A total of 46 women completed the questionnaires and accelerometer assessment and are included in this analysis. Demographic data are presented in Table 4.1.The median value for physical activity was 36.9 minutes per day of MVPA (when calculating only bouts of activity of at least ten minutes in duration), with 65% of participants meeting published physical activity guidelines of 150 minutes per week of MVPA in bouts of ten minutes or more. Median sedentary time was recorded as 5.9 hours per day. No differences were found between those who did and did not meet physical activity guidelines for any of the descriptive characteristics, with the exception of minutes per day of MVPA and sedentary time. Overall participants were middle aged (47.5 ± 4.8 years), slightly overweight, non-smokers and mostly postmenopausal (80%). The majority worked full time (82.6%), on rotating shifts (91.3%), with an average of 7.5 night shifts per month. The majority of participants were health care workers such as nurses or care aides (54.3%), paramedics (13.0%), other health care workers (6.5%).

Table 4.1 Demographic information and work schedule characteristics of participants who meet and do not meet physical activity guidelines

	All Participants (n = 46)		Met Guidelines (n = 30)		Did Not Meet Guidelines (n = 16)		
	Mean ± SD	**N (%)**	**Mean ± SD**	**N (%)**	**Mean ± SD**	**N (%)**	***p***
Age	47.5 ± 4.8		47.0 ± 4.7		48.3 ± 4.9		0.39
Body Mass Index (kg/m^2)	26.6 ± 5.4		26.2 ± 5.4		27.4 ± 5.5		0.32
Menopausal Status							
Premenopausal		9 (19.6)		6 (20.0)		3 (18.7)	0.99
Postmenopausal		37 (80.4)		24 (80.0)		13 (81.3)	
Education							
High school		7 (15.2)		7 (23.3)		0	0.15
Diploma, Trade school or certificate		26 (56.5)		15 (50.0)		11 (68.8)	
Bachelor's degree or higher		13 (28.3)		8 (26.7)		5 (31.2)	
Marital Status							
Married/living with a partner		32 (69.6)		23 (76.7)		9 (56.3)	0.18
Divorced/Separated		6 (13.1)		4 (13.3)		2 (12.5)	
Single, never married		7 (15.2)		2 (6.7)		5 (31.2)	
Prefer not to answer		1 (2.2)		1 (3.3)		0	
Children							
No		15 (32.6)		9 (30.0)		6 (37.5)	0.28
Yes		31 (67.4)		21 (70.0)		10 (62.5)	

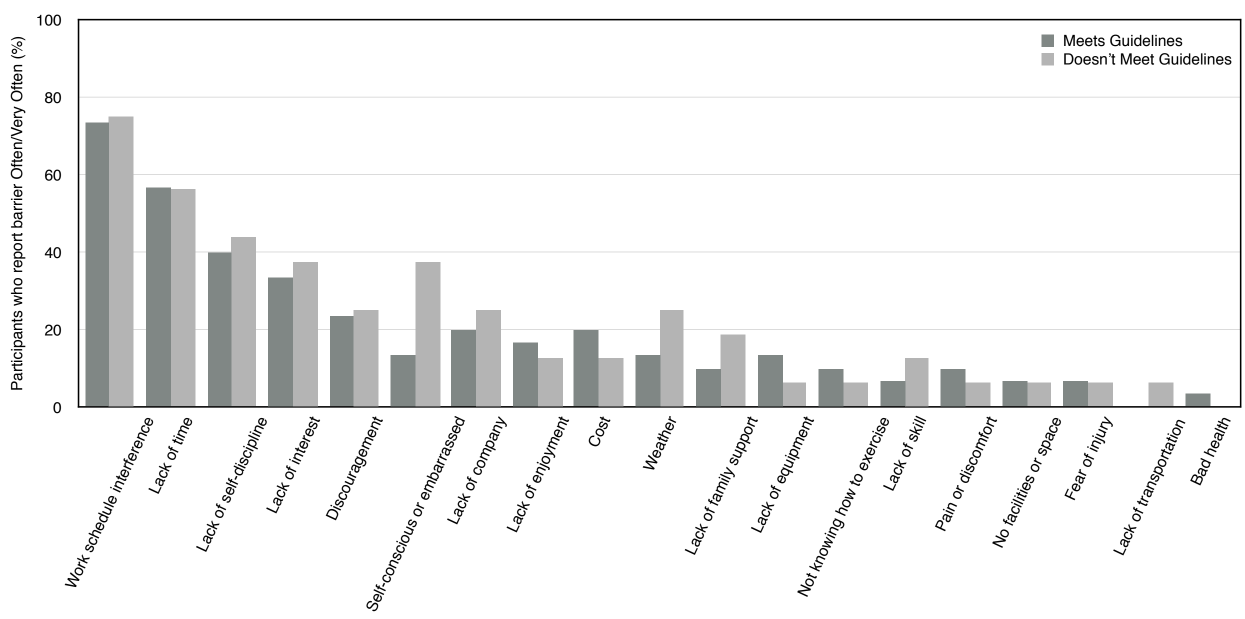
	All Participants (n = 46)	**Met Guidelines (n = 30)**	**Did Not Meet Guidelines (n = 16)**	
Smoking Status				
Smoker	1 (2.2)	1 (3.3)	0	0.99
Non-smoker	45 (97.8)	29 (96.7)	16 (100.0)	
Shift Schedule				
Permanent night shift	4 (8.7)	4 (13.3)	0	0.28
Rotating night shift	42 (91.3)	26 (86.7)	16 (100.0)	
Job Category				
Nurses or care aides	26 (54.3)	15 (50.0)	10 (62.5)	0.54
Emergency dispatch	7 (15.2)	6 (20.0)	1 (6.3)	
Paramedic	6 (13.0)	4 (13.3)	2 (12.5)	
Other health care worker	3 (6.5)	1 (3.3)	2 (12.5)	
Other	5 (10.9)	4 (13.3)	1 (6.3)	
Work Status				
Full Time	38 (82.6)	23 (76.7)	15 (93.8)	0.23
Part Time	8 (17.4)	7 (23.3)	1 (6.2)	
Duration of shift work (years)	16.5 ± 8.3	16.4 ± 7.2	17.8 ± 10.2	0.55
Night shifts worked/month	7.5 ± 2.4	7.3 ± 2.3	7.9 ± 2.7	0.48
MVPA (min/day, >10 min bouts) [a]	36.9 (15.7, 54.4)	47.7 (40.7, 72.9)	11.3 (8.4, 15.7)	**< 0.01**
Sedentary time (h/day, >10 min bouts) [a]	5.9 (5.0, 7.3)	5.6 (4.1, 6.3)	7.1 (6.4, 8.2)	**< 0.01**

[a] Data presented as median and interquartile range due to the skewed distribution of data

4.4.1. BARRIERS TO PHYSICAL ACTIVITY

No significant differences were found between those who did and did not meet physical activity guidelines for the percentage of participants who encountered each individual barrier. Across both groups, the most common reported barriers to engaging in regular physical activity were work schedule interference (73.9%), followed by lack of time (56.5%), and lack of self-discipline (41.3%) (Figure 4.1). Fear of injury, availability of facilities, lack of transportation, and bad health were least frequently reported to be barriers. On average, those who did not meet physical activity guidelines encountered 4.3 $\pm$3.6 barriers often or very often, compared to 3.8 $\pm$3.1 in those who did meet guidelines, although this difference was not statistically different (p = 0.61).

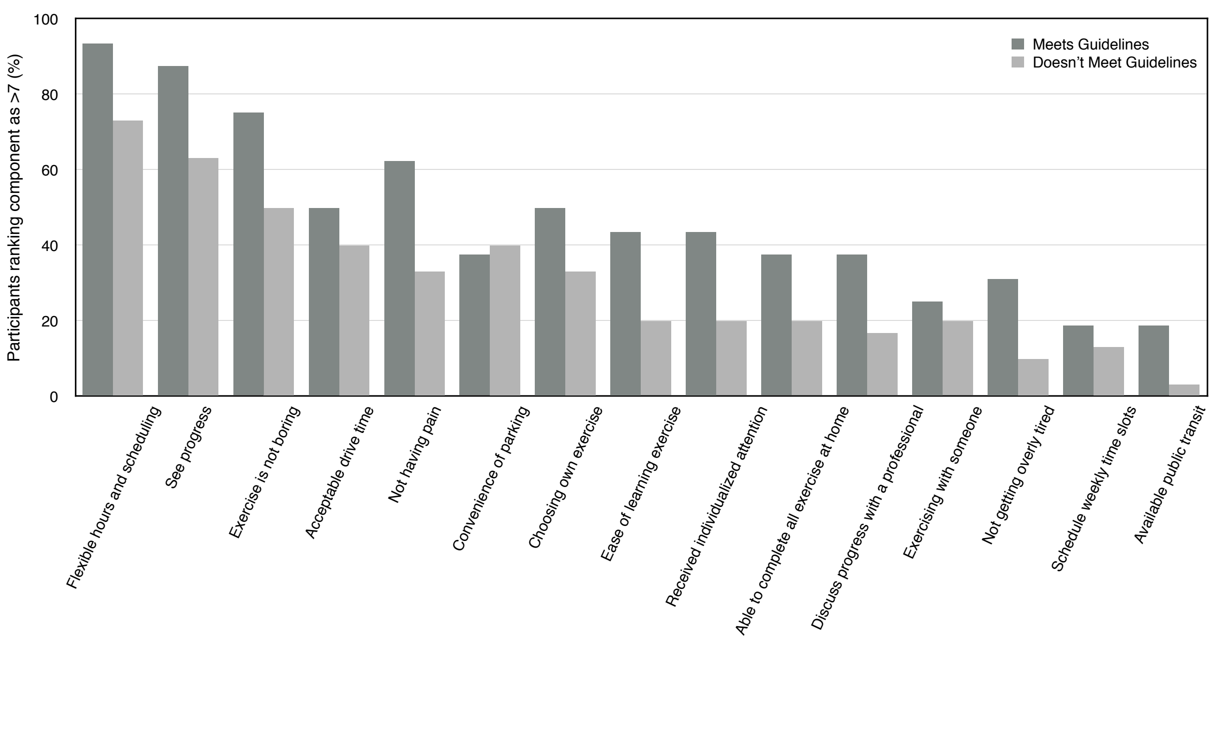
Figure 4.1 Barriers to participating in regular exercise, ranked on a scale of 1 (never) to 5 (often)



4.4.2. IMPORTANCE OF EXERCISE PROGRAMMING COMPONENTS

No significant differences were found between those who did and did not meet physical activity guidelines when ranking importance of exercise programming components. Across both groups, the components of an exercise program that were reported to be most important were flexibility in hours and scheduling (80.4%), that participants are able to see progress (71.4%), and that exercise not be boring (58.7%) (Figure 4.2). Availability of public transit, ability to schedule weekly timeslots and that exercise not be tiring were ranked as important least frequently.

Figure 4.2 Important components of an exercise program, ranked on a scale of 1 (not important) to 10 (very important)



4.4.3. Specific Preferences for Exercise Programming

Preferences for specific features of an exercise program are listed in Table 4.2. No differences were found between those who did and did not meet physical activity guidelines. Overall, participants reported a stronger preference for exercise outside of the home, with face-to-face instruction, and flexible or drop in hours completed on days off. Participants reported a wish to participate in both aerobic and strength training exercise, and ranked walking/jogging/running as the mode they would most prefer. Half the participants reported a preference for exercise without supervision from an exercise professional, and two-thirds reported a preference for exercise with others or in a group, rather than alone.

