THE RATE AND PREDICTORS OF CONTINUOUS POSITIVE AIRWAY PRESSURE ADHRENCE IN CANADIAN PATIENTS WITH OBSTRUCTIVE SLEEP APNEA

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Abstract

Rationale: Obstructive sleep apnea (OSA) impacts mood, cardiovascular morbidity, and mortality. Continuous positive airway pressure (CPAP) is the first-line treatment for patients with moderate to severe OSA. CPAP ameliorates respiratory disturbances, leading to improvements in daytime sleepiness, quality of life, blood pressure, and cognition. However, despite its high efficacy, CPAP adherence is often sub-optimal. There are many factors that are proposed to affect CPAP adherence including: socio-demographic/economic characteristics, disease severity, psychological factors, side-effects, and initial experience with CPAP. Intervention studies have suggested that augmented support/education, cognitive behavioral therapy, and telemedicine may improve CPAP adherence. However, no studies regarding the rate and predictors of CPAP have been done within a Canadian context. Consequently, we sought to determine the rate and predictors correlated with CPAP adherence amongst Canadians.

Methods: Patients referred for suspected OSA to the University of British Columbia Hospital Sleep Clinic between 2003 and 2009 were recruited. All patients underwent full polysomnography and completed a health questionnaire. Patient charts were reviewed, and CPAP adherence was defined as using the device for ≥4 hours for ≥70% of the time being used. CPAP predictors including severity of OSA, daytime sleepiness, age, BMI, depression, etc. were analysed. A P value of < 0.05 was considered to be statistically significant.

Results: There were 1,250 patients in total; 844 were prescribed CPAP and 406 were not. Of those who were prescribed CPAP, 421 (49.9%) adhered to CPAP and 423 (50.1%) did not. In the multivariate model, the severity of OSA measured by AHI was the only predictor of CPAP adherence ($p < 0.0001$). The severity of OSA in adherers and non-adherers was 34 vs. 27 events/hr respectively. Patients in both groups were on average 51 years old, mostly males, mostly non-smokers, had an Epworth sleeping scale (ESS) of 11, depression score of 16 and

were mostly involved in car crashes. Those with a higher education (≥ college) were more adherent (63% vs. 57%) ($p = 0.14$). But this was not significant.

Conclusions: In our data, CPAP adherence was low (49.9%) and OSA severity, as measured by AHI, was its only significant predictor.

Lay summary

Obstructive sleep apnea (OSA) is a common sleep disorder affecting 5-10% of the general adult population. Continuous positive airway pressure (CPAP) is its main treatment and is effective in improving the harmful side effects of OSA. Yet, adherence rate to CPAP treatment ranges from 30-60% despite various improvements to the mask and the device itself. The published studies regarding the predictors of CPAP adherence are inconsistent in their findings and have not been investigated within a Canadian context. Consequently, the goal of this study was to find predictors of CPAP adherence amongst Canadians. By doing so, patient care and quality of life may improve amongst Canadians. Patients referred to University of British Columbia's Sleep Clinic were recruited between 2003-2009. Overall, 844 patients were prescribed CPAP but only 421 (49.9%) were adherent and the only predictor associated with CPAP adherence was OSA severity as measured by AHI.

Preface

The work presented herein was part of an ongoing research study, which started in 2003 at the sleep clinic at the University of British Columbia. This study was designed by the principle investigator Dr. Najib Ayas and approved by the UBC Clinical Research Ethics board H13-00346.

A version of chapter 1 has been sent for publication to the Journal of Lung and the manuscript is being published. Mehrtash, M., Bakker, J. P., & Ayas, N. (2018). Predictors of Continuous Positive Airway Pressure Adherence in Patients with Obstructive Sleep Apnea. I conducted a broad research of the literature regarding OSA, predictors of CPAP adherence and interventions that may improve adherence. I wrote most of the manuscript.

This thesis is the original intellectual product of the author, M. Mehrtash, who was responsible for collecting and analysis of data. Dr. N. Ayas was involved in the early stages of developing the concept and the design of the study. He also supported concept development throughout the duration of the research and contributed thesis edits. N. Fox was in charge of ordering the medical charts from Iron Mountain Inc. B. Peres and A. Hirsch were in charge of helping clean the data from the medical charts and the health questionnaire and merging the datasets.

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List of abbreviations

AHI	Apnea Hypopnea Index
APE	Active patient engagement tool
BMI	Body Mass Index
CBT	Cognitive behavioural therapy
CPAP	Continuous Positive Airway Pressure
ECG	Electrocardiographic
EDS	Excessive daytime sleepiness
EEG	Electroencephalographic
EMG	Electromyographic
EOG	Electrooculographic
ESS	Epworth Sleepiness Scale
HR	Hypopneas recorded
NA	Not available
ODI	Oxygen Desaturation Index
OSA	Obstructive Sleep Apnea
PHQ-9	Patient Health Questionnaire
PLM	Periodic limb movement
PSG	Polysomnography
RCT	Randomized controlled trial
SaO2	oxygen saturation
SAS	Statistical Analysis System
SD	Standard deviation
Tel-Ed	Web-based OSA education

Tel-TM	CPAP telemonitoring with automated patient feedback
TLC	Telephone-linked communications
UBC	University of British Columbia
UCM	Usual care monitoring

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Dedication

To my loving family, who have supported me endlessly no matter the challenges I faced.

Chapter 1: Introduction

1.1 Purpose and objective

The most prevalent respiratory sleep disorder is obstructive sleep apnea (OSA), which is characterized by repetitive episodes of upper airway obstruction while asleep that leads to sleep fragmentation and hypoxemia.[1] Common symptoms of this disorder include loud snoring, excessive daytime sleepiness, and frequent nocturnal awakening.[2] Patients with untreated OSA are at increased risk of car crashes, acute cardiovascular events, and impaired neurocognitive performance. [3] Similarly, cardiovascular (CV) co-morbidity is very common among OSA patients, with observational studies suggesting an independent relationship between OSA and the development of CV sequelae including hypertension, heart failure, cardiac arrhythmia, stroke, resting heart rate, and pulmonary artery pressure.[4] OSA occurs in both genders and all age groups and affects 10-20% of the population. [1] OSA treatment can relieve a huge economic burden (billions of dollars per year).[5] Direct expense of OSA burden in Canada alone in 2008 was around 145 million dollars. [5] According to a recent study, the treatment of moderate to severe OSA is cost effective and depending on the patients' choice of therapy and the severity of their OSA, cost utility ratios can range anywhere from $7420 to $43889. [6] This finding matches the findings of other countries. [7] According to a recent study by Hillman and colleagues, the direct health costs of sleep disorders were $160 million and $1.08 billion for associated conditions in Australia alone. [8]

The first description of continuous positive airway pressure (CPAP) as a potential treatment of OSA was published by Dr. Colin Sullivan in 1981. [9] Since then, CPAP has become the first-line therapy for OSA. CPAP is efficacious in reducing and in many cases eliminating snoring, hypoxemia, and the resultant arousals in patients with OSA, resulting in significant

improvements in health-related quality of life, alertness, and neurocognitive function. [10] CPAP is associated with reduced daytime and nighttime blood pressure increases in OSA patients, and patients with greater use of CPAP have more robust blood pressure reductions. [11] However, despite the high efficacy of this device, adherence rates range from 30-60% and of those that continue using it, 20-30% of them apply it insufficiently. [10] CPAP adherence is commonly defined as using the device for ≥ 4 hours for ≥70% of the nights monitored. [12] According to a recent study that only looked at sixty-six randomized control trial (RCT) or longitudinal cohort studies that were published between 1994-2015, the rate of non-adherence was 34.1%. [12] However, this number may not be accurate and generalizable to the whole population as all the studies were RCT studies. This finding suggests that despite numerous interventions (i.e. educational, telemedicine, behavioural, etc.) that were designed to improve CPAP adherence over the long term, trends do not seem to show clinically impactful changes. According to different studies, various predictors such as socio-demographic characteristics, disease severity, psychosocial factors and side effects may affect how adherent OSA patients are with CPAP. [12] However, their results are inconsistent, which may be due to small sample sizes. Moreover, none of these studies have been done in Canada and data is thus lacking in a Canadian context. The overarching aim of this retrospective study was to identify the rate and predictors of CPAP adherence in Canadian OSA patients. The results of this study may eventually lead to the overall improvement of patient care and the patients' quality of life by improving their CPAP adherence. The main objective of this project was to review the medical charts and health surveys of patients that were referred to the University of British Columbia (UBC) Sleep Disorders Clinic between 2003-2009 and to determine the rate and predictors that may have affected CPAP adherence within this cohort among those who could adhere and not adhere to CPAP.

1.2 Methods

In this retrospective cohort study, patients who were referred to the UBC sleep clinic for possible OSA diagnostic were recruited between 2003-2009. At the time of recruitment, the severity of the patients' OSA as measured by apnea hypopnea index (AHI), which was based on their results of their polysomnography (PSG) test had to be ≥ 5 events/hours in order for each patient to be considered in the study. The patients that were included also had to complete a health survey. Furthermore, of those that were considered to have OSA (AHI ≥ 5 events/hours), patients were further divided into those that were prescribed CPAP and those that were not prescribed CPAP. Of those that were prescribed CPAP, patients' charts were later reviewed for CPAP adherence. After analysis was completed, CPAP adherence was defined as using the device for ≥ 4 hours for $\geq 70\%$ of the time being used. According to this definition, patients were further divided into two groups including: 1) adhered to CPAP, 2) did not adhere to CPAP. We then looked at a broad group of different predictors that may be have been correlated with CPAP adherence of the recruited patients (Table 1.2). Multivariate logistic regression analysis was used to determine the relationship between numerous variables and CPAP adherence by using SAS 9.4.

Table 1.2. Potential predictors of CPAP adherence.

Patient characteristics	Age
	Gender
	Body mass index (BMI)
	Education
	Income
	Menopausal status
	Smoking status
	Marital status
	Bed partner status
	Neck circumference
	Alcohol intake (i.e. wine, beer, liquor)
Sleep Related	OSA severity measured by apnea hypopnea index (AHI)
	Daytime sleepiness measured by Epworth Sleepiness Scale (ESS)
	Number of car crashes
	Restless leg syndrome
	Periodic limb movement (PLM)
	Sleeping aid medication intake
	Snoring severity
Cardiovascular related	Stroke status
	Cardiac arrhythmia status
	Myocardial infraction status
Mental health related	Depression scale measure by patient health questionnaire (PHQ-9)
	Mood disorder
	Anxiety disorder
	Antidepressant medication
Overall health	Hypertension
	Occupational injury

Definition of abbreviations: AHI = apnea–hypopnea index; BMI = body mass index; ESS = Epworth Sleepiness Scale; PLM = periodic limb movement; PHQ-9 = patient health questionnaire;

1.3 Significance

OSA is the most common respiratory disorder of sleep. However, the majority of the patients with OSA are undiagnosed. OSA is associated with many adverse health outcomes some of which include increased rate of motor vehicle crashes, hypertension, stroke, daytime sleepiness, reduced quality of life, and cardiovascular diseases. CPAP is the primary treatment for OSA and is effective in treating it. CPAP includes a mask on the nose which pushes air into the throat to support the upper airway from collapsing at night. Those who use CPAP have less daytime sleepiness, cardiovascular diseases, motor vehicle crashes, and a better quality of life. However, many of the patients that are diagnosed with this disorder do not adhere to CPAP. Various factors and predictors including bed partner, age, gender, race, and etc. may affect whether a patient will or will not adhere to CPAP. However, studies are inconsistent about the rate and predictors and the factors that may influence CPAP adherence mostly because they had a small sample size. More importantly, none of the studies have been done within a Canadian context. As a result, this study, which to the best of our knowledge is the largest study done in Canada, addresses the rate and predictors of CPAP adherence within a Canadian population. Also, by identifying the predictors of CPAP adherence and improving adherence to CPAP, patient care and the overall quality of life of these patients can be improved.

Chapter 2: Background and Literature Review

There are a number of factors that may affect CPAP adherence (Table 2.0).

Table 2.0. Factors associated with CPAP adherence.

