A Cross-sectional Survey on The Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease: A Pilot Study

by

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An oral defense of this thesis took place on April 6th, 2021, in front of the following examining committee:

Examining Committee:

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The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

ABSTRACT

Chronic Obstructive Pulmonary Disease (COPD), a progressive respiratory disorder, is the third leading cause of death globally. Temperature and humidity weather extremes influence the respiratory system. A cross-sectional self-reported survey assessed extremes of temperature and humidity on health outcomes in three conditions: moderate or ideal, and extremes of hot and humid, and cold and dry. Due to the challenge of recruitment, we included a small sample of individuals with COPD and related chronic respiratory diseases for this pilot study. Results (n=37, mean age 65 years) found both extreme conditions were associated with lower health status, decreased amount and difficulty level of physical activity, higher exacerbations, increased rescue inhaler use and hospitalizations. Future prospective research should consider confounders, disease severity, individual geographical regions, and spectrums of temperature and humidity. Understanding the effects of temperature on COPD outcomes will help create a foundation of self-management programs for individuals living with COPD conditions.

Keywords: Chronic Obstructive Pulmonary Disease; Temperature; Humidity; Health Status; Physical Activity

AUTHOR'S DECLARATION

I hereby declare that this thesis consists of original work of which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Samantha Mekhuri

STATEMENT OF CONTRIBUTIONS

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication. I have used standard referencing practices to acknowledge ideas, research techniques, or other materials that belong to others. Furthermore, I hereby certify that I am the sole source of the creative works and/or inventive knowledge described in this thesis.

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LIST OF ABBREVIATIONS

BCSS	Breathlessness, Cough, and Sputum Scale
BMI	Body Mass Index
CAT	COPD Assessment Test
COPD	Chronic Obstructive Pulmonary Disease
CPAP	Continuous Positive Airway Pressure
CRA	Comprehensive Respiratory Assessment
CTS	Canadian Thoracic Society
D-PPAC	PROactive Daily Physical Activity in COPD Questionnaire
FEV1	Forced Expiratory Volume in 1 second
FVC	Forced Vital Capacity Ratio
HRQoL	Health-Related Quality of Life
IPAQ	International Physical Activity Questionnaire Short Form
LRI	Lower Respiratory Infection
MCID	Minimum Clinically Important Difference
NIV	Non-invasive Ventilation
PADL	Physical Activity in Daily Life
PEF	Peak Expiratory Flow
PR	Pulmonary Rehabilitation
SGRQ	St. George’s Respiratory Questionnaire
WHO	World Health Organization
6MWT	6-Minute Walk Test

OVERVIEW

Thesis Format

This thesis is divided into five sections:

1. Introduction
2. Literature Review
3. Manuscript: A Cross-Sectional Survey on the Effects of Temperature and Humidity on Health Outcomes in Individuals with COPD
4. Conclusions
5. Appendices

CHAPTER 1: INTRODUCTION

1.1 Introduction to the Thesis

1.1.1 Chronic Obstructive Pulmonary Disease

Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory disorder that causes airways in the lungs to be inflamed and airflow to be obstructed (COPD Fact Sheet, 2018). COPD is one of the top chronic diseases globally; in Canada, approximately 500,000 people over the age of 35 have COPD. COPD is preventable and treatable; however, it is currently one of the top three causes of death worldwide (Halpin et al., 2019). A Global Burden of Diseases, Injuries, and Risk Factors Study found that in 2019, COPD was one of the top ten leading causes of disability-adjusted life-years in individuals aged 50 years and older (Vos et al., 2020). This ranking highlights the need for smoking cessation programs, and to reduce exposure to indoor and outdoor air pollution, especially in low-income, and middle-income countries which comprise 62.6% of COPD's global burden (Vos et al., 2020).