Table 4.2 Preferences for specific exercise programming components

	All Participants (n = 46)	Met Guidelines (n = 30)	Did Not Meet Guidelines (n = 16)	*p*
	N (%)			
Where would you most like to do exercise on a regular basis?				
Outdoors, away from home	24 (52.2)	17 (56.7)	7 (43.8)	0.76
In a health club	12 (26.1)	7 (23.3)	5 (31.2)	
At home	8 (17.4)	4 (13.3)	4 (25.0)	
At work	1 (2.2)	1 (3.3)	0	
Other	1 (2.2)	1 (3.3)	0	
How would you most like to receive exercise counseling or instruction?				
Face-to-face	31 (67.4)	19 (63.3)	12 (75.0)	0.77
Internet (website/email)	11 (23.9)	8 (26.7)	3 (18.7)	
Written materials	2 (4.3)	2 (6.7)	0	
DVD	2 (4.3)	1 (3.3)	1 (6.3)	
Podcast/audiotape	0	0	0	
Telephone	0	0	0	
How would you prefer to perform exercise?				
Unsupervised	23 (50.0)	17 (56.7)	6 (37.5)	0.30
Supervised by an exercise professional	14 (30.4)	9 (30.0)	5 (31.3)	
No preference	9 (19.6)	4 (13.3)	5 (31.3)	

	All Participants (n = 46)	Met Guidelines (n = 30)	Did Not Meet Guidelines (n = 16)	*p*
If you were to participate in an exercise program, which would you prefer?				
Both aerobic and strength training	34 (73.9)	21 (70.0)	14 (87.5)	0.66
Aerobic or cardiovascular exercise	5 (10.9)	4 (13.3)	1 (6.3)	
Strength training exercise	2 (4.3)	2 (6.7)	0	
No preference	4 (8.7)	3 (10.0)	1 (6.3)	
What type of exercise would you most prefer?				
Walking, jogging, running	22 (47.8)	13 (43.3)	9 (56.3)	0.31
Yoga/Pilates	8 (17.4)	5 (16.7)	3 (18.7)	
Resistance training (free weights, weight machines, bands, etc.)	7 (15.2)	6 (20.0)	1 (6.3)	
Cycling	5 (10.9)	4 (13.3)	1 (6.3)	
Water activities or swimming	2 (4.3)	0	2 (12.5)	
Other	2 (4.3)	2 (6.7)	0	
How would you prefer to exercise?				
With others/in a group	29 (63.0)	20 (66.7)	9 (56.3)	0.53
Alone	17 (37.0)	10 (33.3)	7 (43.8)	
What would you prefer the structure of the exercise session to be?				
Flexible (i.e., drop in hours)	38 (82.6)	26 (86.7)	12 (75.0)	0.58
Scheduled (i.e., book an appointment time)	4 (8.7)	2 (6.7)	2 (12.5)	
No preference	4 (8.7)	2 (6.7)	2 (12.5)	

	All Participants (n = 46)	Met Guidelines (n = 30)	Did Not Meet Guidelines (n = 16)	*p*
When would you prefer to exercise?				
On days off	43 (93.5)	29 (96.7)	14 (87.5)	0.27
Before a night shift	1 (2.2)	0	1 (6.3)	
After a night shift	1 (2.2)	1 (3.3)	0	
Before a day shift	0	0	0	
After a day shift	1 (2.2)	0	1 (6.3)	

4.4.4. Self-Efficacy and Outcome Expectancy

Self-efficacy and outcome expectancy scores are presented in Table 4.3. Overall, no differences were found between those who did and did not meet physical activity guidelines. Across all participants, scores were higher for task self-efficacy, compared to exercise self-efficacy (p <0.001). Scheduling self-efficacy was found to be higher for days off compared to day shift or night shift (p <0.001) with no differences between day and night shifts (p=0.44). Participants scored higher on ratings of affective outcome expectancies compared to health outcome expectancies (p = 0.03).

Table 4.3 Self-efficacy and outcome expectancy scores for those who did and did not meet physical activity guidelines

	All Participants (n = 46)	Met Guidelines (n = 30)	Did Not Meet Guidelines (n = 16)	
	Median (IQR)			*p*
Self-Efficacy, 0 (Not confident) to 10 (Very Confident)				
Task	7.5 (6.3, 8.7)	7.5 (6.3, 8.3)	7.8 (6.3, 9.0)	0.56
Exercise	4.3 (3.1, 6.3)	4.5 (2.9, 6.1)	4.3 (3.2, 7.2)	0.77
Scheduling: Day Shift	2.0 (0.3, 5.8)	2.0 (1.0, 4.8)	2.5 (0.0, 6.3)	0.99
Scheduling: Night shift	3.0 (1.0, 7.0)	2.5 (1.0, 6.8)	5.0 (2.0, 7.3)	0.41
Scheduling: Days off	8.0 (6.0, 9.0)	8.0 (5.3, 9.0)	8.0 (6.8, 10.0)	0.59
Outcome Expectancy, 1 (Strongly Agree) to 5 (Strongly Disagree)				
Health Outcomes	1.5 (1.0, 2.0)	1.7 (1.0, 2.0)	1.2 (1.0, 2.0)	0.55
Affective Outcomes	2.0 (1.0, 2.5)	2.0 (1.5, 2.5)	2.0 (1.0, 2.0)	0.13

4.5. DISCUSSION

In this sample of women shift workers, which primarily consisted of health care workers, factors related to the work schedule and scheduling or timing of physical activity were identified as the primary barriers to participating in regular physical activity, and were also amongst the most important perceived components of an exercise program. This suggests that future programs that aim to increase physical activity levels in women shift workers must incorporate flexibility in scheduling, and may consider prioritizing activity on workers' days off in order to promote adherence.

We found no significant differences between those who met and did not meet physical activity guidelines in relation to barriers to or preferences for physical activity, or measures of self-efficacy or outcomes expectancy related to physical activity. Based on objectively measured physical activity levels, many of the participants were already quite active, with 65% meeting physical activity guidelines of 150 minutes per week of MVPA in bouts of ten minutes or more, with median of 36.9 minutes per day of MVPA. This is a much higher proportion than reports from a representative sample of female Canadians in the same age group, which included individuals who were not working, in which only 14.1% (95% CI: 9.1 – 19.1) met guidelines[243]; but is similar to a reported median of 32 minutes per day of MVPA a day in obstetricians who work night shifts[262].

While objectively measured physical activity levels overcome reporting and recall biases that are inherent to self-report questionnaires, they are not without limitations. Relevant to this study, accelerometers cannot distinguish between activities across different domains (i.e., occupational, recreational, transportation) and thus we are unable to differentiate those who have higher levels of occupational activity (for example, nurses working on a busy medical ward) and those who participate in purposeful exercise outside of work time. This may partly explain the lack of differences observed between groups, as the group classified as meeting physical activity guidelines may include both women who purposefully engage in MVPA, and women who are active because of the nature of their job, but do not engage in purposeful MVPA outside of the workplace. The barriers to and preferences for activity may also be different amongst people those who are currently active, those who are trying to become more active, and those who are not trying to become more active, which we did not assess in this study. These differences require further investigation.

These findings are in line with those from a previous studies from other occupational groups, including a qualitative study of employees of a large city government[263]. Blue-collar city workers, who predominantly worked rotating shift schedules, reported abnormal work hours and time as the primary barriers to participating in regular physical activity. These workers also reported a preference for leisure-time physical activity away from the workplace, while white-collar office workers (who worked exclusively during the day) desired worksite programs that would allow them to integrate physical activity into their workday. In our study, only one participant (who met physical activity guidelines) reported a preference for physical activity at the workplace. We hypothesize that shift workers' desire to leave the workplace for physical activity could be related to the long shift duration (e.g., twelve-hour shifts) that is common amongst permanent and rotating shift schedules.

Aside from the important implications around work schedule, our finding that time was an important barrier to physical activity is not dissimilar to reports of barriers in the general population. In one study of healthy Australian adults, the most important barriers to activity in women were time, motivation, and injury, and the most preferred mode of exercise was walking, jogging or running[264]. Another cross-sectional survey of working women found that lack of time related to both work and family, as well as levels of energy and motivation, were the most common barriers to participating in regular physical activity[265].

Of note were our participants' preferences for face-to-face physical activity advice (63.3 and 75.0% in those who do and do not meet guidelines, respectively), and for physical activity with others or in a group (66.7 and 57.3% in those who do and do not meet guidelines, respectively). While the benefits of exercising with others to enhance social support, increase accountability and promote adherence have been well documented as important components of a successful behaviour change intervention[266], this may be harder to implement for shift workers whose free time for physical activity may occur when many others are either at work or sleeping. The design of future physical activity programs must balance the logistical time constraints for those working shift work, with known best practices for encouraging behaviour change and identified preferences of these individuals. The use of new and emerging technologies, such as smart phone applications or using online platforms or social media, may be one creative way for shift workers to connect with exercise professionals in a virtual setting, and strategies to connect shift workers to one another to encourage physical activity should also be explored.

Our findings have several limitations. Our study sample consisted of women shift workers who were recruited to participate in an intervention study aimed at improving their sleep. As such, the barriers and preferences for physical activity seen here may not be representative of all shift workers. The sample primarily included health care workers, who may have different barriers and preferences from those in other occupational groups. This study was also conducted in Vancouver, Canada, an urban city with a generally moderate climate, excellent public transportation infrastructure and a high density of both outdoor and indoor recreational facilities. Not surprisingly, these aspects did not rank highly on the list of barriers or important components of an exercise program, although may be more of a concern in other cities, or in rural areas.

From our findings, we conclude that work schedule and time demands are the most important aspects to consider when planning a physical activity program for women shift workers, particularly those who work as nurses, or in other health care positions. Our findings emphasize the need for creativity and flexibility in program design to promote uptake and adherence of physical activity in this high-risk group. Innovative methods to track or monitor adherence, and to offer behaviour change support outside of the traditional model of supervised exercise interventions must also be considered. Physical activity stands to be a relatively simple and cost-effective intervention that may improve the health and wellbeing of shift workers, while reducing their long-term risk of chronic disease. Next steps should include determining which strategies actually result in the greatest adherence to physical activity programs, and the greatest improvements in the health of these workers.

4.6. Conclusion

Based on these findings, an intervention aiming to increase physical activity levels of women shift workers was developed. In accordance with the findings from the quantitative questionnaires, the intervention proposed using a distance-based approach in order to maximize flexibility and minimize time demands in this group. However, in order to provide a deeper understanding of the barriers and preferences to physical activity, and to ensure the proposed intervention was acceptable to this population, focus groups were conducted with a number of women shift workers.

5. Chapter 5: A Qualitative Assessment of Barriers to Physical Activity and Strategies to Overcome These Barriers in Women Shift Workers

5.1. Synopsis

An in-depth understanding of the barriers to engaging in regular physical activity that shift workers face, and effective strategies that could be used to overcome these barriers is critical for researchers developing interventions in this population. The purpose of this study is to expand upon the findings from quantitative questionnaires to qualitatively describe both the barriers to and preferences for physical activity, and to also elicit feedback on a proposed intervention targeted at this occupational group. Eleven participants took part in focus groups with a trained facilitator. Focus groups were transcribed verbatim and thematic analyses were conducted. The most common barriers to physical activity that shift workers face are time, and fatigue following a nightshift. Shift workers prefer activities on days off, and find incorporating physical activity into other activities (social activity, transportation, running errands) to be helpful. Shift workers prefer flexible, drop-in, affordable programming to enhance adherence. The proposed intervention was well received and several changes were made in response to participants' opinions. This qualitative study provides further insight into shift workers' physical activity habits and provides more confidence in the development of a proposed intervention for this population.

5.2. INTRODUCTION

Lack of physical activity, potentially in combination with lower levels of physical fitness, has been hypothesized as a mechanism contributing to the increased risk of breast cancer and other chronic diseases observed in shift workers[229]. In some studies, shift workers have been shown to be less likely than day workers to participate in moderate-to-vigorous physical activity (MVPA)[55] and shift workers have been consistently shown to display low overall levels of MVPA. To date, there is little intervention research that has been conducted in the area of shiftwork and physical activity. Based on our previous findings using quantitative questionnaires (Chapter 4), it appears that the work schedule, time and lack of motivation are the key barriers to physical activity, and that incorporating flexibility in scheduling and exercise on days off may be important factors to consider in the development of a physical activity program. These data were gathered in order to inform the development of a physical activity intervention in shift workers. Based on the preliminary findings, we developed a telephone and web-based physical activity intervention for women shift workers, designed to overcome the primary barriers identified in the survey (Figure 5.1).