Socio-demographic characteristics	Age [13, 14]
	Gender [14, 15]
	Race/Ethnicity[13, 16]
	Socioeconomic status (e.g., income, and education)[17, 18]
Disease severity	Severity of OSA[19, 20, 21]
	Severity of symptoms (e.g., daytime sleepiness) [22]
Psychosocial factors	Psychological variables [23]
	Social support [24, 25]
Side-effects	Dry nose [26, 27, 28]
	Dry mouth [26, 27, 28]
	Mouth leak [28]
	Mask leak [23]
	Nasal congestion [29]

2.1 Socio-demographic characteristics

Patient characteristics of relevance include age, gender, race and socioeconomic status. In general, the studies have been fairly inconsistent in associating these factors with adherence. For example, one study concluded that African American patients use the CPAP machine less often than Caucasians. This finding was supported by results from another study. [16] However, in a more recent study, sleep duration differed by race and those that slept shorter hours used CPAP for fewer hours and consequently, this may have skewed their results. [30]

Studies have been inconsistent with their results in regard to the correlation between gender and CPAP adherence. In a study by Budhiraja and colleagues, 57 Caucasian patients were compared to 39 African American patients who had electronic adherence information to a laboratory-based computer relayed by the CPAP machine through a telephone modem. [13] They concluded that only age ($p = 0.018$) and race were associated with CPAP adherence, more specifically, Caucasians had higher daily CPAP use compared to the African Americans ($p = 0.005$). [13] The

authors also concluded that gender and severity of OSA showed no association with CPAP adherence. [13] However, the number of patients in their study was not sufficient to draw firm conclusions. Another study that included 507 OSA patients concluded that women were less adherent to CPAP than men. [31] They also concluded that African American patients (i.e. both males and females) were 5.02 times more likely to be nonadherent to CPAP than Caucasians; however, this finding may be biased because there were only 18 Caucasians in this study compared to 196 African Americans. [31] In another study by Collen and colleagues, 400 patients were included after presenting for initial follow up between 4-6 weeks of CPAP therapy. Most of their patients were men (78%) with a mean age of 47±7.7 years.[32] Among this cohort, CPAP was used 78.1% of the time while asleep with an average of 3.13 hours/night.[32] Only age (48.2 ± 8.0 years vs. 45.8 ± 7.3 years; p=0.02) was associated with good adherence in this cohort and patients >50 years of age were more adherence with CPAP.[32] No other variable such as gender, degree of sleepiness or disease severity predicted adherence in their study. Another study concluded that age (18-79 years, P=0.156, n=605) and gender (P=0.553) were not associated with long term CPAP adherence.[20] However, in this study, many of their medical records were unattainable as they were misfiled, lost and moved.

Socio-economic factors such as income and education level may play a role in CPAP adherence. In one report of 162 OSA patients, patients who made >120% of the average income of the study sample had an increased odds of CPAP adherence (defined as ≥ 4 hours/night) compared to those who made less than 80% of average income. [17] Years of education among low, average and high-income level patients in this study were 9.9 ± 3.4, 13.1 ± 3.0, and 15.2 ± 3.4 respectively ($p < 0.001$). [17] Moreover, many patients cite cost as a reason for not adhering to CPAP therapy. For example, out of 265 OSA patients in one study, only 21% of the patients with low income accepted and purchased CPAP compared to 51.4% of those with average income and 75.6% of

those with higher income. [18] However, patients' income may vary depending on the country. Table 2.1 shows the findings of various studies regarding socio-demographic variables and whether or not they effect patients' adherence to CPAP. Top five studies with the largest sample size where chosen.

Table 2.1. Overview of socio-demographic characteristics variables influencing CPAP adherence.

Variables	Impact on CPAP adherence	Sample size (n)	Reference
Age (Increased)	Increase	16,783	Palm 2017 [33]
		4,281	Woehrle 2011 [34]
		1,772	Means 2010 [35]
		1,155	Mcardle 1999 [22]
	No difference	1,141	Gagnadoux 2011[36]
Gender (male)	Increase	4,281	Woehrle 2011 [34]
		16,783	Palm 2017 [33]
	No difference	1,141	Gagnadoux 2011 [36]
		750	Stuck 2012 [37]
		639	Kohler 2010 [20]
Race (African American, non-white, Maori, non-European)	Decrease	1,772	Means 2010 [35]
		507	Joo 2007 [31]
		403	Pamidi 2012 [38]
		214	Campbell 2012 [39]
	No difference	330	Platt 2009 [40]
Socio-economic status (higher socio-economic status) (may include both or only one of these variables: income, education)	Increase	330	Platt 2009 [40]
	No difference	1,141	Gagnadoux 2011 [36]
		265	Gulati 2017 [18]
		124	Wallace 2013 [41]
		303	Galetke 2011 [42]

Definition of abbreviations: CPAP = continuous positive airway pressure.

2.2 Disease severity

Disease severity, as measured by the apnea-hypopnea index (AHI) and nocturnal hypoxemia may improve CPAP adherence. In general, the more severe the disease, the higher the chance of adhering with CPAP therapy. However, the results are once again inconsistent. While many studies suggest that patients are more adherent to CPAP when their OSA is more severe, [22, 43, 44, 45] others suggest no correlation between the two variables. [46, 47] A large study of 639 patients concluded that severity of OSA determines adherence to the CPAP therapy. [20] They further explained that the hypopneas recorded (HR) of 0.97 for oxygen desaturation index (ODI) indicated an increase of 10 in ODI, which is linked to a risk reduction of 26% for not adhering to CPAP. [20] They concluded that the rate of CPAP adherence was 81% and 70% after 5 years and 10 years respectively and that patients used it for 6.2 hours/night on average. [20] However, many of their medical records were missing due to misfiling or moving within the hospital, which can potentially affect the records of people adhering with CPAP therapy. On the other hand, another prospective study containing 112 newly diagnosed OSA patients concluded that no correlation existed between the severity of OSA and CPAP adherence. [48] The authors concluded that frequent apneas were associated with better adherence at 1 month after initiating CPAP ($p=0.039$) but not at 3 months ($p=0.22$). [48]

Excessive daytime sleepiness is one of the most important determinants of CPAP adherence and is usually measured by the Epworth Sleepiness Scale (ESS). The degree of excessive daytime sleepiness (EDS) along with the severity of OSA is associated with the long-term use of CPAP therapy. There have been considerable investigations on the effects of CPAP on EDS and many investigators have confirmed that EDS is reduced by continuous use of CPAP. [49, 50, 51] One small study of only 14 patients concluded that 85% of their patients who had severe OSA (AHI>80) and used a pressure of 12 cm H_2O for a treated mean AHI of <10 showed significant

improvement in EDS.[23] However, they did not indicate how many of their patients required repeated titration to achieve the most effective CPAP level but the investigators did have a follow up with the patients after 1 week of CPAP use at home. Moreover, most of the results from the studies show a strong relationship between EDS reduction and CPAP adherence. In contrast to other studies, one large study with 639 patients concluded that EDS was not associated (P=0.185) with CPAP adherence and that other important determinants of long-term adherence with CPAP may affect the quality of life in OSA patients. [20] However, they had limited data on other daytime symptoms, which could potentially change their results regarding CPAP adherence. Table 2.2.1 and Table 2.2.2 show the findings of various studies regarding disease severity variables and whether or not they effect patients' adherence to CPAP. Top five studies with the largest sample size where chosen.

Table 2.2.1. Overview of severity of symptoms influencing CPAP adherence.

Variable(s)	Impact on CPAP adherence	Sample size (n)	Reference
Severity of symptoms daytime sleepiness) (improved symptoms)	Increase	16,783	Palm 2017 [33]
		1,155	Mcardle 1999 [22]
		740	Rosenthal 2000 [52]
	No difference	1,141	Gagnadoux 2011 [36]
		1,105	Budhiraja 2017 [53]

Definition of abbreviations: CPAP = continuous positive airway pressure.

Table 2.2.2. Overview of severity of OSA (AHI) influencing CPAP adherence.

Severity of OSA (AHI) (Increased severity)							
Impact on CPAP adherence	**Sample size (n)**	**Male (%)**	**Mean age (years) (SD)**	**Mean BMI (kg/m^2) (SD)**	**Mean AHI (apneic events/h) (SD)**	**p-value**	**Reference**
Increase	16,783	**Adherent**					Palm 2017 [33]
		NA	58.6 (13.6)	NA	38.1 (22.1)	<0.001	
		Non-adherent					
		NA	56.5 (13.6)	NA	30.3 (20.7)		
	1,889	**Adherent**					Marin 2012 [54]
		84	49.5 (9.7)	31.4 (3.9)	41.2 (19.9)	<0.001	
		Non-adherent					
		82	49.9 (11.0)	30.8 (3.9)	31.3 (13.4)		
	1,155	**Adherent**					Mcardle 1999 [22]
		86	50 (43-58)	30 (27-35)	31 (18-53)	0.07	
		Non-adherent					
		69	44 (32-57)	30 (27-36)	22 (13-53)		
	1,141	**Adherent**					Gagnadoux 2011 [36]
		NA	NA	32.9 (6.7)	46.4 (22.1)	0.0002	
		Non-adherent					
		NA	NA	32.1 (6.9)	41.5 (21.3)		
	826	**Adherent**					Tarasiuk 2012 [55]
		77	54.4 (9.9)	33.5 (5.4)	41.5 (19.1)	0.001	
		Non-adherent					
		81	47.1 (10.1)	31.2 (5.3)	36.1 (20.5)		

Definition of abbreviations: AHI = apnea–hypopnea index; BMI = body mass index; CPAP = continuous positive airway pressure; SD = standard deviation; NA = not available.

Adherent patients: continuous positive airway pressure (CPAP) use ≥4hours/night.
Non-adherent patients: CPAP use <4 hours/night.

2.3 Psychosocial factors

Psychological variables including health value, health locus of control, and self-efficacy were investigated by Wild and colleagues, using Wallston's model of social cognition. [56] The locus of control scale measures beliefs in regard to health along three dimensions including internality (patient's perception as to the extent to which their health is within their own control), chance (external control of their health outcome) and powerful others (belief that others have control). [56] Self-efficacy measures the person's belief in their own ability to accomplish a task. [56] The authors found that higher adherence was associated with higher internal locus of control and lower powerful others. This may be because those who believe they have control over their own circumstances and environment are more likely to internalise the advice that is given to them by their sleep specialist; they may then adhere more to CPAP despite its inconveniences. [56] Of note, these traits are modifiable and could be influenced by positive experiences. [56]

Social factors including social support in general, and more specifically the involvement of a bed partner, are important factors associated with a patient's adherence to CPAP. If the idea to seek medical attention was not the patient's but of the bed partner's, adherence to CPAP is negatively influenced as the patient may not be ready to commit to therapy. [57] Of note, when patients use CPAP, bed partners often have improved subjective sleep quality, quality of life, alertness, mood and marital relationships. [57] Furthermore, sleeping with a bed partner who provides feedback on symptomatic improvements such as snoring may promote CPAP adherence. [57]

How an individual manages and copes with anxiety and difficult situations in their life can also influence adherence to CPAP. [58, 59] Patients who are motivated to resolve their health problems tend to adhere better to CPAP compared to those who are less motivated and worry less about their health. [58] Moreover, self-efficacy in addition to social support and knowledge predict CPAP adherence during the first week of CPAP use and one month after starting CPAP. [60] There are

inconclusive findings in regard to the association between anxiety, depression and adherence. Some studies have found a relationship between these variables and adherence, [35, 61, 62] whereas others did not. [63,64, 65] Studies regarding depression and anxiety are generally small in sample size and are at risk of being underpowered. Table 2.3 shows the findings of various studies regarding psychosocial variables and whether or not they effect patients' adherence to CPAP. Top five studies with the largest sample size where chosen.

Table 2.3. Overview of psychosocial variables influencing CPAP adherence.

Variables	Impact on CPAP adherence	Sample size (n)	Reference
Psychological			
Self-efficacy (Increased)	Increase	404	Philip 2018 [66]
		288	Micoulaud-Franchi 2018 [67]
	No difference	126	Bakker 2011 [68]
		124	Wallace 2013 [41]
		119	Wild 2004 [56]
Anxiety (mental disorder, depression symptoms) (presence of anxiety symptoms/disorder)	Decrease	1,772	Means 2010 [35]
		242	Kjelsberga 2005 [61]
		240	Law 2014 [69]
	No difference	1,141	Gagnadoux 2011 [36]
		124	Wallace 2013 [41]
Social support			
Marital status (living alone)	Decrease	1,141	Gagnadoux 2011 [36]
	No difference	330	Platt 2009 [40]
		124	Wallace 2013 [41]
		110	Kaplan 2007 [70]
		122	Poulet 2009 [71]

Definition of abbreviations: CPAP = continuous positive airway pressure.

2.4 Side-effects

There have been many technological advances to make the use of the CPAP machine easier. These advancements evolved due to the patients' difficulty complying and using the device. Many patients refused to use CPAP because of its side effects, which include nasal congestion, mask discomfort, claustrophobia and dry nose and mouth. [72, 73] Two thirds of OSA patients will experience a side effect from using the CPAP device. [65] However, these side effects are not predictive of CPAP adherence, and those who have experienced one or all of these side effects have used CPAP more often than those who do not experience these side effects. [74,75] That is, patients who do not use CPAP obviously will not suffer the side effects.