The significant symptoms of COPD are shortness of breath (dyspnea), wheezing, coughing, limitation on physical activity, and exacerbations (experiences of acute worsening of respiratory symptoms and lung function; Alahmari et al., 2015). According to the Centers of Disease Control and Prevention (CDC), the complications that arise due to COPD are physical activity limitations (such as climbing stairs), unable to work, and less engagement in social activities (such as eating out, going to group events; CDC, 2019). Health complications include increased hospitalizations, comorbidities (such as arthritis, heart failure, heart disease, stroke, asthma), mental illnesses, sleep disturbances, and reports of poor health status (CDC, 2019; Miravitlles & Ribera, 2017). In addition, the impact of COPD on the daily functioning of life is fatigue, limitations in daily life activities (getting dressed, doing household chores, engaging in sports and hobbies), emotional, cognitive, and social functioning (Kouijzer et al., 2018). Some individuals with COPD report reduced enjoyment in their life or even the will to live (Kouijzer et al., 2018). Some individuals also reported the need for effective treatment and a multidisciplinary approach for patient care (Kouijzer et al., 2018).

One of the significant risk factors for COPD is smoking (COPD Fact Sheet, 2018). In Canada, smoking is responsible for approximately 80-90% of COPD cases (COPD, 2018). However, non-smokers can develop COPD as well. Some other causes of COPD are genetics, environmental factors such as air pollution and dust, second-hand smoke, and frequent lung infections earlier on in life (COPD, 2018).

Measuring lung capacity is necessary to establish a diagnosis of COPD, which is assessed by spirometry. The forced expiratory volume in 1 second to forced vital capacity ratio (FEV1/FVC) is an important measurement to identify obstructive impairment (O'Donnell et al., 2007). This ratio is the amount of air exhaled in the first second, divided by all the exhaled air during a maximal exhalation (Healthwise Staff, 2018). Airflow obstruction (COPD) is defined as an FEV1/FVC ratio of less than 0.7, which is not fully reversible after the use of an inhaled bronchodilator (Johannessen et al., 2006; O'Donnell et al., 2007).

It is imperative to focus on the management of symptoms and limitations due to COPD. Pharmacological approaches such as bronchodilators (opens the airways), and inhaled corticosteroids (decreases airway inflammation) in conjunction with nonpharmacological methods, have been found to improve the quality of life and prolong survival for individuals with COPD (Talag & Road, 2008). Examples of interventions are smoking cessation, oxygen therapy, pulmonary rehabilitation, lung volume reduction surgery, and lung transplantation (Talag & Road, 2008). In addition, individuals with COPD are encouraged to participate in regular physical activity to avoid lung and muscle deconditioning (a decline in the ability to exercise; COPD Fact Sheet, 2008).

1.1.2 Weather

Studies have found that both extremes of temperatures and humidity affect individuals' health (WHO, 2018; Wolkoff, 2018). Older adults (≥ 65 years) are more vulnerable to weather-related factors due to their limited mobility (individual's ability to move effectively in their surroundings) and social isolation (Clarke et al., 2015). Extremes of hot and humid weather are ≥ 25°C and > 50% relative humidity (Lin et al., 2018; Wolkoff, 2018). Extremes of cold and dry weather are ≤ 5°C and < 30% relative humidity (Lin et al., 2018; Wolkoff, 2018). Clarke et al. (2015) conducted a study to examine the impact of weather on older adults' daily lives to determine which populations are most vulnerable to various weather conditions. Results found that winter weather conditions were the primary reason why older adults changed how they went about their daily life activities (with no age differences). In the summer, rain and heat were also challenging for adults to deal with. Older adults (≥ 65 years) indicated that heat changed how they went about their daily lives compared to younger adults (< 65 years). This age group also represents the highest extra hospital visits and deaths during heatwaves (Kenney et al., 2014). As the world's population is aging and weather extremes may become more severe because of climate change (Kenney et al., 2014), there is a need for further research on the impact of weather-related factors on the health of individuals with COPD.