Figure 5.1 Proposed physical activity intervention

- Twelve-week duration
- **Study goal**: 150 minutes per week of moderate-vigorous physical activity
- Weekly contact with a physical activity coach
    - Phone, Skype or FaceTime
    - Provide educational information about physical activity and help participants to schedule physical activity
- Fitbit® activity tracker
    - Wrist-worn device to measure activity and track progress towards physical activity goals
    - Connection to a smartphone app or computer
    - Use of exercise coaching software to connect physical activity data to coach
        - Participants can interact with the coach using online messaging tool

In order to improve the chances of implementing an acceptable and appropriate intervention, and to ensure there were not any key ideas that were not captured by the quantitative survey data, we conducted focus groups with women shift workers. The purpose of these focus groups was twofold. First, we attempted to more fully understand the main barriers to participating in physical activity that these workers face, as well as the most effective strategies shift workers use to overcome these barriers. Secondly, we aimed to gain feedback from the participants about specific components of the proposed physical activity intervention before implementing it in this population.

5.3. METHODS

5.3.1. PARTICIPANTS

Eligible participants were English-speaking women, eighteen years of age or older, who had worked in occupations requiring work at night at least five times per month for the last two years and were willing and available to participate in the focus group. There were no exclusion criteria for this study. Participants were recruited by email through a list created from a previous study involving female shift workers who had given consent to be contacted for future research studies, as well through postings at workplaces that employed a large number of shift workers. Ethical approval was obtained from the University of British Columbia's Behavioural Research Ethics Board, and all participants provided written, informed consent.

5.3.2. STUDY DESIGN

To gain further understanding from the quantitative survey research previously conducted (Chapter 4), a qualitative research design using focus group methodology was used[267]. A total of eleven women participated in three focus groups (ranging from two to five women per group), held in a conference room at the University of British Columbia. Each focus group lasted approximately one hour, and participants were provided with a small honorarium to thank them for their time. A trained facilitator, with previous experience leading focus groups and conducting qualitative research, led the groups using a structured interview guide (Figure 5.2). The questions in this guide were selected to identify women shift workers' barriers to physical activity and strategies used to overcome these barriers and to elicit feedback about an intervention proposed based on our previous quantitative study (Figure 5.1). All focus groups were audiotaped and transcribed verbatim. Descriptive baseline demographic information was collected using self-report questionnaires.

Figure 5.2 Interview guide

1. What is your job and what type of shift schedule do you typically work?
2. How does your work schedule affect your motivation and/or your ability to exercise regularly? Outside of your work schedule, what other things make it hard for you to exercise regularly? What would you consider to be the number one barrier to fitting regular exercise into your everyday routine?
3. Do you use any strategies to help overcome these barriers?
4. If you were to enrol in a formal program to become active or get more active, what kind of program would be most appealing to you?
5. Due to the popularity of smartphones and other devices, there are a lot of smartphone apps and websites that could possibly help people get healthier. Have you used any of these types of apps or programs? What aspects did you find most useful? What aspects did you dislike? If you haven't used these would you be interested? Why or why not?
6. (Participants are given a description of the proposed program – a twelve-week intervention with weekly contact with a physical activity coach by phone, plus the use of a Fitbit). What do you think about this program? What parts sound most appealing to you? What aspects of the program do you think would not be helpful? What would you change about this program to make it more useful to women shift workers?
7. We could also give participants the option to connect their physical activity information to their Facebook or Twitter accounts. This would let your friends and family know what your doing and support you, and could also allow you to connect with other women who are taking part in the program. Do you think this part of the program would be useful to women shift workers?

5.3.3. Data Analysis

Demographic information is presented as mean and standard deviation, or percentage where appropriate. Verbatim transcripts were read line by line, and data were categorized under one of the following four groupings, which paralleled the focus group guide: 1) barriers to physical activity; 2) useful strategies for implementing physical activity; 3) preferences for physical activity programming; and 4) opinions on the proposed physical activity intervention. Responses under each of these themes were further coded to identify important themes within each grouping that would serve to inform the development of the physical activity intervention. One investigator (SENS) was responsible for categorizing participants' responses and coding responses into important themes, as responses were very clear and concrete, requiring little interpretation.

5.4. RESULTS

All participants were health care workers (n = 11), and were predominantly nurses (n = 8). Our sample was a combination of full and part-time employees, but all part-time employees reported picking up extra shifts that usually amounted to full time work hours. Shift hours and schedules varied, but the most common schedule consisted of two days, two nights, four days off, with hours from 0700-1900h or 1900 to 0700h. All participants reported currently working rotating shift schedules, working an average of 9.1 night shifts per month, and had been engaged in night shift work for an average of 11.7 years (Table 5.1).

Table 5.1 Demographic and work schedule characteristics of focus group participants (n = 11)

	Mean ± SD	N (%)
Age (years)	44.1 ± 11.4	
Body Mass Index (kg/m^2)	26.1 ± 4.8	
Occupation		
Nurse		8 (72.7)
Paramedic		1 (9.1)
Other hospital employee		2 (18.2)
Employment Status		
Full Time		6 (54.5)
Part Time		2 (18.2)
Part Time, picked up extra shifts		3 (27.3)
Number of days per month with work between midnight and 5am	9.1 ± 4.3	
Number of years of shift work experience	11.7 ± 9.6	
Living with		
Partner		5 (45.5)
Sibling		1 (9.1)
Children		3 (27.3)
Alone		2 (18.2)
Parents		2 (18.2)

5.4.1. Barriers to Physical Activity

Shift work schedules, and more specifically fatigue after a work shift, were the biggest barriers to fitting in regular activity. When asked what the number one barrier was to participating in regular physical activity, all participants agreed on after-shift fatigue. Most participants reported working twelve-hour shifts, during which they were on their feet for most of the shift. Because of this, finding the energy to exercise either before or after a shift was difficult. Women also reported experiencing a “hangover day” following their last night shift. On this day, they reported feeling extremely tired and unwell and had no energy for exercise. Catching up on groceries, housework and other errands that were often neglected on working days frequently took precedence over exercise. Some participants reported feeling that they did not have a need for exercise on days they were working, because they were on their feet or moving around throughout the day.

> *“I think the irony is as health professionals we know ... we should be exercising. But I think also, the long hours, like a twelve-hour shift, my feet are killing me, so the last thing I want to do [is exercise]. I know there are people, one person I met who does exercise after shift, but I can’t. I need to put my feet up, so that’s kind of a motivator and not a motivator. And I feel, I can relate to when you’ve done a night shift, it does, it literally takes me two days to recover, like when you’re off shift, when you finish, no matter how many overnight shifts you’re doing, you need to sleep. And then the next day, I feel like I have jetlag.”*

Logistics and timing were also common barriers to participating in regular activity. Many women reported a desire to sign up for exercise classes or programs, but were unable to do so because of the week-to-week change in their schedules. Participants also reported frustration over the higher cost of drop-in fees for classes that do not require registration, and this frustration led to them not wanting to take part in that class at all.

"And you look at schedules of any sort of yoga classes or any sort of classes, and you're going well that's not going to work, well that's not going to work, well that's not going to work and you just get discouraged because it's like nothing fits into your schedule. It might this week but it's not going to next week, so drop in is difficult, signing up for a class is impossible, you know for any regular times."

Related to lack of time, another important barrier reported was family commitments, particularly related to caring for children or aging parents. Many women reported feelings of guilt for missed family time during days of twelve-hour shifts, which could in reality be more than fourteen hour days when including commuting time. Because of this, some women reported that they felt "selfish" when choosing to exercise on their time off.

5.4.2. Strategies to Overcome Barriers

The strategy most often employed by the participants to overcome barriers to participating in activity was combining exercise with another activity such as walking the dog, or exercising (such as going for a walk) while children were doing sports or other extra-curricular activities. Some form of active transport, whether it be cycling to work, or incorporating a few minutes of walking into a commute by car or public transit, was common amongst participants.

"I'm lucky that I live in Vancouver so I can walk to the grocery store, I can make choices about whether or not I can walk somewhere. So that helps me. I had a couple of appointments last week and I walked to them, so that's one thing that I can do to increase my physical activity throughout the week."

Participants were divided on the idea of scheduling activity on their way home from a work shift. While some reported exercise after work was convenient and helped them to sleep better, others reported that this would absolutely not be possible due to fatigue after work.

When asked about specific components of a program that would help to overcome barriers to activity, participants overwhelmingly voiced the need for a range of options in terms of days, times of day, and types of classes offered to accommodate a wide variety of shift workers. In line with earlier comments, they also desired a drop-in fee structure that was comparable to the costs of regular programming that is available to regular day workers.

> *"For me, it would have to be drop in, it would have to not be scheduled - like if it was formally through whatever, a workplace it would have to be seven days a week drop in, like any hours"*

5.4.3. Use of Technology to Support Physical Activity

Roughly half of the women had used some type of computer or smartphone software aimed at improving health. The most common were activity trackers (such as Strava or Run Keeper) that track time and distance during walk/run or cycling activities using a smartphone's GPS. One woman in the study was currently using a Jawbone wrist-worn activity tracker (similar to a Fitbit), and found that it motivated her to increase her step counts. Many women had tried online diet trackers, with limited success, and two women had been part of online weight loss programs including educational materials, and social support via webinars or a private Facebook group.

The act of tracking and recording behaviour over time was the aspect that was most useful amongst all of the tools that were used. Participants reported that it was motivational to see their progress, or sometimes lack thereof. However the time and effort involved for some of these tools was prohibitive, especially for the diet tracking software where every individual item consumed per day had to be entered in manually.

> *"Yeah, I used the Nike one… it's just a little GPS and it tells me how far I've walked and it's "Oh I did three kilometers in that night" and that wasn't so bad … It just helps me to know how far I'm walking and if I can do three I can do five or six no problem. You know, oh that was three kilometers, that's not bad. And it is a bit of a motivator. I've used some of the calorie ones where it tracks your [diet], but I find that too labour intensive."*

Of those who had not used this type of technology before, interest in using it in the future was split. Some women said they would be interested only if the software was user friendly, and did not require a lot of effort. Others were not interested in anything that they had to use a smartphone for, and only wanted to use their phone for telephone calls and/or text messaging. Some would consider a computer-based program.

5.4.4. Feedback on Proposed Intervention

Participants identified the feeling of accountability to the physical activity coach to be an appealing component of the proposed program. The use of the Fitbit® as a passive tracking tool that didn't require data entry, or the need to keep their smartphone with them at all times was also appealing. When participants were informed that the Fitbit® also tracks sleep, almost all were interested in using that function, as sleep was an important concern for all of them.

Some participants were concerned that using the Fitbit® could become labor intensive, especially if they chose to use it to enter other activities not captured well by the step tracker (e.g., cycling, water activities), and worried about how seamlessly it would sync to the coaching software. There was also concern that checking the app or computer every day to communicate with the physical activity coach could become burdensome. The primary concern around the program was the sustainability. While many participants stated that they were often excited and motivated by new tools and apps, this commonly wore off after a few weeks or months of use.

> *"I think though, again it comes back to motivation, how what your goals of your life are. Like it's exciting, cause it's a new gadget and you're excited about it like with any new exercise program you have that - it's the beginning, and it's excitement, but no matter how, we can't get away from it really - that this requires effort. Caring for yourself requires effort and you know, a gadget isn't going to actually make you do anything."*

Specific suggestions for improvement included an initial face-to-face meeting with the physical activity coach to make the program feel more personalized, and to increase accountability. The participants also expressed that the coach should be someone who was familiar with the challenges of shift work and could be empathetic to their schedule. Several participants told stories of not feeling heard by their family physicians, or other health care professionals, when asking for advice on how to cope with shift work.

> *"But it's funny, those, the Monday to Friday people, unless they've experienced shift work in the past and have made that change, they don't have a clue of what you're experiencing or what you're feeling and they don't understand it. And I don't, I'm not sure how many people have the empathy for it either."*

Finally, several participants suggested that going through the program with friends or co-workers would also be of interest. However, when asked about any interest in connecting their data with social media, none of the participants were interested in this. Several participants did express an interest in some type of online group, but only if it was study specific and separate from their private Facebook or Twitter accounts.