CPAP has a variety of interfaces such as nasal, orinasal and oral, which include nasal mask, nasal pillow, face mask and oral mask. [72] It is critical for the patients to choose the optimal interface because it will influence their acceptance of CPAP therapy and their long-term adherence with the device. There is not a universally accepted mask interface that will fit every patient and as a result, a properly fitted and comfortable mask interface is crucial when it comes to adhering with CPAP. [76] Using the mask for some time often irritates the skin in a particular spot or causes a feeling of claustrophobia. [77] In a retrospective study, those who used CPAP less often felt claustrophobic more frequently than those who used CPAP on a regular basis. [27] Similarly patients who use CPAP on a regular basis experience mask side effects and discomfort more often compared to those who do not use their device as often. [27] Nasal congestion is a very common side effect when using CPAP and as much as 65% of the patients using the device report nasal congestion, dry nose or throat and discomfort. [78] Patients that encounter nasal congestion are typically mouth breathers and consequently while asleep, the temporomandibular joint retracts and further reduces the retroglossal airway. [9]

The early CPAP machines included a mask attachment using silastic glue and/or rudimentary

straps. Over time, there have been significant improvements in mask technology with a variety of interfaces available; however, it is unclear whether changes in mask type improves adherence to CPAP or if these reflect a marketing strategy. There is a lack of research that compares these interfaces. One of the most common side-effects of using CPAP is mask leaks, which results in the patient not receiving the proper air pressure to treat their sleep apnea and consequently reduces CPAP effectiveness. [79] Mask leak can cause discomfort and dryness in the nasal passage. [79] However, its measurement and reporting terminology are inconsistent since CPAP downloads do not typically report the amount of leak (i.e. average leak or large leak) and also do not report total leak minus expected leak or even artifact-free leak. [79]

Furthermore, patients that sleep with their mouth open have a higher chance of upper air-way collapsibility. [80] Mouth leak occurs in 10-15% of patients [80] and is undesirable for many different reasons including the fact that they reduce the effect of pressure which drives air into the lungs or splint open the upper airway. [28] In order for this treatment to be effective, higher pressure must be applied at the nose mask to compensate for the leak. Moreover, mouth leaks may lead to drying of the mucosal surfaces in the presence of a one-way flow (i.e. air enters through the nose and passes out of the mouth). [28] This condition may then lead to nasal obstruction (i.e. dry and stuffy nose and mouth) which may be intolerable for many patients. [28] As a result, those that are mouth breathers have low adherence to CPAP therapy. [80] Also, mouth leak may compromise CPAP therapy and the first period of CPAP use does in fact predict long-term adherence. [81]

Humidification is another technological advancement designed to reduce CPAP side effects such as dry mouth, throat, or nose. [78] Two types of humidity are commonly used: cold passover humidity and heated humidity. [78] Heated humidity is used more often as it improves the patient's comfort by preventing the increase in mucosal blood flux, which means that the drying effect of the airflow is responsible for this change. [78] However, it is unclear whether heated humidity

increases CPAP adherence. In a couple of studies, there was no difference in side effects between patients who used heated humidification and those who did not.[82, 83] In contrast, another study found that patients exposed to heated humidity compared to no humidity adhered more to CPAP (5.52 hrs/night vs. 4.93 hrs/night; p = 0.008). [84] This particular study noted that heated humidity reduced dry mouth, throat, and nose and increased refreshed feeling upon awakening. [84] Table 2.4 shows the findings of various studies regarding side-effect variables and whether or not they effect patients' adherence to CPAP. Top five studies with the largest sample size where chosen.

Table 2.4. Overview of side-effect variables influencing CPAP adherence.

Variables	Impact on CPAP adherence	Sample size (n)	Reference
Adverse effects (may include one or all of mask leak, nasal congestion, dry nose and mouth) (presence of side-effects)	Decrease	2,311	Borel 2013 [85]
		385	Kreivi 2010 [86]
		300	Kalan 1999 [87]
		204	Engleman 1996 [45]
	No difference	193	Pepin 1995 [88]

Definition of abbreviations: CPAP = continuous positive airway pressure.

2.5 Interventions to improve CPAP adherence

Although a wealth of research demonstrating the efficacy of many of these interventions exist, they can be difficult to implement clinically due to issues around feasibility and cost. Some of the most effective interventions regarding CPAP adherence include supportive, educational, telemedicine, cognitive behavioural, and technological (Table 2.5). Supportive interventions are described as reinforcement, support and/or enhanced access to sleep specific and healthcare resources. [82] Educational interventions mainly focus on patient education and highlight the potential benefits of using CPAP, function and care of the device, and ways to eliminate the side effects and problems that patients may experience. [12] Telemedicine is defined as "the use of information and communication technology to deliver health services, expertise and information over distance, geographic, time, social and cultural barriers". [89] Moreover, telemedicine interventions have been used to reinforce CPAP adherence by sending digital images via email, fax machines, telephone and videoconferencing. [90] Cognitive behavioural interventions are simply described as how the patients make their decisions. This intervention focuses on enhancing patients' new learning experiences and work on correcting their irrational beliefs through exposure to positive stimuli. [82] Finally, technological interventions include the improvements of the CPAP machine and its mask (i.e. nasal cushions (sealing around the outside of the nose), nasal pillows (sealing around the base of each nostril), oronasal (also known as a 'full face mask', sealing around the outside of the nose and either below the lower lip or under the chin) and oral (used rarely)). [12]

Table 2.5. Interventional studies to improve CPAP adherence.

Supportive Interventions					
Study	**Design**	**Sample size (n)**	**Intervention**	**CPAP adherence metric**	**CPAP adherence outcome change (Y=yes; N=No)**
Stepnowsky 2007 [91]	RCT	45 (Experimental group=20; Control group=20)	Patients in the experimental group were assigned to telemonitored clinical care (i.e. joint decision making and partnership between provider and patient). These patients had objective flow generator data monitored as frequently as needed per specified clinical pathways throughout the active 2-month treatment period compared to the control group that had their CPAP adherence data downloaded at 1mo.	Mask-on time	Y at 2mo; Telemonitored group used CPAP for 4.1 hours compared to 2.8 hours in the control group (p=0.07).
Smith 2006 [59]	RCT	19 (Experimental group=10; Control group=9)	Telehealth (i.e. telephone delivered) intervention. The experimental group had a conversation in their home and with their research nurse for a period of 12 weeks. The phone calls were to reinforce nightly, use of CPAP by emphasizing the improvement of general health and how to manage barriers of CPAP use and its related problems. The control group received phone calls regarding the importance of using vitamins every day. Both groups received	Machine-on time	Y at 12wk; 9 out of 10 in the experimental group compared to 4 out of 9 in the control group adhered to CPAP after the intervention (p=0.03).

			telehealth contact 3X during the first week of CPAP initiation and weekly for the remaining 11 weeks of the study.		
Educational Interventions					
Study	**Design**	**Sample**	**Intervention**	**CPAP adherence metric**	**CPAP adherence outcome change (Y=yes; N=No)**
Wiese 2005 [92]	RCT	100 (Experimental group=51; Control group=49)	During the first visit, both groups received explanations about the importance of using CPAP. The experimental group also received a 15-minute videotape about what CPAP was, what CPAP felt like on a sensory basis, and how it improved the patients' conditions.	Un-defined	Y; Those in the experimental group had a return rate of 72.9% compared to 48.9% (p=0.017) at 1month follow-up.
Golay 2006 [93]	One group pre-test; post test	35	Patients were enrolled in an educational program including what CPAP serves for, workshops, hospital CPAP titration sleep study, Ear Nose and Throat consultation, round table with the spouses, and treatment plan discussion groups.	Machine-on time	Y; Baseline CPAP readings averaged 4.4 h while the readings raised to 5.1 h after 3 months (no statistical significance was reported).
Telemedicine Interventions					
Study	**Design**	**Sample**	**Intervention**	**CPAP adherence metric**	**CPAP adherence outcome change (Y=yes; N=No)**
Sparrow 2010 [94]	RCT	250 (telephone-linked communications for CPAP (TLC-CPAP)	The experimental group received TLC-CPAP (i.e. motivational enhancement therapy for CPAP). A Sleep Symptoms Checklist, the Functional Outcomes of Sleep Questionnaire, the	Mask-on time	Y at 6mo and 12mo; CPAP use was higher in the intervention group compared to the control group at 6mo (1hr/night higher;

		=124; Placebo control=126)	Center for Epidemiological Studies Depression Scale and the Psychomotor Vigilance Task were administered at study entry and at 6-mo and 12-mo follow-up.		p=0.006) and 12mo (2hr/night higher; p=0.004).
Hwang 2018 [95]	Four arms, randomized, factorial design clinical trial	1,455 (home sleep apnea testing=956; Prescribed CPAP=556)	Two telemedicine interventions were implemented with primary endpoint of 90-day of CPAP usage: *1*) web-based OSA education (Tel-Ed) and *2*) CPAP telemonitoring with automated patient feedback (Tel-TM). Patients were randomized to *1*) usual care, *2*) Tel-Ed added, *3*) Tel-TM added, or *4*) Tel-Ed and Tel-TM added (Tel-both).	Mask-on time	Y; CPAP average daily use at 90 days was 3.8, 4.0, 4.4, and 4.8 hours in usual care, Tel-Ed, Tel-TM, and Tel-both groups. Usage was significantly higher in the Tel-TM and Tel-both groups versus usual care ($P = 0.0002$ for both) but not for Tel-Ed ($P = 0.10$).
Cognitive Behavioural Therapy Interventions					
Study	**Design**	**Sample**	**Intervention**	**CPAP adherence metric**	**CPAP adherence outcome change (Y=yes; N=No)**
Richards 2007 [96]	RCT	100 (Intervention group=50; Control group=50)	The intervention group received Two 1-hour sessions along with their partners regarding distorted beliefs and promoting a positive outlook for CPAP.	Mask-on time	Y at both 7-days ($p<0.0001$) and 28-days ($p<0.0001$); A Higher adherence to CPAP therapy was found in the intervention group (2.9 hours difference).
Aloia 2007 [97]	RCT	142 (Motivational enhancement therapy group=54;	Motivational enhancement therapy group and traditional education group received two, 45-min, face-to-face therapy sessions	Mask-on time	N at 13 weeks; The three groups' adherence did not differ ($p > 0.05$). 61% of the individuals in the control group,

		Traditional education =47; Control group=41)	beginning after 1 week with CPAP treatment compared to the control group, which only received brochures regarding OSA and the importance of CPAP adherence.		68% of those in the traditional education group and 67% of those in the motivational enhancement group adhered to CPAP.
Technological Interventions					
Study	**Design**	**Sample**	**Intervention**	**CPAP adherence metric**	**CPAP adherence outcome change (Y=yes; N=No)**
Malhotra 2018 [98]	Retrospective study	128,037 (active patient engagement tool (APE)=42,679; usual care monitoring (UCM)=85,358)	AirView, which was used in the UCM group, is a cloud-based technology. CPAP data were transferred automatically to this cloud daily and clinicians managed adherence and therapy for patients with OSA. MyAir, which was used in the APE group, provided real-time feedback and coaching to patients based on their data within AirView. Activation date in the APE group was within 7 days of therapy initiation. Patients in both groups were followed for 10months.	Mask-on time	Y; The addition of APE increased CPAP adherence (5.9hr; p=<0.0001) compared to those with UCM (4.9hr).
Mador 2005 [99]	RCT	98 (treatment group=49, control group=49)	Patients received heated humidification at CPAP initiation in the treatment group. Patients were followed for 1months, 3months and 12 months.	Mask-on time	N; heated humidification did not improve CPAP adherence with 4.3 hr/night at 1month, 4.8 hr/night at 3 months, and 4.8 hr/night at 12 months in the control group and

	4.3 hr/night at 1 month and 3 months, and 4.2 hr/night at 12 months in the treatment group.

Definition of abbreviations: RCT = randomized control trial; CPAP = continuous positive airway pressure; mo=month; TLC= telephone-linked communications; OSA=obstructive sleep apnea; Tel-Ed = web-based OSA education; Tel-TM = CPAP telemonitoring with automated patient feedback; APE = active patient engagement tool; UCM = usual care monitoring; CBT = cognitive behavioural therapy.

2.6 Rationale

OSA is a common sleep disorder and it is commonly undiagnosed. Symptoms of this disorder include loud snoring, excessive daytime sleepiness, frequent nocturnal awakening, neurocognitive impairments, increased rate of car crashes and cardiovascular events including heart attacks, strokes, and hypertension.[100] Patients with untreated OSA are at increased risk of car crashes, acute cardiovascular events, and impaired neurocognitive performance. [101] OSA occurs in both genders and all age groups and affects 10-20% of the population. [1] OSA treatment can cause a huge economic burden in Canada. Adherence rates to CPAP, which is the most effective treatment for OSA, are low (30%-60%) and over the past twenty years or so, the adherence rates have not increased despite numerous interventions (i.e. patient education, supportive, technological, telemedicine and cognitive behavioral), which are aimed to improve adherence. [10] CPAP adherence is affected by various factors including socio-demographic characteristics (i.e. age,[13-14] gender,[14-15] race, [13, 16] and socio-economic status [17-18]), disease severity (i.e. severity of OSA [19-21] and its symptoms [22]), psychosocial factors (i.e. psychological variables [23] and social support [24-25]), side-effects (i.e. dry nose [26-28], dry mouth [26-28], mouth leak [28], mask leak [28], and nasal congestion [29]) and is a complex behavioral problem. However, to the best of our knowledge, none of the studies were done within a Canadian context. As a result, the aim of this thesis was to identify the rate and predictors of CPAP adherence in Canadian OSA patients.