The World Health Organization (WHO) provides housing and health guidelines for indoor temperatures to protect individuals from the harmful health effects of hot and cold air (WHO, 2018). The WHO conducted a series of systematic reviews and found that indoor temperatures of 18-21°C protect the health of the general population during cold temperatures (WHO, 2018). With respect to individuals with COPD, one cross-sectional study found better health status with more hours of indoor temperature ≥ 21°C (Osman et al., 2008). Another cohort study reported reduced respiratory problems for adults with COPD with indoor temperatures around 18°C (Mu et al., 2017). On the other end of the temperature spectrum, the WHO suggests that those who live in areas with high temperatures must utilize strategies to protect themselves from excess indoor heat (WHO, 2018). One study found that a reduction in the number of days 27°C and above, corresponded with improved quality of health in older adults (Ahrentzen et al., 2016). By following these temperature guidelines, this may help individuals with COPD to effectively manage their weather-related symptoms and lower the negative impact of adverse outcomes on their health status.

1.1.3 COPD and Weather

The lungs are permanently exposed to the local environment, and as a result, may be affected by weather change (Gotschke et al., 2017). Previous research has found a relationship between humidity and temperature on airway mucosal function (Williams et al., 1996). Temperature and humidity have also been found to affect the lung function of individuals with COPD (Hansel et al., 2016), with most studies emerging from European (Donaldson et al., 1999; Ferrari et al., 2012; Furlanetto et al., 2017; Jehn et al., 2013; Jenkins et al., 2012; Miravitlles et al., 2003; Monteiro et al., 2013; Seemungal et al.,

1998) and Asian countries (Lin et al., 2018; Tseng et al., 2013). There is little and inconsistent empirical evidence regarding the burden, and specific types of extreme weather conditions that comprehensively describe the impact on important COPD outcomes. This includes health-related quality of life (HRQoL) or health status, respiratory symptoms, physical activity, frequency of rescue medication use, exacerbations, and healthcare utilization in individuals with chronic lung disease, especially for those living in Canada.

1.2 Study Purpose

The goal of this research is to describe the effects of temperature and humidity on health status, respiratory symptoms, physical activity, frequency of rescue medication use, exacerbations, and healthcare utilization in individuals with COPD living across Canada. A cross-sectional self-reported survey was used to address the research questions. It is of critical importance to examine the relationship between the impact of weather and COPD outcomes to determine the appropriate strategies to support the future management of COPD.

1.3 Impact and Significance

This study is a first step to explain the effects of temperature and humidity on lung function, symptoms, and physical activity. The results may help create a foundation for a weather-related COPD management program, including educating patients on the impact of temperature on physical activity, and how to take the appropriate measures to increase physical activity, reduce breathlessness and improve exercise tolerance during certain types of weather (O'Shea et al., 2007).

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CHAPTER 2: LITERATURE REVIEW

2.1 Literature Search Process

2.1.1 Literature Review Objective

The objective of this literature review is to describe the associations between extremes of weather and health status, symptoms and lung function, physical activity, and hospitalizations and exacerbations.

2.1.2 Inclusion and Exclusion Criteria

PubMed and Ovid Medline were the databases used to locate studies on the influence of weather on COPD outcomes, lung function, physical activity, exacerbations, and hospitalizations. Additional studies were identified from the reference list of original articles found. MeSH terms 'COPD' combined with 'weather/temperature,' 'symptoms,' 'lung function,' and 'physical activity' were used (along with the associated subject headings for each term). For this literature review, there was no exclusion of publication date or geographical area where the study took place. Table 2.1 provides details of publication eligibility criteria.