5.5. Discussion

These focus groups confirmed many of the findings from the quantitative questionnaires, and also highlighted several novel points that were not captured by the previously administered questionnaires. Focus group discussion confirmed that work schedule interference and time were the major barriers to fitting in regular physical activity in women shift workers, as well as the need for flexibility in scheduling of any proposed program in this occupational group. These focus groups confirmed that structured, supervised physical activity sessions were unlikely to be successful in this group unless they were offered at all times throughout the day and night, which was not feasible for the research team due to budget, staffing and space availability constraints. Similar to findings from the questionnaire, in which 93.5% of participants reported a preference for exercise on days off, these groups reinforced that a focus on encouraging exercise on days off would be most acceptable and seem most realistic to the majority of women.

A major new finding that was not captured in the questionnaire was the importance of prioritizing time with family or friends on days off, and that these activities often prevented women from taking part in physical activity. No questions were asked about family or social time on the barriers to exercise questionnaire, and this aspect should be included in future studies involving shift workers. On our original questionnaire asking about important components of an exercise program, we did ask about exercising with others, but did not specify exercise as a social activity with family or friends in particular. Interestingly, 63% of participants who took part in the questionnaire study reported a desire for exercise in a group or with others. Based on findings from the focus group, it may be that women shift workers were reporting a desire to exercise with family or friends during their days off, whether or not this is a realistic plan.

Many participants also reported that coupling exercise with other activities they needed to do (such as walking or cycling to complete errands) or exercising with family and friends helped them to manage competing time demands. Incorporating others into exercise may also serve to enhance accountability to exercise, although this may be difficult to manage logistically due to shift workers' irregular work schedules. The use of social media to connect individuals, or provide social support and accountability, may be a way to help overcome this.

Overall participants voiced support for the proposed intervention, and were interested in learning more about it. They particularly liked the ability to track their activity without a great deal of effort, and thought that the addition of the physical activity coach would help to increase motivation and accountability without being overly burdensome to their already busy schedules. This is in line with our previous questionnaire findings, where 67.4 % of participants stated a desire for face-to-face exercise counseling or advice. However, participants did raise concerns about the ease of use of the Fitbit. This especially surrounded using the Fitbit® in combination with the coaching software because of participants' previous negative experiences using more labour intensive health behaviour trackers, or their lack of interest and experience using this type of technology.

Based on the results from this focus group, several changes were made to the proposed intervention. An initial face-to-face meeting was added to the protocol, during which the physical activity coach would be able to obtain consent from participants, as well as show them how to set up and use the Fitbit® to help them overcome technological difficulties in setting up the device. The use of the coaching software was removed from the protocol, due to the extra step required by participants in syncing the data and the potential for it to become too burdensome to participants. Instead, Fitbit® Premium accounts would be set up for all participants so that participants could download their activity data and share with the coach if they desired.

There are several limitations to this study. First, despite overwhelming consensus on many of the questions amongst participants in each of the study groups, the sample size was small, and it is possible that more and different themes would emerge across larger groups. As well, all of the included participants were health care workers, whose barriers to physical activity and needs from a physical activity intervention may be quite different from women in other occupational groups. Demographically, these participants were quite similar to those who completed the quantitative questionnaire, which may explain the similarities in our findings across both studies. There is still much to be learned about barriers to physical activity and potential strategies that could be used to overcome these barriers in female shift workers who work outside of the health care field.

In summary, based on the knowledge of the various health consequences workers face as a result of shift work, in combination with lessons learned from previous health promotion strategies conducted in shift workers, and information gathered from both quantitative and qualitative studies on the barriers to and preferences for activity in women shift workers, we developed a physical activity intervention targeted to this group.

6. Chapter 6: Feasibility of a Telephone and Web-Based Physical Activity Intervention for Women Shift Workers

6.1. Synopsis

Shiftwork is associated with an increased risk of breast and other cancers. Physical activity is known to reduce breast cancer risk; however, shift workers have challenges in being active due to their irregular work schedules. The purpose of this study was to evaluate the feasibility of a distance-based physical activity intervention in women shift workers. Sedentary women, < 55 years of age who worked at least five night shifts per month for a minimum of three years were eligible to participate in this twelve-week intervention. The intervention consisted of eight phone-based behavioural counselling sessions and use of a Fitbit, with a goal of 150 minutes per week of moderate-vigorous physical activity. Recruitment, retention, capacity, adherence and participant satisfaction were tracked to determine feasibility. Feasibility was defined *a priori* as meeting the recruitment goal in < 4 weeks, < 10% loss to follow-up, > 75% adherence and > 75% participant satisfaction. Intervention capacity (time spent during each session and technological problems related to the Fitbit) was recorded to assess staffing and resource needs for a future large-scale randomized controlled trial. Preliminary efficacy outcomes, including change in physical activity, sedentary time, sleep and quality of life, were also measured. Recruitment (n = 20) was completed in 10 days, with 61 participants on a waitlist for future studies. After twelve weeks, retention was 100% and adherence was 89.8%. Behavioural counselling sessions lasted an average of 12.9 minutes (range 3.1 – 32.1.1) and participants reported several problems using the Fitbit. Overall, 84.2% of participants were very or somewhat satisfied with the intervention. No change was observed in weekly moderate-vigorous physical

activity when calculated in bouts of ten minutes or more, but a significant increase in total physical activity (both objectively measured and self-reported) and decrease in sedentary time was observed. Significant improvements were also observed for energy/vitality and mental health domains of health-related quality of life, and in sleep disturbance and daytime dysfunction domains of sleep quality. Based on our pre-defined criteria, the intervention appears to be feasible to conduct in this population. The next step will involve testing the efficacy of the intervention in a larger scale randomized-controlled trial.

6.2. INTRODUCTION

Shift workers are at increased risk for a number of negative health outcomes, including a higher risk of cancer and other chronic diseases[7,168]. While the precise mechanisms linking shift work and disease are not yet completely understood, there are two main pathways that are hypothesized to cause in increased chronic disease risk: first, biological changes that are the result of poor lifestyle habits related to occupational shift work (e.g., low physical activity, poor nutrition); and second circadian rhythm dysfunction related to exposure to light at night and poor sleep hygiene[229]. With 4.1 million individuals (28% of the workforce) working outside of regular day shift hours in Canada, this represents the highest exposure rate of any occupational carcinogen[228]. In Canada, both employers and employees recognize the need for interventions to improve health in this population. In a recent survey of workers, union representatives, employers, researchers and policy-makers, conducted by the Occupational Cancer Research Centre (OCRC), 71% of respondents felt that they were ‘moderately’ or ‘very aware’ of the negative health effects of shift work[9]. When asked about the biggest concerns related to shift work, the most commonly reported was quality of life (81.6%), with 36% of respondents reporting cancer-risk as a concern related to shift work[9].

There is very limited research on effective health promotion strategies for this group of workers, who face unique challenges to engaging in health behaviour change. To date, only four behavioural interventions aiming to improve health outcomes in shift workers have been published (see Chapter 2)[165,166,212,213,215]. In the only published physical activity intervention conducted in shift workers to date, 119 nurses were randomized to a four-month supervised physical activity intervention of two to six sessions per week, or no-intervention control group. In those who completed follow-up (n=75), the intervention group experienced improvements in aerobic fitness (VO_2max) and muscle strength, as well as decreased fatigue and musculoskeletal symptoms from baseline compared to the control group. However, the authors reported low adherence (17% missed >25% of scheduled sessions) and a large loss (37%) to follow-up, perhaps due to the requirement for supervised scheduled exercise sessions[165,166].

Physical activity is known to have a protective effect on breast cancer risk[268], along with a variety of other positive physical and psychological health outcomes, and may be a simple and cost-effective intervention that could be implemented in workplaces and by individual workers to mitigate this increased risk. While increased duration of physical activity is associated with greater breast cancer risk reduction in dose response studies, a risk reduction begins to be observed with 120-180 minutes per week of moderate-vigorous physical activity (MVPA)[130]. This is consistent with Canada's Physical Activity Guidelines for Adults[128] and the American Cancer Society's Guidelines for Cancer Prevention[131] of 150 minutes per week of MVPA. Evidence suggests that shift workers may be less likely to engage in healthy lifestyle behaviours such as regular physical activity, that may contribute to an increased risk of many adverse health outcomes[55].

Promotion of physical activity behaviour change is well understood to be a challenge and requires targeted efforts in order to have individuals reach physical activity levels linked to cancer risk reduction and other health outcomes[167]. Due to irregular shift schedules and daytime time constraints, shift workers may be less likely to adhere to a traditional supervised physical activity intervention with face-to-face behavioural support (see Chapters 4 and 5). Women shift workers most commonly categorized work schedule interference and lack of time as ‘often’ or ‘very often’ being significant barriers to participating in physical activity, and that physical activity schedule flexibility was identified as the most important component of a physical activity program. This points to the need for creative and innovative programming to promote physical activity in shift workers, as traditional supervised physical activity programming with face-to-face behavioural support is unlikely to be successful in this population.

Remotely administered interventions, in which participants exercise on their own, independent of the study staff or other study participants (also known as distance-based interventions) may include telephone counseling and website or smart phone application-based technology. These types of interventions may be the key to overcoming barriers related to timing and scheduling that are unique to this population. These distance-based interventions are advantageous in that they provide convenient 24-hour access to intervention materials and support to participants[269], and may be a cost-effective way to tailor interventions to individuals while being able to target a larger number of participants. In a recent meta-analysis of online health-promotion interventions, a positive correlation was found between the number of influence components and the effect size seen in interventions, with aspects such as goal setting, record/tracking behaviour, use of feedback and social norms being the most commonly reported influential components[270]. In another review of interventions that used mobile technology (primarily text messaging) to increase physical activity or decrease sedentary time, tailoring the intervention to individuals was most important for effective behaviour change[269]. Specific successful elements of tailoring included journaling/tracking activity, displaying progress towards a goal, and providing personalized feedback[270].

Before attempting to test the efficacy of this type of intervention in this under-studied population, the feasibility of the intervention must first be established. Feasibility studies are important for establishing the processes that are most effective and the resources needed in order to put forward interventions that are most likely to be efficacious[271]. The primary objective of this study was to test the feasibility of a distance-based telephone and web-based physical activity intervention in female shift workers, including the demand for, and acceptability and implementation of this type of intervention. A secondary objective was to conduct a preliminary exploration of the efficacy of the intervention, in order to estimate an effect size for future studies.

6.3. METHODS

6.3.1. PARTICIPANTS

Participants were recruited through contacts established through previous studies conducted in women shift workers, specifically nurses' unions, emergency services unions, and contacts at casinos and the Vancouver International Airport. This involved postings at the workplace, on company intranet and social media pages. Hospital employees were recruited through recruitment emails sent through Vancouver Coastal Health and Providence Health authorities, which employ a large number of shift workers. Recruitment also occurred via word of mouth, through women who had participated in or been screened for a previous study of women shift workers, and who agreed to be approached about future studies.

Women shift workers who work or live in the greater Vancouver area, have daily telephone and Internet access, and could read, understand and speak English were eligible to participate. For the purposes of this study, shift work was defined as a job that requires at least five shifts per month with work between 2200h and 0500h, for the last three years. Women were excluded if they were currently participating in greater than 90 minutes per week of MVPA, were pregnant or planning to become pregnant in the next twelve weeks, had a self-reported body mass index (BMI) $\geq$40.0.0 kg/m^2, were greater than 55 years of age (in accordance with the American College of Sports Medicine's guidelines for additional pre-exercise screening needed for women over 55 years of age), or answered 'Yes' to any questions on the Physical Activity Readiness Questionnaire (PAR-Q)[272]. The University of British Columbia's Clinical Research Ethics Board provided ethical approval, and all participants provided written informed consent.

6.3.2. Study Design

As the primary aim of this study was to assess feasibility, a single-group pre-post design was used. All outcomes related to the feasibility of the intervention were collected before, during and following the twelve-week intervention.

6.3.3. Study Procedures

At baseline, all participants had one face-to-face meeting with the physical activity coach at a mutually convenient location to provide informed consent, and receive all data collection-related materials (i.e., Actigraph accelerometer, instructions for completing questionnaires).