2.7 Hypothesis and objectives

2.7.1 Objective

The objective was to assess adherence rates with CPAP in patients with OSA. Various factors including age, gender, apnea hypopnea index (AHI), Epworth sleepiness scale (ESS), body mass index (BMI), patient health questionnaire (PHQ-9), education, income, menopausal status, rate of car crashes, smoking status, marital status, bed partner status, snoring severity, occupational injury, restless leg syndrome, neck circumference, mood disorder, anxiety disorder, alcohol intake, stroke status, cardiac arrhythmia status, myocardial infraction status, periodic limb movement (PLM), hypertension, sleeping aid medication intake, and antidepressant medication were determined.

2.7.2 Hypothesis

We hypothesized that predictors including age, gender, apnea hypopnea index (AHI), Epworth sleepiness scale (ESS), body mass index (BMI), depression, education, income, menopausal status, rate of car crashes, smoking status, marital status, bed partner status, snoring severity, occupational injury, restless leg syndrome, neck circumference, mood disorder, anxiety disorder, alcohol intake (i.e. wine, beer, liquor), stroke status, cardiac arrhythmia status, myocardial infraction status, periodic limb movement (PLM), hypertension, sleeping aid medication intake, and antidepressant medication correlate with CPAP adherence; however, given the inconsistency within the literature, it is likely that some of these factors will not be predictors of CPAP adherence.

Chapter 3: Methods

3.1 Overall study design

Patients that were referred to UBC sleep clinic between 2003-2009 for a possible OSA diagnosis were recruited (Figure 3.1). Patients were divided into those that had done an overnight PSG test and those that had not done an overnight PSG test. Of these patients, only those with an AHI ≥ 5 apneic events/hour were included in the study. Furthermore, patients with an AHI ≥ 5 apneic events/hour were divided into those that were prescribed CPAP and those that were not prescribed CPAP. Moreover, patients that were prescribed CPAP were further divided into those that adhered to CPAP and those that did not adhere to CPAP. CPAP adherence was in accordance to other studies and was defined as using the device for ≥ 4 hours for ≥70% of the nights monitored. Lastly, in order to find the factors that could potentially predict CPAP adherence, we looked into those that adhered to CPAP.

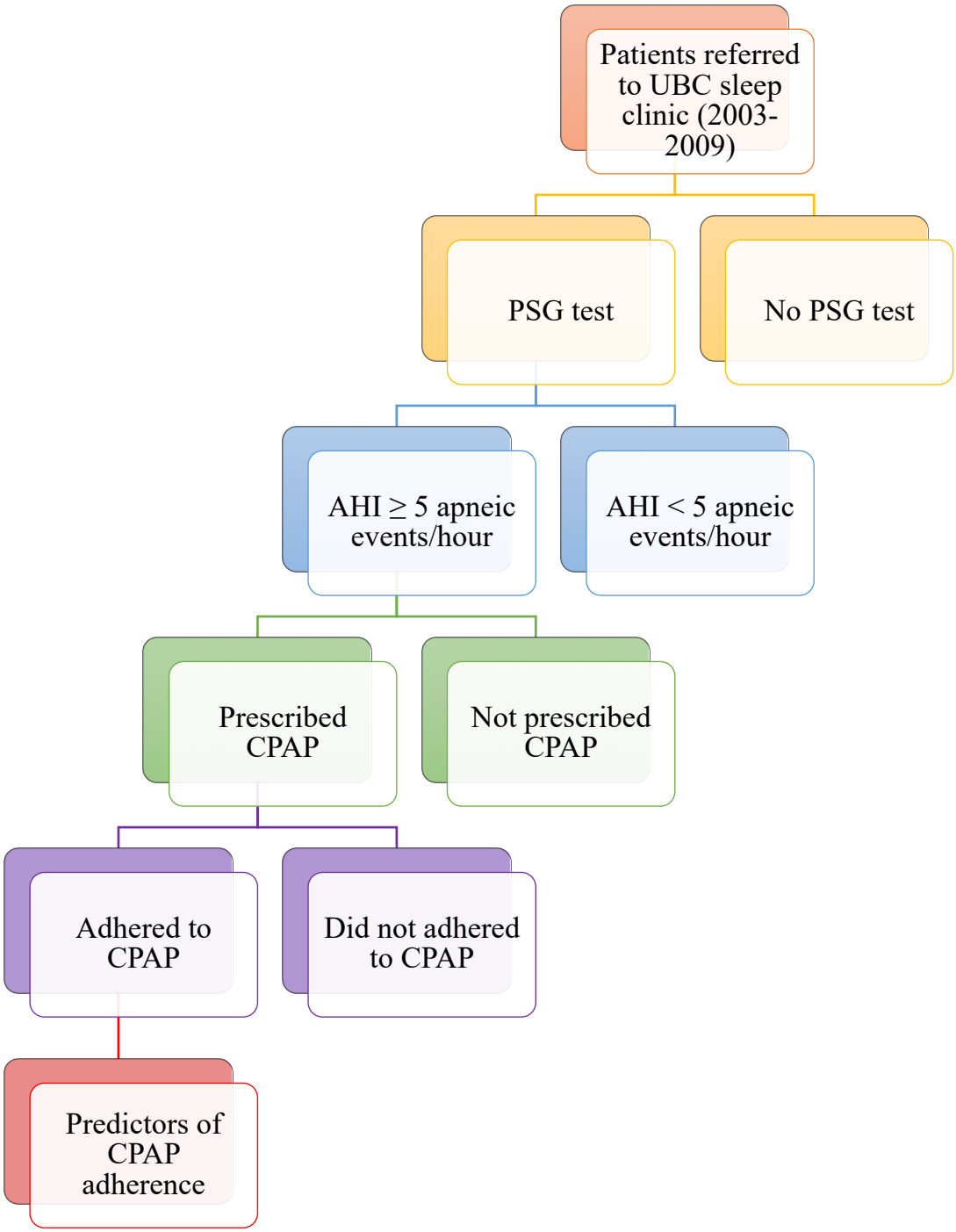

Figure 3.1. Overall study design. As shown in the figure, patients were recruited from UBC sleep clinic from 2003-2009. These patients were further categorized into those that had done a PSG test and those that had not done a PSG test. Of those that had done a PSG test, only patients with an AHI of ≥ 5 apneic events/hour were included. Of the patients with an AHI of ≥ 5 apneic events/hour, patients were further categorized into those that were prescribed CPAP and those that were not prescribed CPAP. In order to find adherence in this cohort, patients that were prescribed CPAP were once more divided into those that were to CPAP and those that did not

adhere to CPAP. Lastly, in order to find the predictors of CPAP adherence, adherent patients were considered.

3.2 Patient recruitment

The protocol of this single center study was approved by the Clinical Research Ethics Board (H13-00346) at the University of British Columbia. Patients who were referred to UBC sleep clinic for a possible OSA diagnosis were recruited from 2003-2009. Moreover, PSG is recommended by both the American Thoracic Society and the American Academy of Sleep Medicine and was performed by using conventional instrumentation and analysis according to the recommendations on the definition of syndrome and measurement techniques, which was published by the American Academy of Sleep Medicine. [102] The overnight PSG test was used to objectively identify OSA and its severity according to AHI. Consenting patients were also given an extensive questionnaire (Appendix A) regarding their demographics, sleep habits, and subjective sleepiness as measured by Epworth Sleepiness Scale (ESS), which needed to be completed before the patients left the clinic the next day. For this project, patients with AHI of ≥ 5 events/hr as assessed by their overnight PSG were considered to have OSA.

3.3 Inclusion criteria

Study subjects were recruited at the University of British Columbia's sleep clinic between 2003-2009 in accordance to the ethics approval from UBC's research ethics board. They had to be referred to UBC sleep clinic for a suspected OSA diagnosis. The inclusion criteria included: 1) being able to read and understand English, 2) being able to provide informed consent, 3) not used CPAP within the past 3 months prior to their PSG test, and 4) being able to fill out the health survey. Patients referred to the UBC sleep clinic for a PSG by sleep psychiatrists instead of respiratory physician were excluded from the study. This was because these patients mainly have non-respiratory issues such as insomnia, depression or narcolepsy and as a result, as such, they

have other disorders leading to EDS. Lastly, those with serious medical conditions including mental disability or dementia, active psychiatric disease and those unable to provide an informed consent form were also excluded from the study.

3.4 Risks and confidentiality

The health survey and the procedures that were used in this project had no physical risks to the patients. Initially, when patients arrived at the sleep clinic to see a sleep specialist regarding their condition, sleep specialists or a research coordinator explained the study to potential subjects and gave them consent forms. Subjects were also told they could withdraw from the study anytime they wished and could have their data removed at any point during the study. The original confidential databases and datasheets were stored in a locked cabinet in an office at Vancouver General Hospital (VGH).

3.4 Polysomnography

Polysomnography is the main procedure used in clinical practice in order to diagnose and quantify OSA severity. Different sleep stages were documented by using electroencephalographic (EEG), electrooculographic (EOG) and electromyographic (EMG) criteria. Airflow was measured by recording the nasal pressure. Moreover, snoring was measured by using a microphone (Model SL120, Pacer Industries, Toronto, Canada), which was attached to the respitrace band at the level of third intercostal space. An electrocardiographic (ECG) was monitored to detect cardiac arrhythmias. Arterial oxygen saturation (SaO2) was monitored with a pulse oximeter (Model N-100, Nellcor Inc., Hayward, CA), which was attached to the index figure. Moreover, chest wall movement was monitored using a respiratory plethysmograph (Respitrace, Ambulatory Monitoring Equipment, Ardsley, NY). The entire record was manually

scored for sleep stage, type of apnea and the duration. The recorded data was eventually merged with the remainder of the data gathered from the questionnaires.

Hypopnea was associated with a reduction in flow with either a 3% or more drop in arterial saturation or an arousal. Similarly, apnea was defined as a pause in respiration for more than 10 seconds. [103] The severity of OSA was defined in terms of the number of apnea or hypopnea events per hour while asleep and is measured by the apnea hypopnea index (AHI).

Patients were further divided into two groups depending on their PSG results. If they had an AHI of 5 events/hour or more, they were considered to have OSA and were put into the "yes" group. Those with an AHI of less than 5 were considered to not have OSA and were put into "no OSA" group. The severity of OSA was further categorized into no OSA (<5), mild OSA (5-14), moderate OSA (15-29), severe OSA (≥30).

3.5 Obtaining patient charts and the health questionnaire

Initially, the health surveys were self-completed when the patients were at the sleep laboratory. The questions in the survey (Appendix A) mostly concentrated on demographic variables and the events the patients experienced within two years prior to their PSG. These variables included self-reported occupational injury, occupational history, sleep habits, witnessed snoring and apneas, past medical history, medication intake, health habits (i.e. alcohol, smoking, caffeine intake), type of industry work, height, weight and lastly, subjective daytime sleepiness as measured by ESS. Body mass index (BMI) was calculated from using the patient's height and weight.

Patients' medical history were collected from Iron Mountain Inc. from 2016 to 2018. The charts were then extensively reviewed and when possible, both subjective and objective CPAP adherence rates were extracted. Objective adherence was obtained from the charts by looking at patients' CPAP's downloaded data. Moreover, subjective data was obtained by looking at the

sleep physician's notes from the patient's last visit and was further categorized into either adhering or not-adhering depending on the doctors' notes. However, at the time of patient recruitment, most of the patient files lacked objective data because at the time the data was collected, objective measurements of CPAP treatment were less ubiquitous than they are today, as a result, the adherence data in this study was taken from both subjective data and objective data that was retrieved from the patient charts at the UBC sleep clinic. Also, when objective data was lacking, subjective data was used on its own. Objective measures were used for threshold. However, about 60% of the collected data was in the form of subjective data as we were missing a large number of objective data. For the objective data, we used the most commonly defined definition of CPAP adherence (i.e. using the device for ≥ 4 hours for ≥70% of the nights monitored), however, for the subjective data, we used the physician's notes from the patient's last visit to that doctor. The doctor's notes commonly identified the patients as either adherent or not adherent, however, when the notes were vague in terms of whether a patient was adherent or not adherent to CPAP, we used our judgement to categorise those patients as either adherent or non-adherent. Two experts reviewed the spreadsheet to determine whether or not patients were adherent with the therapy.