Table 2.1

Publication Eligibility Criteria

Item	Criteria
Participants/ Population	• Individuals with primary diagnosis of COPD (mild, moderate, severe, very severe) • Adults ≥ 40 years of age
Exposure	• Effects of meteorological variables (temperature, humidity, air pressure, wind speed, solar radiation) • Studies focusing primarily on effects of air pollution were not included (not the focus of this study)
Outcomes	• Primary outcome: symptoms (major: dyspnea, sputum purulence, sputum amount; minor: nasal discharge/congestion, wheeze, sore throat, cough) • Lung function, e.g., spirometry testing of peak expiratory flow rate and forced vital capacity • Hospitalizations

	• Morbidity rates • Exacerbation rates • Physical activity, e.g., 6-minute walk test, steps/day
Publication	• Published in English • Any date of publication • Peer reviewed
Study design	• Quantitative: randomized controlled trials, cohort studies, case-control studies, case series, cross-sectional studies • Qualitative and mixed methods studies • Studies with no original participant data, e.g., editorials, review papers, clinical practice guidelines (looked at these for the reference list), and conference abstracts were excluded

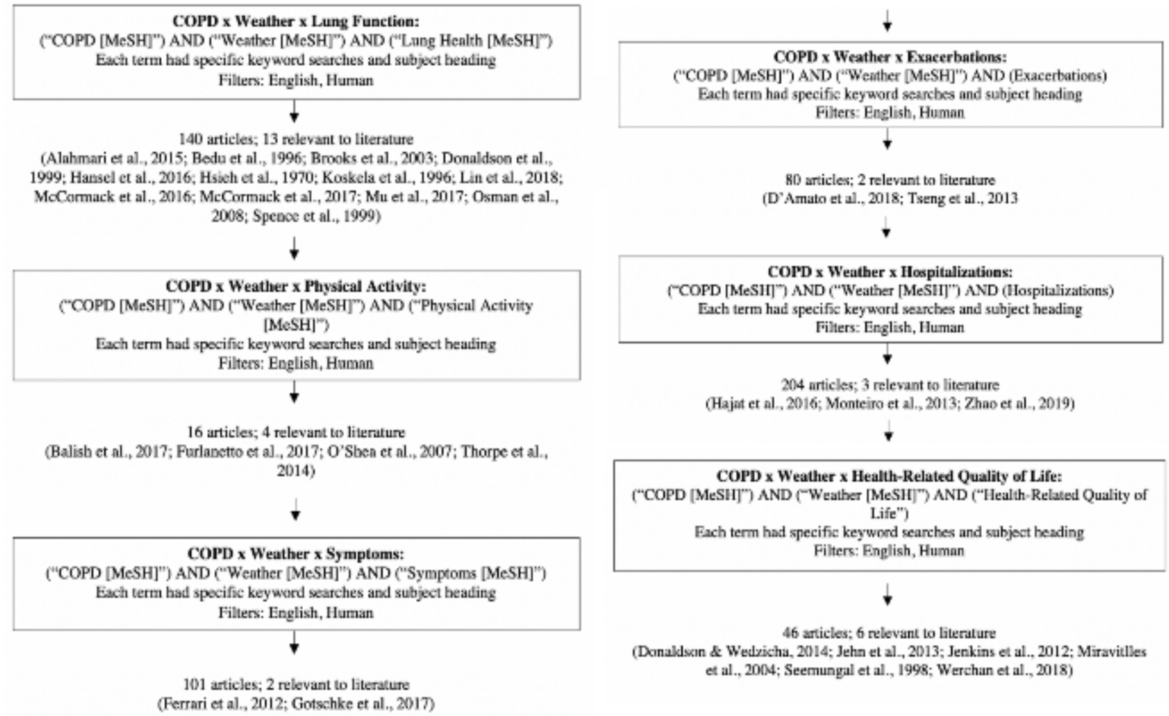
2.1.3 Search Strategy

Searching for articles related to temperature and humidity (on COPD outcomes) was difficult because the majority focused on air pollution. While not specifically looking for articles that addressed air pollution as a primary focus, some articles reporting findings regarding temperature and humidity were included. Figure 2.1 outlines the different searches conducted and number of articles found to support the thesis topic.

The themes identified in the literature review (and described below) are based on the objectives of this study, and include the effects of temperature and humidity on 1) health status, 2) symptoms and lung function, 3) physical activity, and 4) hospitalizations and exacerbations (for individuals with COPD). Appendix A.1 provides a detailed synthesis matrix of literature review articles.