During this initial session, the goals of the study and protocols for data collection were explained, participants were familiarized with the Fitbit® website and smart phone application, and the first behavioural counseling session was scheduled. The Fitbit® itself was delivered to participants following completion of baseline data collection so as not to interfere with baseline data.

The behaviour change intervention to promote an increase in minutes per week of MVPA was guided by the Health Action Process Approach (HAPA) model[273]. This model aims to promote behaviour change through increasing self-efficacy for intention, planning and maintenance of physical activity. The overall goal was for participants to meet Canada's Physical Activity Guidelines for Adults of 150 minute per week of MVPA. Participants took part in eight individualized telephone-based (landline, mobile or video-conferencing using Face Time/Skype) behavioural counseling sessions over the twelve-week intervention. Sessions were scheduled at times that were convenient for participants, and offered between 0600 and 2200h. Physical activity counseling aimed to increase self-efficacy for exercise based on the HAPA model. The first six weeks covered topics including self-monitoring, goal-setting, overcoming barriers, preventing lapses, preparing for independent physical activity, and evaluation and planning. Booster sessions were incorporated at weeks nine and twelve, and focused on evaluating participants' achievement of physical activity goals over the past three weeks and building self-efficacy and planning for the weeks ahead. An overview of the behavioural counselling sessions is provided in Figure 6.1.

Figure 6.1 Overview of behavioural counselling sessions

Week	Title	Topics
1	**Introduction**	- Introduction to study - Understanding the benefits of increasing physical activity and decreasing sedentary time, generally and specifically for shift workers - Using the Fitbit
2	**Goal-Setting**	- General goal setting - S.M.A.R.T. Goals - F.I.T.T Principle
3	**Overcoming barriers**	- Identifying barriers - Identifying strategies to overcome barriers - Barriers and coping plan
4	**Preventing lapses**	- Laws of behaviour change - Behaviour change - Review previous goal and set new goal
5	**Independent physical activity preparation**	- Social and environmental support - Rewards
6	**Evaluation and Planning**	- Monitoring behaviour – mix it up to stay motivated - Maintaining motivation - Reassessment of goals - Plan for physical activity over next 3 weeks
7-8	*No session*	
9	**Booster session**	- Review how physical activity has gone over the last 3 weeks - Attitudes about change - Personal control, self-efficacy, self-esteem - Discuss barriers, plans to overcome
10-11	*No session*	
12	**Booster session**	- Review everything learned - Plan for future continued physical activity - Re-evaluate final goals - Logistics for end of study testing

As a complement to the behavioural counseling sessions, participants were given a Fitbit Flex® (Fitbit, San Francisco, CA) to use throughout the study. This was to aid in physical activity tracking and monitoring goal achievement. The Fitbit Flex® is a wrist-worn activity monitor that monitors step counts, distance covered, and active minutes. The Fitbit® synchronizes wirelessly to computers and smartphones, and participants were able to download their weekly physical activity data to share with the behavioural counseling coach during the intervention.

6.3.4. Outcomes

The primary outcome of the study was feasibility, specifically demand, implementation and acceptability. We selected relevant outcomes related to feasibility in accordance with recommendation for feasibility study methodology published by Thabane[274], Arain[275] and the UK's National Health Service[276]. These outcomes will be assessed using the following methods before, during and following the intervention.

6.3.4.1. Demand

Recruitment rate: All recruitment efforts were tracked, and the number of participants who made contact and were screened was recorded.

Eligibility: All reasons for ineligibility or participant refusal to participate were recorded.

6.3.4.2. Implementation

Capacity: The amount of time spent with each participant during behavioural counseling sessions, dates and times of each session and the number of sessions rescheduled was recorded throughout the intervention in order to help understand the study personnel and availability that would be needed to administer the intervention on a larger scale.

Technological Issues: Any questions about the use of the Fitbit, or problems that arose related to the Fitbit, website or smart phone application throughout the intervention were recorded, as well as solutions used to solve the problem.

6.3.4.3. ACCEPTABILITY

Retention: Participants who were enrolled in the study but failed to complete end of study measurements were defined as dropouts. We planned to attempt to contact all dropouts to determine reasons for non-participation and to collect suggestions for changes that should be made to the intervention. Feasibility was defined *a priori* be defined as drop outs of <10%.

Adherence: Participants' adherence to scheduled behavioural counseling sessions was also collected and calculated. Feasibility was defined *a priori* as adherence of >75% to behavioural counseling sessions. Participants were also asked to share their Fitbit® data with the study team on a weekly basis, using the 'Download' option on the Fitbit® website (http://www.fitbit.com). Non-wear days were defined as those during which fewer than 500 steps were registered. Feasibility was defined *a priori* as <15% non-wear days (or one day per week).

Participant Satisfaction: A mixed-methods approach was used to collect participant satisfaction data at the end of the study. All participants were given an open-ended questionnaire, delivered online along with the end of study questionnaire package to assess participant satisfaction, and were asked to rank various aspects of the intervention such as behavioural counseling sessions, mode of delivery, software, etc. as not at all satisfied, not very satisfied, somewhat satisfied or very satisfied. Feasibility of each aspect of the intervention was defined *a priori* as >75% of participants indicating they were "very" or "somewhat satisfied".

6.3.4.4. SECONDARY OUTCOMES

Secondary outcomes for preliminary evaluation of the efficacy of the intervention were collected at baseline and after the twelve-week intervention. We also collected data on demographics, medical history and lifestyle behaviours to describe our study sample, and investigate potential confounding factors that may have influenced the change in outcomes observed. All questionnaires were completed using an on-line system, Fluid Surveys (Ottawa, ON).

Physical Activity and Sedentary Time: Physical activity and sedentary time were measured objectively using an Actigraph GT3X+ accelerometer (Actigraph, Pensacola FL)[277]. Participants were asked to wear the accelerometer on their waist for 24-hours a day for seven days. Participants were instructed to only take the accelerometer off to bathe or shower. Participants were also asked to record their work hours on each day, in order to differentiate between occupational and other physical activity. Participants also completed the Recent Physical Activity Questionnaire (RPAQ)[278], a subjective measure of physical activity and sedentary time. While objective measures eliminate recall bias, subjective measures capture activities that may not be picked up by accelerometers (such as cycling or upper body activity) and also allow the calculation of occupational, recreational, domestic and transportation physical activity. In participants who were willing to share their Fitbit® data, the number of weeks during which participants met the study goal of 150 minutes per week of MVPA was calculated. In addition, total activity data were averaged over the entire twelve-week study period, as shift workers weeks do not always fall in line with our Monday to Sunday calendar. MVPA was calculated by summing the ‘Active’ and ‘Very Active’ minutes from the downloaded Fitbit® data. The algorithms used to classify these minutes are proprietary to Fitbit, and have not been validated in the scientific literature.

Health-Related Quality of Life: Health-related quality of life was measured using the RAND 36-item health survey[279], a widely used and validated tool for measuring health-related quality of life, and to allow the examination of both physical and mental health components.

Sleep Quality: Self-reported sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI). The PSQI has been shown to be a reliable and valid questionnaire[280] and has been used in a variety of populations, including shift workers. Validated screening questionnaires for Restless Leg Syndrome[281] and Sleep Apnea[282] were also administered.

6.3.5. Data Analysis

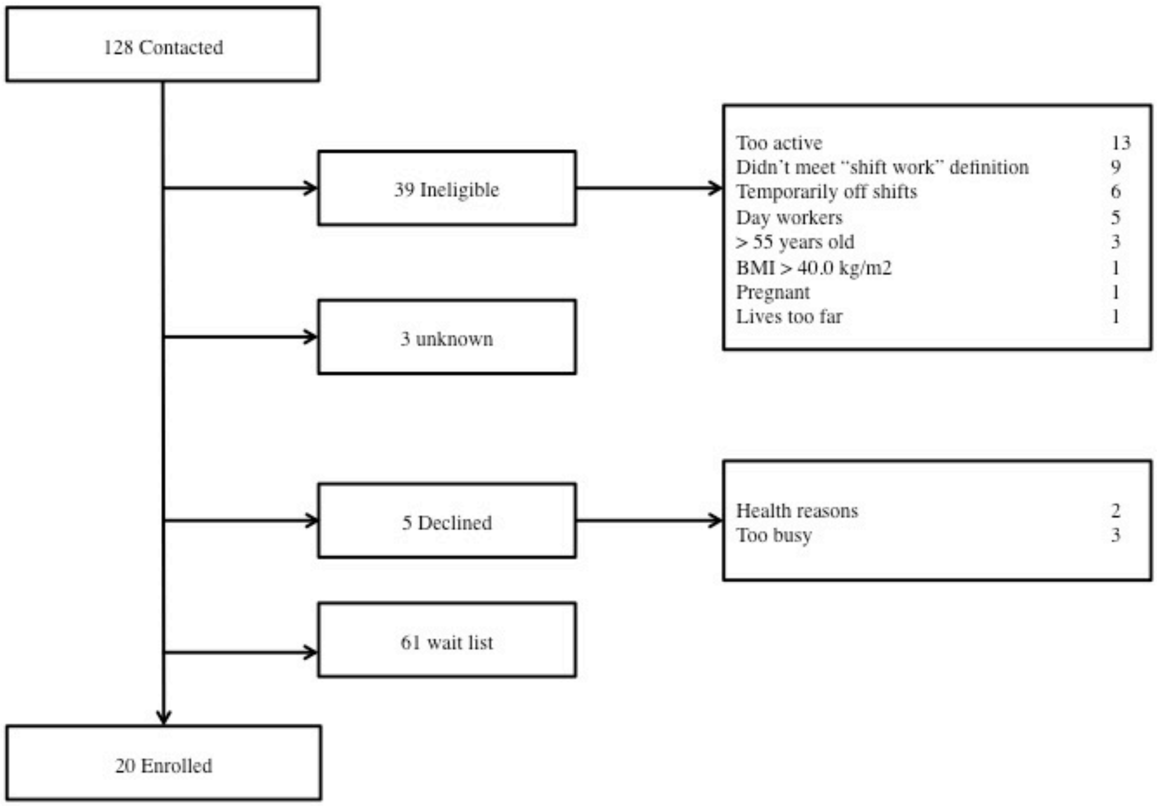
Feasibility was defined *a priori* as meeting our target sample size (n = 20) in the proposed time frame (< 4 weeks), the loss of <10% of participants to follow up, achieving >75% adherence to the behavioural counseling sessions and >85% of physical activity monitoring, and >75% of participants reporting they were “very” or “somewhat satisfied” with the intervention. Failure to achieve these feasibility goals would indicate that modifications were needed to the study design, protocol or intervention prior to moving forward with a full-randomized controlled trial. Secondary outcomes were examined using descriptive statistics (mean, median, standard deviation and percentage where appropriate) and the difference in measures between baseline and end of study was tested using a paired sample t-test.

6.4. RESULTS

6.4.1. FEASIBILITY

The recruitment goal of 20 participants was met within ten days, exceeding the *a priori* goal of four weeks. In total, 128 participants contacted the study coordinator in response to recruitment emails sent to local health authorities' employee email lists, postings on union websites, and postings at work places. Participant flow through the study is listed in Figure 6.2. Of 64 participants screened, 39 participants were deemed ineligible, and five declined to participate. The most common reason for ineligibility was that participants were already participating in more than 90 minutes per week of MVPA (n = 13) or they did not currently meet our predetermined definition of shift work (n = 20). Reasons for refusal to participate were health reasons (n = 2) and that participants were too busy (n = 3). Once the recruitment goal was reached, no further participants were screened, leaving 61 individuals on a wait list to be contacted regarding future intervention studies.

Figure 6.2 Participant recruitment and flow through the study



A total of 20 women were enrolled in the study, with a mean age of 42.2 years. Overall, participants were overweight and well educated and the majority of participants were married or in a common-law relationship. Most participants (85%) were nurses or care aides, and worked full time in a rotating shift schedule. Participants had worked night shifts for an average of 14.7 years, and worked an average of 7.6 night shifts per month. Other demographic information is listed in Table 6.1.