3.6 Data sets and statistical analyses

Completed health surveys were either scanned or manually entered to the patients' database. The only people with access to this database were the members of the research team (i.e. researchers and support personnel). We further maintained the patients' confidentiality by removing the identifying information including names and personal health numbers from the main dataset. Doing so allowed us to identify the patients by a code number and maintain their confidentiality. Patients with an AHI of ≥ 5 events/hour were divided into "prescribed CPAP" or "not prescribed CPAP" depending on their extracted subjective and/or objective data. Patients that were

prescribed CPAP were then divided into “adhered to CPAP” or “did not adhere to CPAP” based on the defined definition of CPAP adherence. There is inconsistency in how CPAP adherence is defined, both empirically and clinically. However, the most common definition of CPAP adherence is to use the device for ≥ 4 hours for ≥70% of the nights monitored. Early in the 1990s, papers reported CPAP was used for 4.7 hours/night on average. However, the authors did not indicate this number to be an adequate amount of CPAP use, a common assumption then emerged wherein use of CPAP for 4 hours per night on 70% of nights was adequate to reverse the negative effects of OSA and as a result, it was established as a clinical and empiric benchmark of CPAP adherence. Furthermore, our definition of CPAP adherence was in accordance to other studies and was defined as using the device for ≥ 4 hours for ≥70% of the nights monitored. CPAP adherence was measured at one point in time (i.e. when the patients went back for a follow-up with their respiratory physician). To begin the analysis, the databases that contained the health survey results and the PSG data were merged. In order to determine the predictors of CPAP adherence in those that were prescribed CPAP, baseline characteristics including age, daytime sleepiness, OSA severity, body mass index (BMI), depression measured by patient health questionnaire (PHQ-9), menopausal status, antidepressant medication, smoking status, restless leg syndrome, marital status, bed partner status, snoring severity, occupational injury, neck circumference, mood disorder, anxiety disorder, periodic limb movement (PLM), hypertension, myocardial infraction, cardiac arrhythmia, stroke, income level, alcohol consumption, education, motor vehicle accident rate, gender, and sleep aid medication were summarized as mean values of proportions as appropriate. For this analysis, education was used as a marker for socioeconomic status because many patients were retired with a low income, but their accumulated asset may have increased their socioeconomic status. Also, higher education is associated with a better health status because those with a higher education tend to understand

the seriousness of OSA and the need to adhere to CPAP better and as a result, adhere more to CPAP compared to those that are not as educated. As a result, using education as a marker of socioeconomic status helped us to determine if people with higher education will be more adherent to CPAP in this study.

We had a relatively large sample size and we wanted to determine which factors, including continuous and categorical variables, would predict CPAP adherence. As a result, a two-sample t-test was performed for continuous variables and χ^2 test was used for non-continuous or categorical variables between the adherent and the non-adherent groups. Group differences were also tested by using χ^2 test. Logistic regression was used to model the odds of using CPAP in those that were prescribed CPAP and those that were not prescribed CPAP. A P value of < 0.05 was considered to be statistically significant. Lastly, statistical analysis was performed with SAS software, version 9.4 (SAS Institute, Inc., Cary. NC).

3.7 Potential predictors of CPAP adherence

Various CPAP adherence predictors and determinants were evaluated within this cohort in this research (Table 1.2).

Chapter 4: Results

4.1 The study population

2,281 patients were enrolled in the original study. We were able to identify 1,250 patient charts for analysis. These patients were all recruited at UBC sleep clinic, underwent PSG, filled out study questionnaire and had available clinic follow-up data within the reviewed charts. Of these 1,250 patients, 844 were prescribed CPAP by a sleep physician and 406 were not prescribed CPAP (Figure 4.1). Since we wanted to investigate the predictors and determinants of CPAP adherence, we focused on patients that were prescribed CPAP. Moreover, out of those that were prescribed CPAP, 421 (49.9%) adhered to CPAP and 423 (50.1%) did not adhere to CPAP.

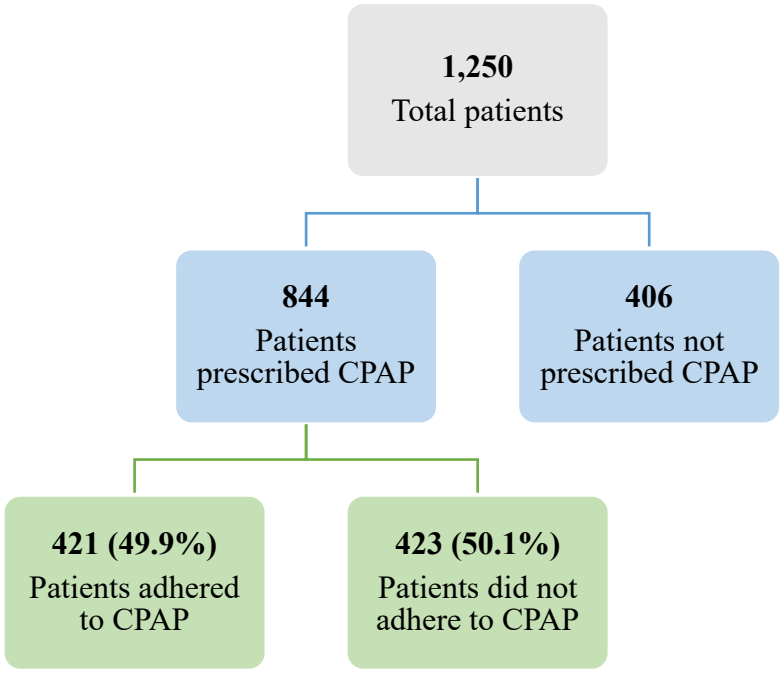

Figure 4.1. Cohort sample size. Overall, 1,250 patients were identified, of which 844 patients were prescribed CPAP and 406 were not prescribed CPAP. Out of those that were prescribed CPAP, 421 patients adhered to CPAP and 423 patients did not adhere to CPAP.

4.2 The correlation between different predictors of CPAP adherence in those that adhered and did not adhere to CPAP

Multivariate analysis (Table 4.2.1 and Table 4.2.2) indicated that CPAP adherence was only associated with one independent variable, which was the severity of OSA as measured by AHI (p=<0.0001).

Table 4.2.1. The correlation between continuous variables and CPAP adherence in adherent and non-adherent group using t-test.

Variables	t-test P	Adherent patients	Non-adherent patients	Standard deviation (Adherent)	Standard deviation (Non-adherent)
AHI (apneic events/hour)	**<0.0001**	**34**	**27**	**25**	**21**
Age (years)	0.80	51	51	11	11
ESS (points)	0.63	11	11	4.6	4.4
BMI (kg/m^2)	0.38	33	32	6.8	7.2
Depression-PHQ-9 (points)	0.68	16	16	5.6	5.7
Menopausal status (years)	0.78	3.6	3.4	6.0	4.5

Definition of abbreviations: AHI = apnea–hypopnea index; BMI = body mass index; ESS = Epworth Sleepiness Scale; PHQ-9=patient health questionnaire.

*Results presented as mean unless otherwise indicated.
Significant level for p-value: <0.05.

Table 4.2.2. Frequency of categorical variables by adherent and non-adherent using Chi-squared test.

Variables	Chi-Squared P	Adherent patients (%)	Non-adherent patients (%)
Antidepressant medication (< 1 night/week)	0.57	95	96
Gender (males)	0.97	73	73
Smoking status (current smokers)	0.91	16	16
Restless leg syndrome	0.76	4.2	4.6
Marital status (living with spouse)	0.21	67	71
Bed partner status (living with a partner)	0.20	70	74
Snoring severity (≥ once/week)	0.52	95	94
Occupational injury	0.16	9.5	13
Neck circumference (17"≥)	0.97	74	74
Mood disorder	0.17	22	18
Anxiety disorder	0.84	7.1	7.5
Periodic limb movement	0.44	0.6	1.2
Hypertension	0.05	25	19
Myocardial infraction	0.78	4.2	3.8
Cardiac arrhythmia	0.75	6.6	7.2
Stroke	0.29	1.8	0.87
Income level (>$40,000)	0.19	70	75
Alcohol consumption (1 drink/day ≥)	0.13	93	90
Education (≥ college degree)	0.15	63	57
Car crashes	0.96	16	16
Sleep aid medication (< 1 night/week)	0.30	88	85

*Results presented as frequency unless otherwise indicated.
Significant level for p-value: <0.05.

4.2.1 AHI and adherence

There was a strong association between AHI and CPAP adherence within our cohort. In fact, AHI was the only predictor significantly associated with CPAP adherence. After performing a two-sample t-test, we found the p-value between the two variables to be <0.0001 with average mean in the adherers and non-adherers to be 34 ± 25 apneic events/hour and 27 ± 21 apneic events/hour respectively (Table 4.2.1). We also categorized patients into mild OSA (5-14), moderate OSA (15-29), severe OSA (≥30) (Figure 4.2.1). [104] The correlation was tested once more and a p-value of <0.0001 was observed, which suggests that there is a correlation between OSA severity categories and CPAP adherence (Table 4.2.3). In figure 4.2.1, we can see the overall pattern of adherence increases as the severity of OSA increases. 57% of those with an AHI ≥30 events/hour were adherent to CPAP compared to 50% of those with AHI ≥15, but <30 and 32% of those with AHI ≥5, but <15.

Table 4.2.3. OSA severity categories and CPAP adherence.

AHI (apneic events/hour)	Adherent	Non-adherent
Mild: ≥5, but <15	16%	34%
Moderate: ≥15, but <30	28%	28%
Total AHI <30	57%	68%
Severe: ≥30	43%	32%

Definition of abbreviations: AHI = apnea/hypopnea index; CPAP = continuous positive airway pressure; OSA = obstructive sleep apnea.

Adherent patients: continuous positive airway pressure (CPAP) use ≥4hours/night for 70%.
Non-adherent patients: CPAP use <4 hours/night.

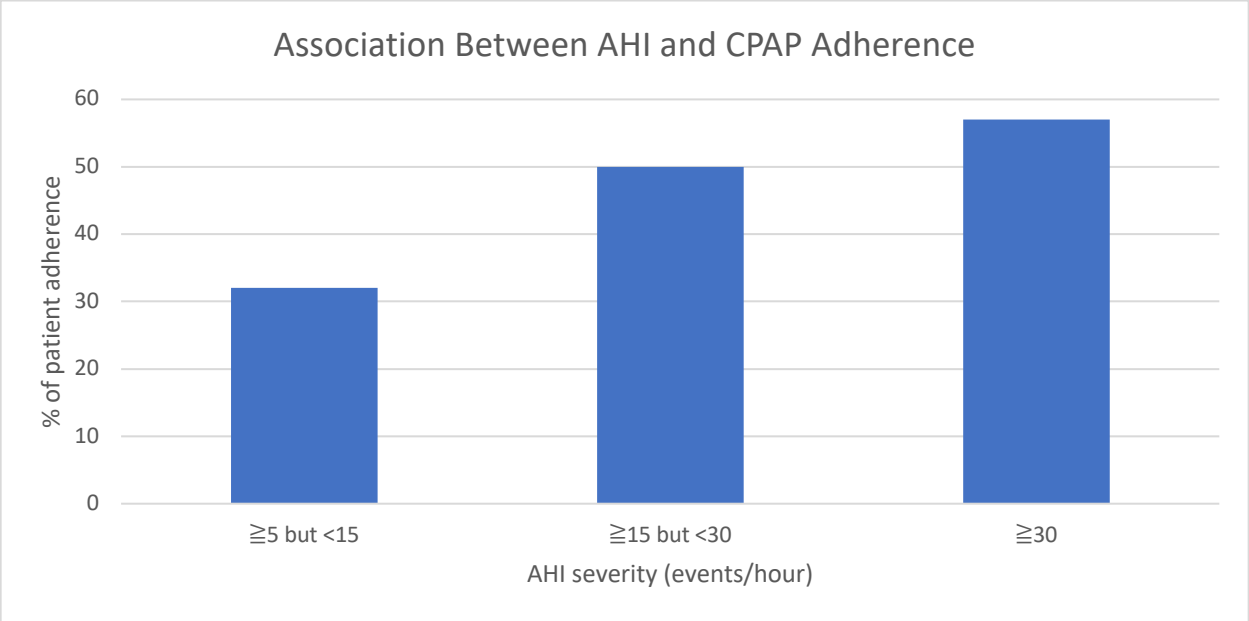

Figure 4.2.1. Association between AHI and CPAP adherence. As shown in the figure, the more severe the OSA, the more patients adhered to CPAP.

4.2.2 Age and adherence

The age of the patients was obtained from the patients' medical history charts and their age at the time of their PSG test was recorded. However, similar to many other studies, we found no association between age in those that adhered and did not adhere to CPAP (p=0.60) (Table 4.2.1). The mean age of those who adhered to CPAP was 51 ± 11 years, which was the same as the mean age of those who did not adhere to CPAP (51 ± 11).

4.2.3 ESS and adherence

ESS, which is a validated self-administered questionnaire, was used to measure sleepiness in this population. Mean ESS scores are shown in Table 4.2.1. The mean ESS for subjects that adhered to CPAP was 11 ± 4.6 points, which was similar to those that did not adhere to CPAP 11 ± 4.4 points. Having an ESS of 11 points means that the patients had mild EDS. There was no significant difference in ESS mean among those that adhered and those that did not adhere

(p=0.63). one of the reasons as to why ESS was not one of the predictors of CPAP adherence could be due to the fact that sleepiness was self-reported so the results may not have been accurate whereas, for AHI, we had the actual results from the PSG test, and it was more accurate. The other reason could be because sleepiness may have been caused from other factors other than OSA such as PLM or the patients may have been tired for other reasons. As a result, they were put on CPAP, so their sleepiness improved. One downside is that we do not know how much their sleepiness improved on CPAP.