Figure 2.1

The search strategy for literature review



Note: No date restriction was set for this search.

2.2 Health Status

In our study, we measured health status, which refers to the functional abilities of individuals, disabilities related to the disease, and effectiveness of treatment (Moons, 2004). There is often discrepancy in the literature since researchers use HRQoL and health status interchangeably (Alahmari et al., 2015; Miravitlles et al., 2004; Seemungal et al., 1999; Werchan et al., 2019). Quality of life describes a range of physical and psychosocial variables such as functioning, health status, behaviour, lifestyle, symptoms, etc. (Moons, 2004) Using the terms interchangeably can cause a misunderstanding as it assumes a fully healthy life equals a high quality of life; but individuals can have significant health problems and not have poor quality of life (Carr & Higginson, 2001).

HRQoL and health status are related and are distinct concepts but should not be used interchangeably (Smith et al., 1999). Hence, for the literature review, the studies described below will refer to health status.

Miravitlles et al. (2004) evaluated the impact of exacerbations on health status in individuals with COPD, including differences between seasons. Researchers conducted a cross-sectional observational study with 336 COPD patients in Spain, measuring lung function, exacerbations, and health status using the St. George's Respiratory Questionnaire (SGRQ) in 6-month intervals over two years. Results found that frequent exacerbations had a negative effect on health status in patients with moderate COPD but not in those with severe COPD. Also, Miravitlles et al. (2004) observed a significant and independent effect of seasonality where worse health status was observed in the winter rather than spring and summer. This may have been due to the lower number of exacerbations reported by participants in the spring and summer seasons.

Werchan et al. (2018) observed a relationship between exacerbation triggers and health status with their development of a psychometrically valid measure of perceived triggers of exacerbations in COPD patients. Researchers recruited 192 patients to complete online surveys to determine potential exacerbation triggers and describe their symptoms and health status via the COPD Assessment Test (CAT) score. Results found that exacerbation triggers were associated with lower COPD functional status, exacerbation frequency, and increased healthcare utilization. Participants described dust, air pollution, smoking, and physical activity as controllable triggers. Uncontrollable triggers were reported as psychological factors, hot and humid weather (13.1% of participants), infections, respiratory symptoms, and sleep. In relation to the CAT score, higher perceived controllability was correlated with a lower CAT score (better health status). Hence, individuals who reported more climate-related triggers (less controllability) had a lower health status. This study may be limited in its generalizability as participants were recruited from Dallas, Texas; a humid, subtropical area of the southern part of the USA where there is more extreme heat and air pollution.

Osman et al. (2008) conducted a cross-sectional observational study to investigate the influence of indoor temperature (between 18°C and 24°C) on the health status of 148 individuals with COPD in the UK. The study participants measured their living room and bedroom temperatures at 30-minute intervals over one week between October 2004 and May 2005 using electronic data loggers. Health status was measured using the SGRQ and EuroQol Visual Analogue Scale at the start of the week before temperatures were measured. Osman et al. (2008) collected lung function measurements from clinical records of patients within the past two years. The results found that individuals who spent fewer days at 21°C for at least 9 hours had significantly worse respiratory symptom scores than those who maintained a warmth of 21°C for at least 9 hours (associated with better health status). Osman et al. (2008) did not record the direct effects of outdoor temperature changes on COPD health.

2.3 Symptoms and Lung Function

A study by Hsieh et al. (1970) evaluated the effect of cold air-breathing on airway resistance at rest and during exercise in COPD patients with a history of sensitivity to cold air. Hsieh et al. (1970) assessed nine patients at both room temperature and -12°C. Seven out of nine patients experienced more distress and an increase in airway resistance during cold air-breathing at rest and during exercise.