Table 6.1 Demographic characteristics of study participant (n = 20)

	Mean ± SD	N (%)
Age (years)	42.2 ± 8.6	
Height (cm)	167.9 ± 6.8	
Weight (kg)	78.7 ± 15.5	
BMI (kg/m^2)	27.7 ± 4.2	
Education		
High school, some college or training school		2 (10)
College graduate		15 (75)
Bachelor's degree		2 (10)
Prefer not to answer		1 (5)
Marital Status		
Single, never married		4 (20)
Divorced or separated		3 (15)
Currently married or common-law		13 (65)
Lives with		
Partner		13 (65)
Children		8 (40)
Alone		7 (35)
Work Schedule		
Full-time		17 (85)
Part-time		3 (15)
Shift Rotation		
Rotating		19 (95)
Permanent		1 (5)

	Mean ± SD	N (%)
Occupation		
Nurses or care aides		17 (85)
Service industry		1 (1)
Airline industry		1 (1)
Communications		1 (1)
Shift work history (years)	14.7 ± 8.3	
Number of night shifts per month	7.6 ± 4.4	
Restless Leg Syndrome		
Yes		4 (20)
No		16 (80)
Sleep Apnea		
Yes		15 (75)
No		5 (25)
Chronotype		
Morning		2 (10)
Evening		4 (20)
Middle		14 (70)

Participants were given the option of receiving behavioural counselling sessions by phone, or video conferencing (Skype or FaceTime), but all participants chose telephone delivery for all sessions. Sessions lasted an average of 12.9 minutes, and ranged from 3.1 to 32.1 minutes. A full summary of session duration, and the number and percentage of sessions rescheduled by week is shown in

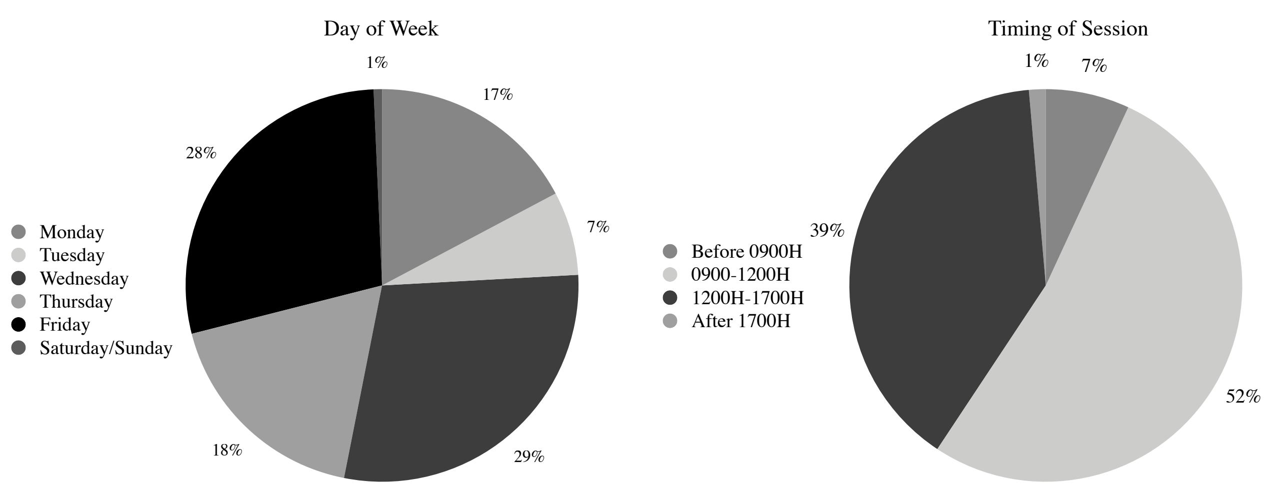
Table 6.2. The number of rescheduled sessions was highest for session seven, the first booster session. Sessions were most often scheduled throughout the week, with only one session

scheduled on a weekend (Figure 6.3). The most common time for sessions to be scheduled was between 0900 and 1200h.

Table 6.2 Duration of behavioural counselling sessions

Session	Duration of Session (min)			Rescheduled Sessions
	Mean	**SD**	**Range**	**N (%)**
1	14.2	5.8	5.7 – 26.2	5 (25)
2	16.7	6.8	6.9 – 32.1	4 (20)
3	13.6	6.1	6.5 – 26.1	7 (35)
4	12.6	5.3	6.8 – 22.0	7 (35)
5	13.5	6.9	5.8 – 27.7	5 (25)
6	13.0	5.6	5.2 – 27.6	6 (30)
7	12.1	4.3	6.4 – 21.2	11 (55)
8	7.6	3.4	3.1 – 13.8	7 (35)

Figure 6.3 Behavioural counselling sessions time and day



Participants did experience technological issues throughout the study. Five of 20 Fitbits (25%) needed to be returned (two stopped holding a charge, and three would not sync to participants' phone or computer) and two participants lost their Fitbit® during the study. Four other participants had issues resolved through phone calls with the manufacturer's technical support. Participants also reported frustration in that the Fitbit® was primarily a step-based activity tracker and did not track certain activities (such as cycling or fitness classes) well.

Retention from baseline to end of study was 100%. All participants completed both baseline and end of study questionnaires, and 19 of 20 (95%) of participants completed the participant satisfaction questionnaire. Two participants did not wear the accelerometer at the end of study (stating they were too busy). Adherence to the behavioural counselling interventions was 90.6% with participants completing an average of 7.3 ± 0.9 out of eight possible sessions.

Use of the Fitbit® was high amongst participants, with all participants reporting using the Fitbit. Eighteen of 20 (90%) participants shared their Fitbit® data with study staff during and after the study. One participant declined to share her activity data, and one participant only used the Fitbit® as a daily monitoring tool, and chose not to sync her data to a computer or smartphone. Of the eighteen participants who provided data, participants wore the Fitbit® 94.5% of the 84 days during the twelve-week study period.

In general, participants were satisfied with the intervention, with 84.2% reporting that they were very or somewhat satisfied with the intervention overall, 84.2% of participants reporting they were very or somewhat satisfied with the behavioural counselling sessions and 78.9% reporting they were very or somewhat satisfied with the Fitbit® (Table 6.3). In the open ended questionnaire, the components of the intervention commonly listed as most helpful were the accountability and motivation from being part of the intervention (n = 7), the awareness of physical activity levels from the Fitbit® counts (n = 4), and regular goal setting or activity planning (n = 4). Recommendations for future included connecting participants in some way for enhanced social support and accountability (n =3), improvements to the Fitbit® and computer or smartphone interface (n =2) and increasing the duration of the study (n = 2).

Table 6.3 Participant satisfaction (n = 19)

	N (%)
Overall satisfaction	
Very/Somewhat satisfied	16 (84.2)
Very/Somewhat unsatisfied	3 (15.8)
Felt that study helped to increase physical activity	
Yes, quite a lot/ Yes, a little	17 (89.5)
No, not very much/ No, not at all	2 (10.5)
Satisfaction with behavioural counselling session	
Very/Somewhat satisfied	16 (84.2)
Very/Somewhat unsatisfied	3 (15.8)
Satisfaction with Fitbit	
Very/Somewhat satisfied	15 (78.9)
Very/Somewhat unsatisfied	4 (21.1)
Plan to purchase a Fitbit® or similar device	
Yes	11 (57.9)
No	8 (42.1)
Would recommend intervention to a friend	
Definitely/probably yes	18 (94.7)
Definitely/probably not	1 (5.3)
Continued to exercise 150 min/week since study ended	
Yes	17 (89.5)
No	2 (10.5)
Continued to use skills or strategies learned during the study	
Yes	16 (84.2)
No	3 (15.8)

	N (%)
Made other lifestyle changes throughout intervention	
Yes	13 (68.4)
No	6 (31.6)

6.4.2. EFFICACY

Changes in MVPA and sedentary time were collected objectively (using the Actigraph GT3X+) and subjectively (using the RPAQ), with results presented in Table 6.4. There was no change from baseline to end of study in objectively measured MVPA when only activities that occurred in bouts of ten minutes or more were calculated (in accordance with Canada's Physical Activity Guidelines). Total minutes of MVPA (bouts of any duration) did increase by an average of 110.3 minutes per week ($p < 0.01$). This was accompanied by a decrease in sedentary time of 1.0 hours per day ($p = 0.02$). Self-reported physical activity increased by 312.6 minutes per week ($p < 0.001$), which was driven by an increase in leisure time activity (+18.1 MET hours per week, $p < 0.001$), with no changes reported in household, occupational or transportation physical activity.

Table 6.4 Change in objective and self-reported physical activity and sedentary time from baseline to end of study (n = 20)

	Baseline	End of Study	Change	*p*
	Mean ± SD			
Objective MVPA (min/week, bouts ≥10 min) [a]				
Overall	95.8 ± 112.7	101.8 ± 103.7	- 2.9	0.91
Work days	38.3 ± 62.6	36.1 ± 52.7	- 2.4	0.81
Off days	60.4 ± 83.4	65.7 ± 60.5	+2.1	0.92
Objective MVPA (min/week, total) [a]	440.8 ± 191.7	551.5 ±165.1	+110.3	**<0.01**
Proportion meeting physical activity guidelines[a] N (%)	4 (20.0)	5 (27.8)	0	0.99
Steps per day [a]	7606.6 ± 2912.9	9145.9 ± 2436.7	+1488.7	**<0.01**
Objective sedentary time (hours/day, bouts ≥10 min)[a]	3.6 ± 1.6	2.7 ± 0.8	-1.0	**0.02**
Self-reported MVPA (min/week)	116.4 ± 141.5	429.0 ± 270.7	+312.6	**<0.001**
Self-reported MVPA by domain (MET-hours/week)				
Home	9.2 ± 6.2	8.9 ± 5.2	- 0.3	0.73
Work	45.7 ± 16.4	46.9 ± 16.4	+ 1.2	0.50
Leisure	2.7 ± 2.5	20.8 ± 16.1	+ 18.1	**<0.001**
Commute	3.2 ± 6.4	4.2 ± 6.0	+1.0	0.59
Self-reported sedentary time (hours/day)	6.4 ± 2.7	5.4 ± 2.7	- 1.0	**<0.01**

[a] Two participants did not wear the accelerometer at the end of study, therefore n = 18 for end of study and change

Throughout the intervention, participants met their study goal of 150 minutes per week an average of 9.8 ± 2.8 out of twelve weeks (81.5%) according to the number of active and very active minutes from the Fitbit® data. When activity data were averaged over the entire twelve-week study (rather than calculated by each seven-day week), 100% of participants met the study goal, averaging more than 150 minutes per week of MVPA.

Other preliminary efficacy outcomes are presented in Table 6.5. Over the course of the intervention, participants lost an average of 0.9 kg of body weight ($p = 0.03$). Significant improvements in quality of life, measured by the RAND 36-item healthy survey were seen in the energy/fatigue (+14.6, $p = 0.01$) and emotional well-being (+9.8, $p = 0.04$) domains, but no significant changes were noted in the remaining six domains. No significant change was noted in total sleep (-1.2, $p = 0.16$) measured by the PSQI; however, participants did report significant improvements in sleep disturbances (-0.2, $p = 0.04$) and day dysfunction due to sleepiness (-0.4, $p = 0.04$).