4.2.4 BMI and adherence

Subjects' BMI was calculated from reviewing their medical charts and obtaining their weight and height. However, after analysing the data, we found no significant association between BMI and CPAP adherence (p=0.38) (Table 4.2.1). Those that adhered to CPAP had a BMI of 33 ± 6.8 kg/m^2, whereas those that did not adhere had a BMI of 32 ± 7.28 kg/m^2. Furthermore, similar to previously mentioned variables, the BMI was categorised into normal (18.5-24.9), overweight (25-29.9), obese I (30-34.9), obese II (35-39.9) and obese III (>40) (Table 4.2.4). There was no association between different BMI categories and CPAP adherence (p=0.20). Surprisingly, those who were overweight (BMI=25-29.9) were much less adherent to CPAP compared to the other BMI categories. However, the results were again insignificant. The cause of OSA in those that have normal BMI or are underweight is multifactorial, but it is mainly due to having enlarged large tonsils. Those with a larger tonsil tend to have greater resistance in their upper airway, which leads to its collapse. [105] Also, abnormal anatomic structure of the nose, in particular septal deviation, may cause symptoms of OSA due to the reduction of nasal airflow and elevated nasal airway resistance. [106]

Table 4.2.4. BMI categories and CPAP adherence.

BMI category (kg/m^2)	Adherent	Non-adherent
Normal weight:18.5-24.9	18%	14%
Over weight: 25.0-29.9	27%	33%
Obese I: 30.0-34.9	26%	26%
Obese II: 35-39.9	15%	15%
Obese III: >40	14%	12%

Definition of abbreviations: BMI = body mass index; CPAP = continuous positive airway pressure.

4.2.5 Depression and adherence

PHQ-9 is a validated questionnaire-based depression scale, which is commonly used to assist primary care practitioners to diagnose depression. [107] Subjects' PHQ-9 scores were obtained through patients' health questionnaire. In this study, there was no significant difference in PHQ-9 scores between those who adhered and did not adhere to CPAP (p=0.68) (Table 4.2.1). The score of those that adhered to CPAP was 16 ± 5.6 points, which was similar to those that did not adhere to CPAP 16 ± 5.7 points. A PHQ-9 score of 16 indicates moderately severe depression.

4.2.6 Menopausal status and adherence

Questions were asked regarding menopausal status in the health questionnaire. Subjects menopausal status were classified as follows: 1) regular menstrual cycles, irregular menstrual cycles—classified as premenopausal, 2) complete absence of periods—post-menopausal, and 3) peri-menopausal. After performing statistical analysis, there was no significant association between menopausal status in women and CPAP adherence (p=0.78) (Table 4.2.1). Women who adhered to CPAP were on average 3.6 ± 6.0 years to their post-menopausal stage, which was very similar to those who did not adhere to CPAP with a mean of 3.4 ± 4.5 years.

4.2.7 Antidepressant medication and adherence

Patients were divided into two groups including those who took antidepressant medication <1 night/week and those who took antidepressant medication ≥ 1 night/week. After testing for the amount of antidepressant medication intake in those who adhered and did not adhere to CPAP, we concluded that there was no significant association between antidepressant medication intake and CPAP adherence (p=0.57) (Table 4.2.2). Of those that adhered to CPAP, 95% of them took antidepressant medication < 1 night/week, whereas 96% of those who did not adhere to CPAP took antidepressant medication < 1 night/week.

4.2.8 Gender and adherence

In general, men have less stable sleep architecture, and greater number of sleep-wake transitions than women, which may predispose to respiratory control system instability and eventually apneas. There were 226 females and 618 males in this study. Similar to many other studies, we did not find a significant association between males and females and whether one is more adherent than the other (p=0.97) (Table 4.2.2). We found 73% of the population in the adherent group to be male, which was similar to the non-adherent group.

4.2.9 Smoking status and adherence

In general, those who smoke tend to be less adherent to CPAP. Those who smoke are more susceptible to upper airway discomfort and as a result, less likely to take advice from the healthcare providers. [108] This latter theory is also confirmed by McArdle and colleagues, who reported that those who smoked were more likely to refuse CPAP therapy. [22] After performing chi-squared test between smoking status of those who adhered and did not adhere to CPAP, not surprisingly, we found no significant association between the two variables (p=0.91) (Table

4.2.2). We found that 16% of those in the adherent group smoked. Similarly, 16% of those in the non-adherent group smoked.

4.2.10 Restless leg syndrome and adherence

After analysing for restless leg syndrome from the health questionnaire, we found that there was no significant association between CPAP adherence and restless leg syndrome (p=0.76) (Table 4.2.2). 4.2% of those that adhered to CPAP had restless leg syndrome. Similarly, 4.6% of those that did not adhere to CPAP had restless leg syndrome.

4.2.11 Marital status and adherence

A patient's perception of the spouse's support increases their adherence to CPAP therapy and as a result, married patients tend to be more adherent to CPAP than those that either live alone or are not married. [36] Consequently, many studies have identified being married as a factor for CPAP adherence. However, in this study, it was not one of the predictors of CPAP adherence (p=0.21) (Table 4.2.2). Patients were divided to the "not married" category if they were: 1) widowed, 2) divorced, 3) separated but not divorced, and 4) never married. In this study, we found that of those who adhered to CPAP, 67% of them were married, whereas, 71% of those in the non-adherent group were married.

4.2.12 Bed partner and adherence

Reports in the literature indicate that those who have a bed partner tend to adhere more to CPAP because they have more social support. [63] Also, sleeping with a bed partner who provides feedback on the symptomatic improvements such as snoring of the patient may increase CPAP adherence. [25] However, in this study, we found no significant association between CPAP adherence and having a bed partner (p=0.20) (Table 4.2.2). In our cohort, 70% of those who

adhered to CPAP had a bed partner, whereas, 74% of those that did not adhered to CPAP had a bed partner.

4.2.13 Snoring severity and adherence

Snoring was divided according to whether the patient had been told by others that they snore more than once a week or more. In this study, snoring was not found to be a predictor of CPAP (p=0.52) (Table 4.2.2). 95% of those in the adherent group snored ≥ once/week. Similarly, 94% of those in the non-adherent group snored ≥ once/week.

4.2.14 Occupational injury and adherence

We did not find a significant association between CPAP adherence and occupational injury (p=0.16) (Table 4.2.2). Of those in the adherent group, 9.5% had occupational injury whereas, 13% of those in the non-adherent group had occupational injury.

4.2.15 Neck circumference and adherence

From the results of this study, we found no significant association between neck circumference and CPAP adherence (p=0.97) (Table 4.2.2). A neck circumference of 17" was chosen as the cutoff point as the neck circumference of men is normally around 20" and for women around 14". Consequently, there was no difference in CPAP adherence between those who had a neck circumference of less than 17" and those who had a neck circumference of 17" or more.

4.2.16 Mood disorder and adherence

In general, those who enjoy the activities in their life tend to have greater motivation to adhere to CPAP and those with mood disorder have poorer adherence. Similar to many studies that found no association between the two variables, us too did not find a significant association between mood disorder (i.e. depression) and CPAP adherence (p=0.17) (Table 4.2.2). In the adherent

group, 22% had mood disorder whereas, in the non-adherent group, 18% of the subjects had mood disorder.

4.2.17 Anxiety disorder and adherence

We found no correlation between CPAP adherence and anxiety disorder (i.e. panic disorder) (p=0.84) (Table 4.2.2). 7.1% of those in the adherent group had anxiety disorder compared to 7.5% in the non-adherent group.

4.2.18 Periodic limb movement and adherence

Periodic limb movement (PLM) is very common in those who have OSA. However, in this study, we did not find an association between CPAP adherence and PLM (p=0.44) (Table 4.2.2). Only 0.6% of those in the adherent group had PLM compared to 1.2% in the non-adherent group.

4.2.19 Hypertension and adherence

Many studies have reported a correlation between hypertension and CPAP adherence and consider it as a strong predictor of CPAP adherence. These studies have shown that OSA may contribute to poor control of blood pressure and that 70% of patients with hypertension have OSA. [109]Accordingly, international guidelines have recognized OSA as one of the most common risk factors of hypertension. However, studies are inconsistent with their findings regarding whether or not those with hypertension adhere to CPAP. In our study, the association between adherence and hypertension was not strong enough for us to count hypertension as one of the predictors of CPAP (p=0.05) (Table 4.2.2). This may be due to the fact that hypertension was self-reported and that patients may have misreported whether or not they had hypertension. In addition, 25% of those in the adherent group had hypertension compared to 19% in the non-adherent group. This may be due to the fact that those with higher hypertension might have been

trying to lower their high blood pressure by using CPAP and trying to improve their quality of life in general.

4.2.20 Myocardial infraction and adherence

According to the results from this study, myocardial infraction (i.e. heart attack) was not one of the predictors of CPAP adherence (p=0.78) (Table 4.2.2). According to our results, 4.2% of those in the adherent group had heart attack compared to 3.8% in the non-adherent group.

4.2.21 Cardiac arrhythmia and adherence

According to the results from this study, no association was found between cardiac arrhythmia (i.e. irregular heartbeat) and CPAP adherence (p=0.75) (Table 4.2.2). 6.6% of those in the adherent group had irregular heart beat compared to 7.2% in the non-adherent group.

4.2.22 Stroke and adherence

OSA has been suggested as a modifiable and independent risk factor for stroke, and some studies have demonstrated that those with stroke and OSA are at increased risk of death or new vascular events. [110] However, after analysing our results, we found no significant association between stroke and CPAP adherence (p=0.29) (Table 4.2.2). However, based on our results, 1.8% of those in the adherent group had stroke compared to only 0.87% in the non-adherent group.

4.2.23 Income level and adherence

Many studies have found income level to be a predictor of CPAP adherence. Low income status is correlated with poorer health literacy, and difficulty accessing healthcare (i.e. sleep clinics and PSG test), but more specifically co-pays, needing childcare and other support, getting time off work and transport to appointments. According to Statistics Canada, the average income in British Columbia in 2015 was around $50,000 before tax and around $40,000 after tax. [111]As a result, the income in our study cohort was divided into those who earned $40,000 or less and

those who earned more than $40,000. However, after analysing the data, we found no significant association between income and CPAP adherence (p=0.19) (Table 4.2.2). In addition, 70% of those in the adherent group earned >$40,000 compared to 75% in the non-adherent group.

4.2.24 Alcohol consumption and adherence

The role of alcohol as a predictor for CPAP adherence is still controversial as the results from various studies are inconsistent. However, one thing that is certain is that alcohol consumption increases nasal resistance. [112] Depending on the type of alcohol consumed, patients were divided into three groups including: 1) wine, 2) beer and 3) liquor. Alcohol consumption was further divided into those who had one glass or less per day and those who consumed more than one glass per day. After analysing the data, there was no significant association between wine consumption, beer consumption and liquor consumption and CPAP adherence with p-values being 0.46, 0.10 and 0.95 respectively. Moreover, the different alcohol consumptions were then combined to test for the overall alcohol consumption and CPAP adherence. Again, we found no significant association between the two variables (p=0.13) (Table 4.2.2). 93% of those in the adherent group drank one glass or less per day compared to 90% in the non-adherent group.

4.2.25 Education and adherence

Patients were divided into two groups, those who had a college degree or higher and those without a college degree (i.e. high school diploma or lower). In total, 451 patients had a college degree or higher, whereas, 302 patients did not. After analysing the results, there was no correlation between education and CPAP adherence (p=0.14) (Table 4.2.2). Unfortunately, postsecondary education is expensive in Vancouver and many patients may not be able to afford to go to college. As a result, they may not get a high paying job and may not be able to afford

CPAP. Similarly, those who can afford to buy CPAP may not understand the importance of adhering to it and consequently, they may have lower adherence rate.

4.2.26 Car crashes and adherence

Many of the published studies found a correlation between the rate of car crashes and CPAP adherence. This may be due to the fact that those who have OSA do not get sufficient sleep during the night and as a result, they get sleepy while behind the wheel. It is also possible that car crashes result from a failure of reaction, which eventually leads to driving off the road or crashing at higher speeds. [113] However, in our study, no significant association was found between the two variables (p=0.96) (Table 4.2.2). 16% of patients in the adherent group were in a car crash, which is similar to those in the non-adherent group.

4.2.27 Sleeping aid medication and adherence

Patients were divided into two groups including: 1) those who took sleeping aid medication < 1 night/week, and 2) those who took sleeping aid medication ≥ 1 night/week. We further found no significant association between CPAP adherence and the intake of sleeping aids (p=0.30) (Table 4.2.2).

Chapter 5: Discussion

5.1 Summary of the results

The main findings from this single centered retrospective cohort study that included 1,250 patients were that 1) only 49.9% of the patients adhered to CPAP and 2) the only predictor that affects CPAP adherence was the severity of OSA, which was measured by AHI. There was surprisingly no significant association between the other variables including: age, daytime sleepiness (ESS), BMI, PHQ-9, menopausal status, antidepressant medication, smoking status, restless leg syndrome, marital status, bed partner status, snoring severity, occupational injury, neck circumference, mood disorder, anxiety disorder, PLM, hypertension, myocardial infraction, cardiac arrhythmia, stroke, income level, alcohol consumption, education, motor vehicle rate, gender, and sleep aid medication and CPAP adherence. However, some of these variables did trend towards significance and might have been with a larger sample size (though this is speculative).