Additionally, Spence et al. (1999) examined the effect of breathing cold air on exercise, lung function, and perceived breathlessness using the Borg scale. Nineteen patients with stable COPD exercised on a cycle ergometer in both room and cold temperatures of -13°C. Contrary to results found by Hsieh et al. (1970), Spence et al. (1999) found an increase in exercise performance when patients breathed cold air. The cold air was found to reduce breathlessness in COPD, inducing relative hypoventilation. There was a small improvement in lung function (increase in FEV1) when patients breathed cold air, though the effect was not statistically significant.

A seminal study conducted by Donaldson et al. (1999) determined the effects of temperature on lung function and COPD symptoms. Donaldson et al. (1999) collected daily lung function and symptom data for a year, from 76 COPD patients living in East London (UK). Donaldson et al. (1999) compared the impact of outdoor and bedroom temperature on lung function. Major symptoms (dyspnea, sputum purulence and amount) and minor symptoms (nasal discharge/congestion, wheezing, sore throat, cough) were assessed. The results demonstrated that a decrease in outdoor and bedroom temperature was associated with an increase in exacerbations and a decline in lung function. Additionally, Donaldson et al. (1999) found an association between an increase in common cold symptoms and a decrease in temperature during the winter. This study suggested that cold weather-related reduction in lung function, and an increase in exacerbations, may contribute to high cold-related morbidity in COPD patients, although the mechanism of this relationship was unknown (Donaldson et al., 1999). The authors speculated from previous literature, decreases in lung function may compromise patients with COPD, increase airway inflammation (Johnston et al., 1995; Nicholson et al., 1993), and/or increase susceptibility to infections (Mann et al., 1993; McHardy et al., 1980; Spicer et al., 1966). Cold temperatures may also reduce lung capacity due to increased peripheral vasoconstriction and shunting of blood centrally (Wilmshurst et al., 1989).

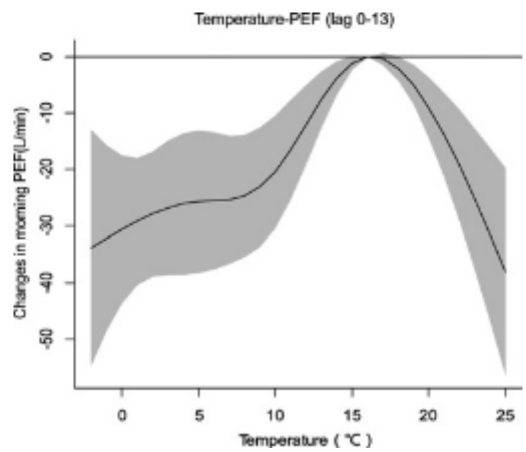
In more recent research, McCormack et al. (2017) investigated individuals with COPD during the cold weather season to determine the effect of daily temperature on daily symptoms, lung function, and use of rescue inhaler. The study consisted of 84 individuals with COPD over the age of 40, former smokers, and living in Baltimore, USA. Data was collected from November 1, 2008, to March 31, 2011. McCormack et al. (2017) assessed participants at baseline, three months, and six months. At each time interval, participants underwent a one-week home assessment of: indoor air sampling, twice daily lung function tests, daily diary of activities, symptoms (Breathlessness, Cough, and Sputum Scale [BCSS]), and use of rescue inhaler. The air sampling assessed the indoor temperature, humidity, and nitrogen dioxide. McCormack et al. (2017) also collected daily outdoor temperature, humidity, and pollution from publicly available datasets. McCormack et al. (2017) found that a 5.5°C decrease in daily minimum outdoor temperature was associated with an increase in the use of rescue inhaler, a 0.17-point increase in BCSS score (increase in adverse respiratory symptoms), and a mean reduction of 38 mL and 26 mL in morning and evening FEV1, respectively. The daily indoor temperature did not significantly affect COPD outcomes, except when the temperature was below 21°C; below 21°C, lower indoor temperature was associated with a higher BCSS score. Variables of humidity and indoor nitrogen dioxide concentration did not impact COPD outcomes. Overall, individuals were susceptible to the effects of cold temperature exposure, despite spending limited time outdoors (McCormack et al., 2017).