Table 6.5 Change in self-reported efficacy outcomes from baseline to end of study

	Baseline	**End of Study**	**Change**	***p***
	Mean ± SD			
Body weight (kg)	78.7 ± 15.5	77.9 ± 15.9	- 0.9	**0.03**
Body mass index (kg/m^2)	27.7 ± 4.2	27.4 ± 4.4	- 0.3	**0.04**
Quality of Life (RAND 36-item health survey)				
Physical functioning	88.8 ± 11.1	90.8 ± 14.2	+2.0	0.57
Role limitations due to physical health	87.5 ± 25.0	92.9 ± 16.7	+5.4	0.40
Role limitations due to emotional problems	70.0 ± 38.8	81.7 ± 31.4	+11.7	0.11
Energy/fatigue	46.7 ± 16.8	60.3 ± 13.5	+14.6	**0.01**
Emotional well-being	69.2 ± 16.0	79.0 ±10.1	+9.8	**0.04**
Social functioning	80.0 ± 22.0	91.3 ± 13.5	+11.3	0.06
Pain	80.4 ± 14.0	80.9 ± 12.3	+0.5	0.89
General health	64.3 ± 18.2	72.8 ± 14.3	+8.5	0.08
Sleep (Pittsburgh Sleep Quality Index)				
Total score	8.2 ± 3.8	7.0 ± 3.9	- 1.2	0.16
Duration of sleep	0.7 ± 0.7	0.8 ± 1.0	+0.1	0.54
Sleep disturbance	1.5 ± 0.6	1.3 ± 0.5	-0.2	**0.04**
Sleep latency	1.6 ± 1.2	1.2 ± 0.9	-0.4	0.09
Day dysfunction due to sleepiness	1.2 ± 0.5	0.8 ± 0.7	-0.4	**0.04**
Sleep efficiency	1.1 ± 1.3	1.2 ± 1.1	+0.2	0.49
Overall sleep quality	1.3 ± 0.7	1.1 ± 0.8	-0.3	0.20
Need meds to sleep	0.9 ± 1.1	0.7 ± 1.0	-0.3	0.14
Poor Sleep Quality (%)	14 (70)	11 (55)	-3	0.45

6.5. DISCUSSION

Based on our *a priori* definitions of feasibility, this intervention was shown to be a feasible intervention to implement in this population. Our recruitment goal was met in ten days, showcasing the demand for an intervention of this type in this population. The majority of participants enrolled were nurses or care aides. While this may indicate a stronger demand in this occupational group, it is most likely the result of recruitment strategies used. Online postings and physical posters were placed at a number of different worksites, but we were able to send a recruitment email to all employees of two local health authorities, which greatly increased the rate of recruitment. Future work is needed to understand how to engage other occupational groups.

The most common reasons for ineligibility were that participants were already participating in at least 90 minutes per week of MVPA, or that they did not meet our definition of shift work. This suggests that the demand for this type of intervention exists for individuals who work a variety of different work schedules. In this small feasibility study, we chose to limit our sample to more homogeneous group in terms of shift schedule. However, future studies could be expanded to include workers on a variety of different schedules, with modifications to the strategies used to increase physical activity.

A variety of lessons were learned with respect to the implementation of the intervention. First, we anticipated that video sessions either by Skype of FaceTime would be a popular choice to increase the level of accountability, rather than conducting sessions over the telephone. No participant chose this mode of communication for the behavioural counselling sessions. The average session length was 12.9 minutes, with sessions ranging from 3.1 to 32.1 minutes. Based on this, sessions in a larger trial could reasonably be booked in 30 minute time slots, allowing the person delivering the behavioural counselling some time in between for any note or record keeping. A large number of sessions were rescheduled by participants, either before the session or after a missed session. An online scheduling system, where participants have the ability to change their sessions in advance, with reminder emails or text messages may be a tool to reduce the number of rescheduled sessions in the future. Despite shift workers' irregular schedules, they did choose to complete almost all sessions during Monday to Friday time slots, with 91% of sessions conducted during the hours of 0900-1700h. This suggests that most participant sessions could be accommodated during regular working hours in future studies.

Technological issues related to the Fitbit® were the most common complaints by participants. Five out of 20 devices were returned during the intervention, which is much higher than anticipated. Because of this, a different type of activity tracker may be considered in the future. Using the Fitbit® was also burdensome to some who chose not to use the smartphone application, as they weren't always on their computers every day to make it a useful motivating tool. It may be that for some, a simple pedometer may have been just as effective at motivating behaviour change, and participants may be given a choice of trackers to use in future studies.

This study achieved excellent retention and adherence to the intervention, suggesting the intervention was acceptable to those who were enrolled. Overall, participant satisfaction was high at 84.2% reporting they were very or somewhat satisfied, exceeding our predetermined cut point of 75%. Satisfaction was higher with the behavioural counselling sessions than the Fitbit, perhaps due to the technological issues outlined above. While 94.7% of participants stated they would definitely or probably recommend the program to a friend, only 57.9% of participants indicated that they planned to purchase a Fitbit® or similar device, suggesting that component was perceived to be less helpful overall. Interestingly, 68.4% of participants stated that they made other lifestyle changes during the intervention. Using a multi-pronged approach to health promotion, perhaps by incorporating dietary, weight loss or sleep hygiene strategies, should be explored in future studies.

Physical activity was measured both objectively and subjectively at the beginning and end of the study in order to investigate preliminary efficacy outcomes, and to estimate anticipated effect size change for powering future studies. When only MVPA that occurred in bouts of ten minutes or more was calculated, no statistically significant change was seen from baseline to end of study. However both sedentary time, and total minutes of MVPA improved significantly from baseline to end of study. This may suggests that while overall physical activity was increasing, perhaps participants were not able to fit in the recommended activity in sustained bouts of ten minutes or more. Another potential reason for this lack of change may be due to the limitations of the accelerometer. Accelerometers cannot be worn in the water, and thus do not pick up water activities such as swimming. They also have limited ability to pick up other activities such as cycling[283], which several participants reported doing in the self-report questionnaire. Therefore, if participants had increased their activity throughout the study primarily through water or cycle-based activities, this change would not be recorded using the accelerometer.

Self-reported physical activity increased significantly from baseline to end of study. While self-report physical activity is subject to recall and self-report bias, it does overcome some of the limitations of the accelerometer by capturing all types of activities. It also reports activities over the last four weeks, and is less influenced than the accelerometer by one irregular week of physical activity. While both have limitations, together the various outcomes measured through both the accelerometer and the RPAQ, as well as Fitbit® data from participants who shared that data, provide a full picture of participants' physical activity patterns[284]. Based on our findings, we believe that participants did increase their overall physical activity throughout the study, but more emphasis should be placed in future studies on accumulating activities in bouts of at least ten minutes or more.

Despite no focus on weight loss in the present study, using self-reported weight participants lost an average of 0.9 kg over the twelve-week intervention. While we hypothesize that this is likely due to the increase in physical activity, it may also be the result of any dietary changes made by participants throughout the study. We did not collect any measures of dietary intake in this study, but this should be considered for future studies.

In addition to changes in physical activity, participants experienced a significant increase in the energy/fatigue domain of health-related quality of life, and surprisingly also the emotional well-being domain. Changes also approached significance for role limitations due to emotional problems, social functioning, and general health domains. Higher levels of physical activity are known to be associated with higher health-related quality of life in the general population[285]. As shift work is hypothesized to have adverse events on mental health[7], this improvement may have important implications for overall well-being of shift workers.

A significant reduction in sleep disturbance and day dysfunction due to sleepiness was observed at the end of study using the PSQI, although no significant change in total sleep quality score was found. The reported reduction in daytime dysfunction may potentially be the result of the increases in energy and vitality noted by participants on the health-related quality of life questionnaire. Physical activity has been shown to improve sleep; however, the exact frequency, intensity, duration and time of day of activity needed to have the optimal influence on sleep is not yet known. While we did not examine the time of day that participants were physically active during this study, it is an interesting area of research for future studies.

There are several limitations that should be kept in mind when interpreting the findings from this study. Firstly, our sample size was small, was based on a convenience sample of motivated participants and was comprised of primarily nurses or care aids, limiting the generalizability to all women shift workers. While the feasibility of the intervention has been established in this group, changes may need to be made before implementing a similar intervention in more diverse occupational groups. The study also took place in Vancouver, British Columbia a highly active city, where weather patterns are favourable for a variety of outdoor activities. The intervention was also conducted from March to June, when rainfall was minimal, temperatures were warm and daylight hours were increasing. It may be more difficult for individuals in less favourable climates or seasons to incorporate regular MVPA, and different strategies may be needed. Future studies should consider the seasonal effect of interventions on physical activity, or may consider the development of specific behavioural counselling sessions with content for overcoming barriers specific to weather or environmental concerns.

As this was the first study to implement this type of physical activity intervention in this population, a single group design was chosen to ensure the feasibility of delivery before moving on to a larger-scale randomized controlled trial. While this was appropriate for maximizing the number of participants taking part in the intervention, it makes it difficult to attribute changes in preliminary efficacy outcomes to the intervention. The next step would be to implement the intervention on a wider scale, with a control group in order to fully understand the changes that result from the intervention itself.

This intervention was built upon findings from other health-related interventions that have been conducted in shift workers to date (Chapter 2), along with an understanding of physical activity patterns of Canadian shift workers (Chapter 3), and quantitative and qualitative data on the barriers to and preferences for physical activity in women shift workers (Chapters 4 and 5). The accumulation of this evidence allowed us to develop a feasible intervention aimed at increasing physical activity in this group. Along with the established feasibility, preliminary findings suggest it may be an efficacious intervention to increase physical activity, manage body weight, and improve some aspects of sleep and health-related quality of life. A next important step is to implement this intervention on a larger scale, with objective outcome measures and biological markers linked to breast cancer risk, to determine whether these changes in physical activity may lead to meaningful changes in the risk of breast cancer and other chronic diseases in this high-risk group.

7. Chapter 7: Conclusion

7.1. Summary Of Findings

Shift work is prevalent in today's society, and as summarized in the literature reviewed in Chapter 1, the adverse health effects of shift work are well documented. While the exact mechanisms linking shift work to chronic disease are not currently known, there is an urgent need to implement interventions and create policies to protect shift workers from the long-term health effects. To date, there are few examples of successful implementation of these types of interventions in the literature, and even fewer in the community.

Chapter 2 summarized the interventions that have been described in the literature to date. In this chapter, we chose to categorize each intervention into one of four groups: controlled light exposure, changes in shift scheduling, pharmacological agents, and behavioural interventions. Within each group there were examples of interventions that had statistically significant and clinically meaningful changes in a variety of the health outcomes of interest. These typically included simultaneous use of bright light and light-blocking glasses, fast-forward rotating shifts, and interventions targeted at a specific lifestyle (such as physical activity and healthy eating).

There were some overall lessons learned, that we hoped to address in our own research. The use of objective measures (or well-validated subjective measures when self-report was more feasible) is important to accurately measure changes in important outcomes of interest. Validated or objective measures also make comparison across studies possible, which will become important as the breadth of research in this area continues to grow. Poor retention and adherence was also a methodological limitation in many of the studies reviewed. Across different worksites and geographic locations, a number of factors may influence the feasibility of specific intervention types and the likelihood of participants adhering to a given intervention. Thus considering workers' preferences and tailoring interventions to these preferences is an important step in developing feasible and effective health promotion programs.

Before moving on to the development of our own intervention aimed at increasing physical activity, we felt it was important to understand the patterns of physical activity and sedentary time in a representative group of Canadian shift workers. Many of the studies of physical activity in shift workers to date have been conducted outside of Canada, have focused on only one occupational group, used self-report measures which may suffer from recall and self-report bias, and included only a small number of employees who not be representative of shift workers as a whole. The Canadian Health Measures Survey (CHMS) provided an opportunity to overcome many of these limitations, while also comparing objectively measured physical fitness and body composition. Both physical fitness and body composition are highly related to physical activity, and may potentially be more important predictors of long-term health outcomes. While shift workers were no less likely than day workers to meet Canada's Physical Activity Guidelines, they displayed lower levels of aerobic fitness, and were in higher risk categories for body composition. Today in Canada, the proportion of individuals meeting the physical activity guidelines is low, ranging from 13.7% in women to 17.1% in men[243]. Thus, although shift workers were no less likely to meet physical activity guidelines, the overall low levels of physical activity, in combination with low levels of fitness and high levels of obesity seen in the CHMS analysis, and higher rates of chronic diseases reported in the literature to date, supported the need for a targeted physical activity intervention in this group.