5.2 CPAP adherence

CPAP adherence was defined as using the device for ≥ 4 hours per day for 70% of the time being used. Only 421 patients out of 844 adhered to CPAP, which indicates that only 49.9% of the patients in this study adhered to CPAP. Published CPAP adherence rates range from 30-60%, and of those who continue to use the device, 20-30% apply it insufficiently. [10] Moreover, over the past twenty years or so, there has been no significant improvements in CPAP adherence. Even though our result of 49.9% is within the higher range of published studies, it is still low knowing the fact that CPAP is the main treatment for OSA.

5.3 OSA severity

OSA severity, as measured by AHI, is one of the most commonly examined factors in the study of sleep apnea. AHI is commonly defined as the number of apneas and hypopneas per hour while asleep. Although AHI is commonly identified as influential on CPAP adherence, the relationships are relatively inconsistent. Adding to this pool of knowledge, as predicted in our hypothesis, there was a correlation between AHI and CPAP adherence within our cohort (p=<0.0001). In other words, as the patients' OSA was more severe, their adherence to CPAP improved. The mean AHI for those who adhered to CPAP was 34 whereas the mean AHI for those who did not adhere to CPAP was 27. Moreover, 43% of those with AHI ≥30 events/hour were adherent to CPAP compared to 32% in the non-adherent group. On the other hand, 57% of those with AHI <30 events/hour were adherent to CPAP compared to 68% in the non-adherent group. Moreover, our findings support the results of other studies in the literature. [20, 22, 36, 44, 114] According to McArdle and colleagues, AHI was a significant determinant of CPAP adherence (p=0.004) and as the severity of OSA increased in their cohort, the use of CPAP also increased. [22] Similarly, in another study done by Gagnadoux and colleagues, the severity of OSA was a determinant of CPAP adherence increased (p=0.003). [36]

5.4 Strengths

This study has a number of strengths. The most important strength of this study is that it is the first and largest of its kind in Canada. No other study regarding the predictors of CPAP adherence has been done in Canada and within a Canadian context. As a result, this study may help in improving patient care and lower OSA burden in Canada. Similarly, this study was done from 2003 to 2009, which allowed us to look at the patients' medical charts and health surveys comprehensively. By doing so, we were able to accumulate data for a large number of patients and collect as much information as we could from the charts and the health surveys. Moreover,

we uniformly investigated every patient's medical chart who came to UBC sleep clinic for a PSG test. Consequently, we were able to characterise our patients in a consistent manner. In other words, we were able to collect a subset of the "real world" as the patients were not selected for. Lastly, we found a between AHI and CPAP adherence, which is consistent with other published studies.

5.5 Limitations

There are multiple important limitations within this study. The most important limitation of this study is that most of the collected data was of subjective (i.e. the sleep physician's notes from the patient's last visit), we did not have objective data, as this was not downloaded data from the CPAP devices or from PSG tests. This was mainly because during these times, objective adherence from chips in the machines was not commonly available in BC. This could have potentially removed data for patients who may have used the device for ≥ 4 hours when they used CPAP at home, as the doctor may have noted them as being non-adherent. Another limitation of this study was that it was from a single canter, meaning that it was conducted only in one clinic in one geographic area (UBC sleep clinic), which may limit its generalizability to other health regions. Additionally, the majority of the comorbidities were self-reported from the health questionnaire, which could potentially introduce reporting bias in this study. Lastly, based on the literature, CPAP adherence is established fairly early after initiating the therapy and after 2-3 months of using the device, adherence does not decrease. However, in this study, it is unclear whether the patients that adhered to CPAP will continue to use it after a few years of initiating it because we only measured adherence at one point in time (i.e. patients' follow-up appointment).

5.6 Conclusions

OSA is a common respiratory disorder and commonly characterised as repetitive episodes of obstruction of the upper airway while the patient is asleep, which potentially leads to the fragmentation and hypoxemia of sleep. [10] The most common symptoms of OSA include silent pauses in breathing while asleep, loud snoring, excessive daytime sleepiness and frequent nocturnal awakening. [10] OSA affects 3-9% of the general population and is demonstrated to be a risk factor for cardiovascular diseases, increased rate of motor vehicle crashes, low quality of life, daytime sleepiness and impaired neurocognitive performance. [115] Direct expenses of OSA burden in Canada alone in 2008 was around 145 million dollars. [5]

Since the pervasive health effects of untreated OSA are well described, CPAP, which improves numerous OSA-specific health outcomes, should be considered as its primary treatment.[116,117] CPAP adherence rates in the literature range from 4 to 6 hours per night. However, most studies have defined CPAP adherence as using the device ≥4 hours for ≥70% of the time when using the machine. Moreover, a significant proportion of those who have tried CPAP cannot adhere to the device and eventually abandon it and seek for alternate treatments. [115] Despite numerous technological advancements such as quieter pumps, softer and more comfortable masks, and improved portability, CPAP adherence still remains a challenge to OSA patients ranging from 30-60%, and of those who continue to use the device, 20-30% apply it insufficiently. [10] There are many reasons as to why patients may not adhere to CPAP. Some of the most common reasons include comfort, convenience, claustrophobia, socioeconomic status, gender, mask side effects and severity of OSA. Also, many patients remain undiagnosed as the current health care system infrastructure cannot keep up with the increasing demand for diagnostic in-laboratory PSG. [118]As a result, it is critical to study access to sleep clinics along with diagnostic sleep laboratories given then recent trends. [117]

None of the studies that investigated the predictors of CPAP adherence were done in Canada. As a result, this study is the first and the largest of its kind that includes Canadian OSA patients. The goal of this retrospective cohort study was to extensively look at various predictors including severity of OSA, daytime sleepiness, age, BMI, PHQ-9, menopausal status, antidepressant medication, smoking status, restless leg syndrome, marital status, bed partner status, snoring severity, occupational injury, neck circumference, mood disorder, anxiety disorder, PLM, hypertension, myocardial infraction, cardiac arrhythmia, stroke, income level, alcohol consumption, education, motor vehicle rate, gender, and sleep aid medication. Out of 844 patients that were prescribed CPAP, only 421 (49.9%) adhered to CPAP. Also, only severity of OSA was correlated with CPAP adherence ($p < 0.0001$). In other words, as the severity of OSA increased, patients adhered more to CPAP. The findings of this study may result in the improvement of patient care and patients' overall quality of life. More importantly, we can lower OSA burden in Canada.

5.7 Future studies

As mentioned previously, OSA has many negative health outcomes. Some of the most common ones include increased risk for CV co-morbidity [4], motor vehicle crashes [119] and hypertension [120]. In the short term, the next steps following this study would be to identify: 1) whether CPAP adherence results in better outcomes (i.e. cardiovascular outcomes, a lower risk of motor vehicle crashes and occupational injuries), and 2) whether other interventions (i.e. telemedicine, education, technological and behavioral) can improve adherence in Canadians. Doing so may enhance patient care and quality of life within the Canadian population and eventually lower OSA burden.

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Appendices

Appendix A: Health questionnaire

ID Number ☐☐☐☐☐ Today's Date ☐☐ / ☐☐ / ☐☐ MM/DD/YY

Vancouver Coastal Health Authority

North Shore/Coast Garibaldi, Vancouver & Richmond

DEMOGRAPHICS:

1. What is your date of birth: ☐☐ / ☐☐ / ☐☐☐☐ MM/DD/YYYY

2. What is your gender:

   ☐ Male ☐ Female

3. What is your current Marital status:

   ☐ never married
   ☐ married
   ☐ separated but not divorced
   ☐ divorced
   ☐ widowed/widower

4. Does another person regularly share your bed/sleep with you? :

   ☐ Yes ☐ No

5. What is the highest level of education you have completed?

   ☐ Less than high school diploma
   ☐ High school diploma
   ☐ College or University degree
   ☐ Masters or above

SLEEP HABITS:

6. After you have turned out the lights to fall asleep, how long does it usually take you to fall asleep?

   ☐ 0-15 minutes
   ☐ 16-30 minutes
   ☐ 31-60 minutes
   ☐ 61-120 minutes
   ☐ more than 2 hours

7. On average, how many hours of sleep do you get per night on weekdays?

   ☐ ≤5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10+ hours

   On weekends?

   ☐ ≤5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10+ hours

8. On average, how many hours do you spend napping during the daytime on weekdays?

   ☐ None or nearly none ☐ 1-2 ☐ 3-4 ☐ 5-6 ☐ 7+ hours

   On weekends?

   ☐ None or nearly none ☐ 1-2 ☐ 3-4 ☐ 5-6 ☐ 7+ hours

9. Over the last 24 months, which of the following, if any, did you have to do to keep from falling asleep at work? Choose all that apply.

- ☐ I don't have any problems staying awake at work
- ☐ chew gum or candy
- ☐ eat
- ☐ smoke
- ☐ chew tobacco
- ☐ drink coffee
- ☐ drink other caffeinated beverages
- ☐ listen to radio/music
- ☐ moves around/keep physically active
- ☐ other (please describe)

SLEEP-RELATED SYMPTOMS:

10. Do you have difficulty falling or staying asleep?

- ☐ never
- ☐ rarely (less than one night per week)
- ☐ sometimes (1-2 nights/week)
- ☐ frequently (3-4 nights/week)
- ☐ almost always (5-7 nights/week)

11. On average, how many days/nights during the last month have you snored or been told you snored?

- ☐ never
- ☐ rarely (less than once per week)
- ☐ sometimes (1-2/week)
- ☐ frequently (3-4/week)
- ☐ almost always (5-7/week)
- ☐ not sure

12. When falling asleep, how often do you have "restless legs" (a feeling of crawling, aching, or inability to keep legs still)?

- ☐ never
- ☐ rarely (less than one night per week)
- ☐ sometimes (1-2 nights/week)
- ☐ frequently (3-4 nights/week)
- ☐ almost always (5-7 nights/week)

13. In the last 24 months, have you found that you awaken and briefly cannot move your entire body (i.e. felt paralyzed as opposed to feeling very tired)?

- ☐ Yes
- ☐ No

14. In the last 24 months, have you seen or heard things that don't exist upon waking up or falling asleep?

- ☐ Yes
- ☐ No

15. In the last 24 months, have you had sudden muscular weakness (e.g. buckling of your knees) associated with emotion (e.g. while laughing or after hearing a joke)?

- ☐ Yes
- ☐ No

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DAYTIME ACTIVITY

16. In the last 30 days, how likely are you to doze off or fall asleep in the following situations (in contrast to feeling just tired)? This refers to your usual way of life in recent times. Even if you have not done some of these things recently try to work out how they would have affected you

	HIGH CHANCE	MODERATE CHANCE	SLIGHT CHANCE	NO CHANCE
a. Sitting and reading	☐	☐	☐	☐
b. Watching TV	☐	☐	☐	☐
c. Sitting inactive in a public place (e.g. theater, Church)	☐	☐	☐	☐
d. As a passenger in a car for an hour without a break	☐	☐	☐	☐
e. Lying down to rest in the afternoon when circumstances permit.	☐	☐	☐	☐
f. Sitting and talking to someone.	☐	☐	☐	☐
g. Sitting quietly after lunch without alcohol.	☐	☐	☐	☐
h. In a car while stopped for a few minutes in traffic.	☐	☐	☐	☐

HEALTH HABITS:

17. Do you currently smoke cigarettes?

☐ Yes ⇨ If Yes, How many per day? ☐ 1-4 ☐ 5-14 ☐ 15-24 ☐ 25-34 ☐ 35-44 ☐ 45+

☐ No

How many years? ☐☐

18. Please fill in your average use of the following beverages during the past year.

	never or less than once per month	1-3 per month	1 per week	2-4 per week	5-6 per week	1 per day	2-3 per day	4-5 per day	6-10 per day	11-20 per day	more than 20 day
a. Cola or other carbonated beverage with caffeine, e.g. Coke, Pepsi, Mountain Dew (consider the serving size as 1 glass, bottle, or can)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
b. Tea or iced tea with caffeine (1 cup or glass), not herbal teas	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
c. Coffee with caffeine (1 cup)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
d. Beer (1glass, bottle, or can)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
e. Wine (4 oz glass)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
f. Liquor, e.g. vodka, gin, etc. (1 drink or shot)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

OCCUPATIONAL:

19. Which of the following best describes your current occupational status?

- ☐ employee
- ☐ self-employed
- ☐ disabled
- ☐ retired
- ☐ unemployed but looking for work
- ☐ unpaid work at home
- ☐ full-time student

20. In total over the last 24 months, approximately how many months did you work? ☐☐

21. On average, over the last 24 months, during weeks that you worked, approximately how many hours did you work per week?