The interpretation of the results may be unclear since it is difficult to separate the effects of temperature changes from seasonal factors. Prior research suggests there may be a threshold below which colder temperatures adversely impact respiratory health (Jenkins et al., 2012; Keatinge & Donaldson, 2001). Several studies have identified 18°C as a potential threshold of indoor temperature below which adverse health effects may occur (Jevons et al., 2016; World Health Organization, 2007). Further investigation is needed to identify ranges of temperature extremes to inform public health advisories and help increase awareness for individuals with COPD (McCormack et al., 2017).

Lin et al. (2018) evaluated the association between temperature variations and daily fluctuations in pulmonary function in COPD patients. Lin et al. (2018) collected daily lung function measurements from 28 male COPD patients from December 2012 to May 2013, in Shanghai, China. Shanghai Meteorological Bureau provided daily mean temperature and relative humidity data. Statistical models were used to estimate the cumulative effects of temperature on morning and evening lung function (peak expiratory flow (PEF) and FEV1). The results identified an association between daily mean temperature and PEF in an inverted U-shaped relationship (Figure 2.2), both low and high temperatures significantly reduced morning and evening PEFs. There was no apparent association between temperature and FEV1. The proposed mechanisms behind the U-shaped relationship were not clear. Based on previous literature, Lin et al. (2018) speculated that higher temperatures can induce bronchoconstriction (constriction of airways in the lungs; Anderson & Daviskas, 2000) and elevate concentrations of biological aerosols that can cause inflammatory and allergic responses in the respiratory tract (Collaco et al., 2011). Cold temperatures can increase airway inflammation, reduce lung function (Donaldson et al., 1999; Pothirat et al., 2015), increase blood viscosity, and cause peripheral vasoconstriction (Guo et al., 2013; Wilmshurst et al., 1989).

Figure 2.2

Relationship between Temperature and Peak Expiratory Flow (Lin et al., 2018)



The methodologies of the studies by Donaldson et al. (1999), Lin et al. (2018), and McCormack et al. (2017) were conducted prospectively. However, weather data was obtained from fixed monitoring sites rather than individual-level environments, which may lead to inaccuracies of the true effect of temperature on COPD patients' lung function. These studies also may not be generalizable for all individuals with COPD. The studies by Hsieh et al. (1970) and Spence et al. (1999) included only participants that were sensitive to cold air. The studies conducted by Hsieh et al. (1970), Spence et al. (1999), and Donaldson et al. (1999) are also dated, and do not consider recent changes in climate-related weather. The Lin et al. (2018) study consisted of only male participants and was conducted in China.

2.4 Physical Activity

O'Shea et al. (2007) identified adherence factors to an exercise program for individuals with COPD, using semi-structured qualitative interviews. The study enrolled 22 participants into a 12-week trial of progressive resistance exercise. Results found that weather factors (hot and cold temperatures, seasonal weather patterns, particulate matter in the air) were significant barriers to adhering to the program. O'Shea et al. (2007) speculated that atmospheric variability may affect the health of COPD patients. For example, after thunderstorms, there are high concentrations of allergenic particles in the air, which may cause airways to be more reactive and increase exacerbations (Marks et al., 2001). Also, cold weather may induce bronchoconstriction (Koskela et al., 1996).

Similarly, Thorpe et al. (2014) explored the perspectives of COPD patients on the barriers and enablers of participation in physical activity following hospitalization. The study utilized a qualitative descriptive design of semi-structured phone interviews with 28 hospitalized COPD patients with exacerbations between March and November 2011 in Adelaide, South Australia. The results found the main barrier to physical activity after hospitalization, was seasonal weather impact. Some patients reported they would not leave their house because very cold weather caused excess coughing and sneezing. Other patients said the cold air made it difficult to breathe and resulted in shortness of breath.