There are a large number of benefits associated with increased physical activity, several of which were described in Chapter 1. Despite this, it is difficult to get people to be more active, as evidence by the low proportion of Canadians currently meeting our physical activity guidelines. Therefore, it is essential to understand the specific barriers to physical activity that exist for individuals or groups in order to predict which strategies may be most effective at overcoming them. Identifying barriers to physical activity at the individual, social and environmental levels, and preferences for specific components of a health promotion program have been previously used to design interventions aimed at increasing physical activity implemented within the workplace[255]. All of the published literature examining barriers to physical activity and preferences for physical activity programming, as well as behaviour change theory has focused on healthy individuals, or individuals of specific chronic disease groups. To date, no evaluation of these aspects has been conducted specific to shift workers. Therefore, work was needed to understand how to apply previous knowledge to this occupational group with unique time and scheduling demands.

In the studies described in Chapters 4 and 5, we sought to fill this gap. First, we used quantitative questionnaires, administered to a group of women shift workers enrolled in an ongoing study, to begin to understand both barriers to and preferences for physical activity. With these findings in mind, we developed a preliminary protocol of a proposed intervention. This intervention aimed to combine best practices in physical activity and behaviour change research with the findings from Chapter 4. Following this, we conducted several focus groups (Chapter 5) to gain a more thorough understanding of shift workers' perspectives on physical activity generally, and their opinions on the intervention we proposed. These focus groups provided invaluable feedback on the developed intervention. From both the quantitative and qualitative data we learned that flexibility in scheduling was key for shift workers. We also learned that structured, supervised physical activity sessions were unlikely to be successful in this group unless we were able to offer it at all times throughout the day and night, which was not feasible given budgetary, staffing and space availability constraints. We also gained a better understanding of the specific scheduling barriers that shift workers face, allowing us to tailor the behaviour change intervention to shift workers.

Combining all of the information learned, we then conducted a study to test the feasibility of the proposed intervention. The literature reviewed in Chapter 2 gave us an understanding of the challenges of implementing these types of interventions in shift workers. In particular, the only intervention focusing on physical activity in shift workers conducted previously experienced low retention and adherence[165,166]. Thus we felt it was important to establish the feasibility of the intervention before moving forward with a larger trial, adequately powered to test the efficacy of physical activity on improving the health of shift workers. We found the developed intervention to be feasible to implement in this population, based on our pre-specified targets. Our study displayed adequate demand for an intervention of this type, acceptability to participants, and helped us to understand the capacity including staffing, scheduling and supplies needed to move forward to a larger intervention.

7.2. Study Contributions, Strengths and Limitations

The contributions of each study to this dissertation as a whole, and the strengths and limitations of each of the research papers have been described in detail in each of the study chapters (2-6). In general, this dissertation advances the understanding of the role that physical activity may play in reducing breast cancer risk, and improving overall health and quality of life in shift workers, particularly in Canada. The background research and evidence compiled in Chapters 2-5 led us to develop and test a novel, distance-based intervention that was found to be feasible to implement in this population.

Referring back to the theoretical framework that guided this dissertation (Figure 1.1), several of the relationships hypothesized by this framework have been confirmed by our findings. First, based on our quantitative and qualitative findings from Chapters 4 and 5, shift work does impact workers' lifestyle habits, particularly physical activity patterns. While we did find that shift workers were no less likely to meet physical activity guidelines than day workers, limitations of the accelerometer data used make it difficult to distinguish whether total activity intensity, or activities below the threshold of 150 minutes per week in bouts of less than ten minutes differed. Based on the findings that shift workers have lower level of aerobic fitness, a novel finding that has not been explored in the literature, it appears that shift workers would benefit greatly from a physical activity intervention.

These findings also confirm the link between physical activity, obesity and sleep proposed in the framework. Preliminary efficacy results from Chapter 6 suggest that twelve-weeks of physical activity may result in decreased body weight, and improvements in certain domains of sleep quality, as measured by the Pittsburgh Sleep Quality Index (PSQI) in women shift workers. What remains unknown is the link between these lifestyle factors and actual breast cancer risk in shift workers. This is an important future direction, and will be discussed in section 7.3.

A main strength of this dissertation is the integration of research knowledge and the end users (shift workers) throughout the process of developing a novel intervention. This stepwise approach to designing an intervention, combining best practices and behaviour change theory from the literature, with knowledge of what is reasonable and acceptable to participants, proved to be useful and successful in developing a feasible intervention in a group with many time and logistical challenges. This approach has been used successfully in past studies involving workplace physical activity interventions workplace[255], and may be a suitable model for future studies. The use of mixed methods (a systematic review of the literature, an epidemiological analysis using population-based data, quantitative questionnaires, and qualitative focus groups) was invaluable to gain an in depth understanding of the unique desires and needs of the population targeted. This allowed us to implement an intervention that was well received by participants, with preliminary evidence of efficacy in increasing physical activity and improving other aspects of health.

Based on the limitations in the literature to date highlighted in Chapter 2, we prioritized the use of objective, or well-validated measures in this research. For example, in Chapter 3, our choice to use the CHMS rather than other population-based surveys was based on the objective measures of physical activity, using accelerometery, and measurement of body composition and physical fitness outcomes using trained assessors in mobile health clinics. This reduced the risk of information bias, as recall and self-report biases are eliminated. In Chapter 6, we chose to use a combination of objective and well-validated self-report tools (accelerometery[277] and the Recent Physical Activity Questionnaire (RPAQ)[278]) to measure physical activity, in order to gain a full picture of physical activity patterns, and change in physical activity over time, as has been recommended in the literature[284]. We also used well-validated measures to quantify changes in sleep quality[280] and health-related quality of life[279]. The use of objective and validated measures is important not only for increasing confidence in the accuracy of the measured outcomes, and change in outcomes over time, but also allows the results to be compared across different studies that use the same outcome measures. This will be especially important as the field grows and more similar studies are published.

There are several overall limitations to this work that should be taken into consideration when interpreting the results, and applying them to the development of future research or community-based programs and policies. Firstly, the research in Chapters 4, 5 and 6 was all conducted in Vancouver, British Columbia. Vancouver is an ideal location for living an active lifestyle, due to its geographic location, as well as its built environment with a number of opportunities for indoor and outdoor recreational activities. Thus, environmental barriers, such as cold weather or lack of access to walking and cycling paths, are much less of a factor than they would be in other locations. Different strategies and supports would be needed to overcome these barriers and encourage physical activity in other cities, and rural or remote areas.

As identified in Chapter 2, a large proportion of the research conducted to date on health-related interventions in shift workers has been conducted on relatively young, rotating shift workers in manufacturing, health care and public safety sectors in Europe and North America. This was true for behavioural interventions in particular, where two studies were conducted in manufacturing workers, and two studies in health care workers, with ages ranging from 20-49 years old. While we aimed to recruit shift workers across a variety of occupations, the majority of our participants in Chapters 4, 5 and 6 were either nurses or care aides under the age of 55 with little variation in level of education. There is an ongoing need to engage understudied populations, including workers across a wider demographic range (including participants of various age, socioeconomic status, education and ethnicities) as well across a range of workplaces and roles within various workplaces. It is likely that workers represented across these different groups may have different baseline physical activity levels and patterns of activity, barriers to engaging in regular physical activity and preferences or needs for physical activity programming. For example, it may be feasible and beneficial to implement an intervention focused on breaking up sitting time and increasing physical activity in the workplace (through a walking or standing desk, for example) in individuals who spend the majority of their work time seated in a setting such as a call center. This type of intervention may be less feasible in police officers or those working in security, due to the nature of their work. These, and many other characteristics are likely to influence the feasibility of the intervention we have developed. Thus before the intervention we have developed is implemented widely in a variety of settings, more development work (i.e., questionnaires or focus groups) may be needed.

A final limitation to the literature presented in this dissertation as a whole is the connection that any of the outcomes we have measured may have on actual breast cancer risk, or the risk of other chronic diseases. While participation in regular moderate-vigorous physical activity (MVPA) has a well established protective effect on breast cancer risk in the general population[129], it is not known whether the magnitude of risk reduction is similar in shift workers. Based on the dose of physical activity needed to elicit a reduction in breast cancer risk seen in dose-response studies of 120-180 minutes per week of MVPA[130], we proposed an intervention of a similar dose in shift workers. However, whether this dose is sufficient, and what specific intensity of activity is needed to reduce the risk of breast cancer or other chronic diseases in shift workers requires further research.

7.3. Future Directions and Recommendations

Based on our findings and a review of the current literature, several recommendations for future research programs and policy work can be made. There is now emerging evidence for the preliminary efficacy of a number of different interventions aimed at improving the health of shift workers, as described in Chapter 2. These interventions target a number of levels, from structural and organizational (such as optimizing shift scheduling and controlling bright light exposure) to individual (such as pharmacological, or individual behaviour change interventions). Certain intervention types may be more or less feasible to implement in specific workplaces, and certain individuals may be more likely to adhere to specific intervention types. Thus comprehensive, multi-factorial interventions that aim to target multiple aspects of health or health behaviours may be most effective at improving health of shift workers as a whole. Findings from Chapter 6 provide some preliminary support for this notion. Sixty-eight percent of participants reported making some other lifestyle change during the intervention, and in the participant satisfaction questionnaire, some participants suggested dietary or weight-loss advice as a recommendation for future studies. As fatigue after a night shift was identified as a primary barrier to physical activity in Chapters 4 and 5, interventions such as changes in shift scheduling or controlled light exposure that improve sleep and reduce fatigue may also help to encourage shift workers to participate in more physical activity when combined with a targeted physical activity intervention.

The studies presented in this dissertation (particularly Chapters 3, 4, 5 and 6) primarily address factors along the top of the theoretical framework presented in Figure 1.1. Future studies should continue to investigate how these behavioural factors interact with or could be influenced by changes in factors on the bottom half of the framework, namely sleep, exposure to light at night, circadian disruption and melatonin. For example, there is some preliminary evidence (reviewed in section 1.4.3) that physical activity may alter melatonin levels[153,161]. Findings from the Women in Steady Exercise Research (WISER) study (described in section 1.4.2) suggested that 16-weeks of MVPA did not change melatonin levels[157]. This study was conducted in otherwise healthy, premenopausal women with no circadian disruption and the effects of regular MVPA on melatonin levels in women who work shift work, and have a blunted melatonin profile, has yet to be examined.

Collaborations with employers and workplaces in the development and implementation of health-related interventions should be strongly encouraged in future research. This will allow researchers to reach a broader number of shift workers than those who specifically respond to calls for research participants. It will also allow for the implementation of the multi-factorial interventions described above. Employers and workplaces can play an important role in facilitating increases in physical activity by offering programing at the workplace, increasing access to workplace fitness facilities, and partnering with local business to provide employee discounts on gym memberships, for example. Implementing interventions through the workplace also has the potential benefits of enhancing social support for behaviour change, a recommendation that was given by several participants in the participant satisfaction survey in Chapter 6. This may occur by allowing co-workers on similar shift schedules to exercise together, or may provide social support through discussion and encouragement within the workplace.

Finally, future studies should prioritize continued longer-term follow-up than has been commonly done to date. As noted in Chapter 2, mean follow-up time was 23.7 days for studies of controlled light exposure, 8.3 months for studies of shift schedule change, and 21.3 weeks for behavioural interventions. It is likely not feasible for studies to enroll sufficient sample sizes, and to follow participants long enough to observe actual breast cancer cases or other chronic disease outcomes. However, longer follow up is needed to ensure that the interventions conducted promote sustained behaviour change and long-term changes in health outcomes, such as biological markers that are linked to breast cancer or chronic disease risk. A recently completed study found sustained improvements in sleep in women shift workers over a twelve-month intervention period, suggesting such changes are possible and that shift workers are a promising population to work with[256]. It may be that changes or additions to interventions or programs would be needed to achieve maintenance of health and behaviour change following the short-term outcomes observed in many of the studies to date.

7.4. Conclusion

This dissertation describes a stepwise process, consisting of a thorough review of the literature, epidemiological evaluation using population-based Canadian data, and analysis of quantitative and qualitative data from the target population, to develop and test the feasibility of a novel, distance-based intervention aimed at increasing physical activity of women shift workers. Each of these steps led to the development of a feasible intervention, with preliminary evidence of being efficacious at promoting behaviour change and improving the health of this population. This dissertation lays the groundwork for future large-scale randomized controlled-trials to determine both efficacy and effectiveness of similar interventions at improving health, and reducing breast cancer risk in this high-risk population.

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