☐☐☐

22. What was your predominant occupation over the last 24 months (describe)?

_____

23. Please also mark the ONE description that best characterized your occupation over the last 24 months:

Primary Resources:

- ☐ Agriculture
- ☐ Fishing
- ☐ Forestry
- ☐ Oil and Gas or Mineral Resources

Manufacturing:

- ☐ Food and Beverage Products
- ☐ Metal and Non-Metallic Mineral Products
- ☐ Other Products:
- ☐ Petroleum, Coal, Rubber, Plastic, and Chemical Products
- ☐ Wood and Paper Products

Construction:

- ☐ General construction
- ☐ Heavy Construction (e.g bridges, overpasses)
- ☐ Road Construction or Maintenance

Transportation and Warehousing:

- ☐ Warehousing
- ☐ Transportation and Related Services

Trade:

- ☐ Retail
- ☐ Wholesale

- ☐ **Working for the Federal Government**
- ☐ **Military Service**
- ☐ **Public Administration excluding working for the federal government (e.g. law enforcement, working for the local government)**

Service Sector:

- ☐ Accommodation, Food, and Leisure Services
- ☐ Business Services (e.g. accounting, law office)
- ☐ Education
- ☐ Other Services
- ☐ Healthcare and Social Assistance
- ☐ Professional, Scientific, and Technical Services
- ☐ Utilities

Other:

- ☐ Please describe:_____

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24. As a percentage, how many of each of the following shifts did you work over the last 24 months (total should equal 100%)

Day shift (e.g. 8am -5 pm)		%
Evening shift (e.g. 3 pm-11pm)		%
Nightshift (e.g. 11 pm to 7 am)		%

25. Given the hours you work, how much on average would someone employed in a field like yours earn in a year?

- ☐ $0-20 000
- ☐ 21,000 -40,000
- ☐ 41,000-60,000
- ☐ 61,000-80,000
- ☐ 81,000-100,000
- ☐ >100, 000

26. Over the last 24 months, did you suffer an occupational injury?

☐ Yes ☐ No

If YES, please answer the following cluster of questions.
If NO, please skip to question 27.

	0	1	2	3	4+
a. If so, how many injuries did you have?	☐	☐	☐	☐	☐
b. How many of these, if any, were reported to the Workers Compensation Board ?	☐	☐	☐	☐	☐
c. In how many of these, if any, do you think sleepiness or fatigue **in you** contributed?	☐	☐	☐	☐	☐
d. In how many of these, if any, was an emergency room visit required?	☐	☐	☐	☐	☐

e. Please take a moment and tell us a few words about each incident

27. Over the last 24 months, did you cause an occupational injury to someone else (do not include accidents described in the above question)?

☐ Yes ☐ No

If YES, please answer the following cluster of questions.
If NO, please skip to question 28.

	0	1	2	3	4+
a. How many injuries did you cause?	☐	☐	☐	☐	☐
b. How many of these, if any, were reported to the Workers Compensation Board ?	☐	☐	☐	☐	☐
c. In how many of these, if any, do you think sleepiness or fatigue **in you** contributed?	☐	☐	☐	☐	☐
d. In how many of these, if any, was an emergency room visit required?	☐	☐	☐	☐	☐

e. Please take a moment and tell us a few words about each incident

MEDICAL HISTORY:

28. What is your height? ☐ Feet ☐☐ Inches OR ☐☐☐ cm

29. What is your current weight (to the nearest pound)? ☐☐☐ Pounds OR ☐☐☐ kg

30. When was your weight last measured? Within the last ☐☐ Months

31. What is your neck circumference (e.g. shirt size) to the nearest inch?

☐ ≤11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20 ☐ 21 ☐ 22 ☐ 22+
☐ not sure

32. Check the sentence that best describes your situation

☐ I have remained about the same weight (i.e. within 5 pounds) over the last 24 months.

☐ I have gained 5 or more pounds in the last 24 months
Approximately how many pounds did you gain?
☐ 5-10 ☐ 11-15 ☐ 16-20 ☐ 21-25 ☐ >25

☐ I have lost 5 or more pounds in the last 24 months
Approximately how many pounds did you lose?
☐ 5-10 ☐ 11-15 ☐ 16-20 ☐ 21-25 ☐ >25

☐ I am not sure if I have gained or lost weight as I never weigh myself

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33. Has a **physician diagnosed** you with any of the following disorders (check all that apply)?

Psychiatric:

- ☐ A major mood disorder (e.g. depression)
- ☐ A major anxiety disorder (e.g. panic disorder)

Sleep Disorders:

- ☐ Narcolepsy
- ☐ Restless legs syndrome
- ☐ Periodic Limb Movements

Respiratory:

- ☐ Asthma
- ☐ Emphysema
- ☐ Chronic Bronchitis

Cardiovascular:

- ☐ Hypertension
- ☐ Myocardial infarction (heart attack)
- ☐ Cardiac arrythmias (irregular heartbeat)
- ☐ Angina
- ☐ Congestive heart failure

Endocrine:

- ☐ Diabetes
- ☐ Hypothyroidism (low thyroid level)
- ☐ Polycystic ovarian disease

Neurology:

- ☐ Stroke
- ☐ TIA
- ☐ Seizure

34. Have you been previously diagnosed with obstructive sleep apnea by a physician?

☐ Yes ☐ No

If YES, please answer the following questions.
If NO, please advance to question 35.

a. Was this diagnosis based on a full sleep study in which you slept in the sleep laboratory overnight?

☐ Yes ☐ No

b. Was this diagnosis based on a home oximetry study (i.e. where you wore a probe on your finger overnight)?

☐ Yes ☐ No

c. If you answered NO to the above two questions, please describe how your physician made the diagnosis

d. What treatment are you currently using for obstructive sleep apnea?

- ☐ none
- ☐ Positive airway pressure (e.g. CPAP, BIPAP, smart CPAP)
- ☐ dental appliance
- ☐ other (please describe)

35. Have you had surgery specifically to treat your sleep apnea or snoring?

- ☐ Yes ⇨ If YES, please answer the following question: What kind(s) of surgery did you have? (Mark all that apply)
- ☐ No

  - ☐ sinus surgery
  - ☐ laser surgery of the palate/throat
  - ☐ somnoplasty (radiofrequency ablation) of the tongue
  - ☐ formal uvulopalatopharyngoplasty (UPPP) under general anesthesia in the operating room
  - ☐ other. Please describe:

Over the last 24 months, on average, how often did you take:

Any type of the following to get to or stay asleep? (i.e. sleeping aids)

36. Prescription medication:

- ☐ never
- ☐ very rarely (less than once per month)
- ☐ rarely (less than one night per week but more than once per month)
- ☐ sometimes (1-2 nights or days/week)
- ☐ frequently (3-4 nights or days/week)
- ☐ almost always (5-7 nights or days/week)

Name of medication:

37. Non-prescription medication

- ☐ never
- ☐ very rarely (less than once per month)
- ☐ rarely (less than one night per week but more than once per month)
- ☐ sometimes (1-2 nights or days/week)
- ☐ frequently (3-4 nights or days/week)
- ☐ almost always (5-7 nights or days/week)

Name of medication:

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d. What treatment are you currently using for obstructive sleep apnea?

- ☐ none
- ☐ Positive airway pressure (e.g. CPAP, BIPAP, smart CPAP)
- ☐ dental appliance
- ☐ other (please describe)

35. Have you had surgery specifically to treat your sleep apnea or snoring?

- ☐ Yes ⇨ If YES, please answer the following question: What kind(s) of surgery did you have? (Mark all that apply)
- ☐ No

  - ☐ sinus surgery
  - ☐ laser surgery of the palate/throat
  - ☐ somnoplasty (radiofrequency ablation) of the tongue
  - ☐ formal uvulopalatopharyngoplasty (UPPP) under general anesthesia in the operating room
  - ☐ other. Please describe:

Over the last 24 months, on average, how often did you take:

Any type of the following to get to or stay asleep? (i.e. sleeping aids)

36. Prescription medication:

- ☐ never
- ☐ very rarely (less than once per month)
- ☐ rarely (less than one night per week but more than once per month)
- ☐ sometimes (1-2 nights or days/week)
- ☐ frequently (3-4 nights or days/week)
- ☐ almost always (5-7 nights or days/week)

Name of medication:

37. Non-prescription medication

- ☐ never
- ☐ very rarely (less than once per month)
- ☐ rarely (less than one night per week but more than once per month)
- ☐ sometimes (1-2 nights or days/week)
- ☐ frequently (3-4 nights or days/week)
- ☐ almost always (5-7 nights or days/week)

Name of medication:

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38. Herbal or health food medication

- ☐ never
- ☐ very rarely (less than once per month)
- ☐ rarely (less than one night per week but more than once per month)
- ☐ sometimes (1-2 nights or days/week)
- ☐ frequently (3-4 nights or days/week)
- ☐ almost always (5-7 nights or days/week)

Name of medication: | | | | | | | | | | | | | | | | |

Over the last 24 months, on average how often did you take:

Any type of the following to stay awake? (i.e. stimulants)

39. Prescription medication: (eg. Modafinil, Ritalin)

- ☐ never
- ☐ very rarely (less than once per month)
- ☐ rarely (less than one night per week but more than once per month)
- ☐ sometimes (1-2 nights or days/week)
- ☐ frequently (3-4 nights or days/week)
- ☐ almost always (5-7 nights or days/week)

Name of medication: | | | | | | | | | | | | | | | | |

40. Non-prescription medication (eg. caffeine pills)

- ☐ never
- ☐ very rarely (less than once per month)
- ☐ rarely (less than one night per week but more than once per month)
- ☐ sometimes (1-2 nights or days/week)
- ☐ frequently (3-4 nights or days/week)
- ☐ almost always (5-7 nights or days/week)

Name of medication: | | | | | | | | | | | | | | | | |

Over the last 24 months, on average how often did you take:

Any of the following medications (for any reason)

41. Anti-histamines

- ☐ never
- ☐ very rarely (less than once per month)
- ☐ rarely (less than one night per week but more than once per month)
- ☐ sometimes (1-2 nights or days/week)
- ☐ frequently (3-4 nights or days/week)
- ☐ almost always (5-7 nights or days/week)

42. Antidepressant

- ☐ never
- ☐ very rarely (less than once per month)
- ☐ rarely (less than one night per week but more than once per month)
- ☐ sometimes (1-2 nights or days/week)
- ☐ frequently (3-4 nights or days/week)
- ☐ almost always (5-7 nights or days/week)

43. Other medications: (please list)

_____ _____

_____ _____

_____ _____

Driving Questions:

44. On average over the last 24 months, how many kilometers did you drive per week? ☐☐☐ kilometers

45. Over the last 24 months, did you have any motor vehicle accidents or crashes in which you were driving?

☐ Yes ☐ No

If YES, please answer the following cluster of questions.
If NO, please skip to question 47.

	0	1	2	3	4	5+
a. How many crashes did you have over the last 24 months?	☐	☐	☐	☐	☐	☐
b. In how many of these, if any, was a police report filed?	☐	☐	☐	☐	☐	☐
c. In how many of these, if any, do you think sleepiness or fatigue in you contributed?	☐	☐	☐	☐	☐	☐
d. In how many of these, if any, was total property damage greater than $1000?	☐	☐	☐	☐	☐	☐
e. In how many of these, if any, were any vehicles involved towed away?	☐	☐	☐	☐	☐	☐
f. In how many of these, if any, were emergency room visits required by anyone?	☐	☐	☐	☐	☐	☐
g. In how many of these, if any, were fatalities involved?	☐	☐	☐	☐	☐	☐

46. Over the last 24 months, did you have any near miss motor vehicle accidents or crashes in which you were driving? (i.e. narrowly avoided property damage or bodily harm)

☐ Yes ☐ No

If so, how many did you have, on average, over this time period?

- ☐ <1 per month
- ☐ 1-4 per month
- ☐ 1-2 times per week
- ☐ 3-5 times per week
- ☐ more than 5 times per week but not everyday
- ☐ everyday or almost everyday

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MOOD QUESTIONS:

Over the last two weeks, how often have you been bothered by any of the following problems?

	Not at all	several days	more than half the days	nearly every day
47. Little interest or pleasure in doing things?	☐	☐	☐	☐
48. Feeling down, depressed, or hopeless?	☐	☐	☐	☐
49. Trouble falling/staying asleep, sleeping too much?	☐	☐	☐	☐
50. Feeling tired or having little energy?	☐	☐	☐	☐
51. Poor appetite or overeating?	☐	☐	☐	☐
52. Feeling bad about yourself, or that you are a failure, or have let yourself or your family down?	☐	☐	☐	☐
53. Trouble concentrating on things, such as reading the newspaper or watching TV	☐	☐	☐	☐
54. Moving or speaking so slowly that other people could have noticed. Or the opposite; being so fidgety or restless that you have been moving around more than usual.	☐	☐	☐	☐
55. Thoughts that you would be better off dead or of hurting yourself in some way.	☐	☐	☐	☐

56. If you have checked off any problem on these questions (47-55), how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?

- ☐ Not difficult at all
- ☐ somewhat difficult
- ☐ very difficult
- ☐ extremely difficult

57. **Women Only:** What is your menopausal status:

- ☐ Premenopausal
  - If premenopausal: Are your periods
    - ☐ regular
    - ☐ irregular
- ☐ Post menopausal (i.e. complete absence of periods)
  - If post menopausal, how long ago did your periods completely stop? ☐☐ Years ago
- ☐ Peri-menopausal

Thank you very much for completing the survey. Your information is very important to us and we really appreciate your time and consideration.