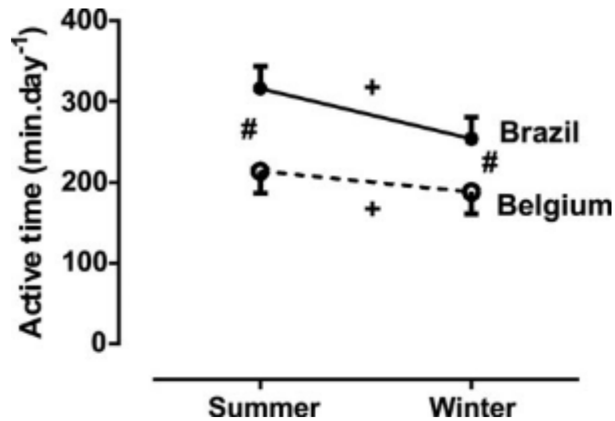
Alahmari et al. (2015), demonstrated the effects of temperature on physical activity in COPD. Seventy-three stable COPD patients in London, England recorded respiratory symptoms daily, measured PEF, and tracked the number of steps per day on a pedometer. British Atmospheric Data Archive provided daily weather data to determine the relationship between the variables. Colder weather was found to reduce daily step count, and activity was lower on rainy days compared to dry days.

Balish et al. (2017) examined the impact of daily variations in weather on physical activity in individuals with COPD. Individuals enrolled in seven pulmonary rehabilitation programs (PR) across Canada, completed a questionnaire, and wore a pedometer for seven days at the beginning and end of PR, and at three and nine months after completing PR. Balish et al. (2017) compared the physical activity to daily weather information from Environment Canada at each PR location. Results found that daily mean temperature and total daily rainfall independently predicted steps per day in 189 patients enrolled in PR. An increase of 10°C was associated with 316 more steps, and precipitation of 10 mm associated with 175 fewer steps.

Furlanetto et al. (2017) conducted a longitudinal, prospective, and observational study with COPD patients from Brazil (n = 24) and Belgium (n = 27) to assess the seasonal changes in physical activity in daily life (PADL) in countries with climatic variations. The median temperature in Belgium was 11°C and 21°C in Brazil. Furlanetto et al. (2017) measured PADL by having COPD patients wear a SenseWear Armband for seven days in the summer and seven days in winter consecutively. A spirometry test, 6MWT, and CAT were also conducted on the patients. Furlanetto et al. (2017) correlated PADL with daily weather data from each national meteorological institute. The meteorological variables used were temperature, precipitation, relative humidity, and calculation of daylight time. The study results found that patients in Brazil and Belgium decreased their active time (PADL) in the winter compared to summer; the reduction was more profound in Brazil (Figure 2.3). Temperature, daylight duration, and relative humidity were significantly related to active time. A 1°C rise in temperature increased the time spent being active by 1.4 minutes in Belgium patients and 6.0 minutes in Brazil patients. For every percentage increase in humidity, the active time decreased by 1.03 minutes. Patients from Belgium decreased their active time by 22 minutes on days with rain, with no significant effect in Brazil.

Figure 2.3

Comparison of active time of COPD patients in Brazil and Belgium (Furlanetto et al., 2017)



The methodologies in the studies by O'Shea et al. (2007) and Thorpe et al. (2014) utilized a qualitative research design. This allowed individuals with COPD to describe their personal experiences on the effects of temperature on their physical activity. Overall, extremes of temperature were perceived as a barrier to participating in physical activity (O'Shea et al., 2007; Thorpe et al., 2014). Balish et al. (2017) and Furlanetto et al. (2017) showed similar results using a longitudinal, observational study design to observe how individuals with COPD engage in physical activity over time, and how the weather may influence their physical activity levels. The limitations of all the studies were the smaller sample sizes, and potential issues with generalizability (geographical location, and they consisted of mostly male patients). In addition, pedometers may have inaccurately measured physical activity because the intensity was not measured, and some individuals did not wear the pedometer every day, lost it, or broke it. Finally, researchers did not assess individual exposure to weather (Alahmari et al., 2015).

2.5 Hospitalizations and Exacerbations

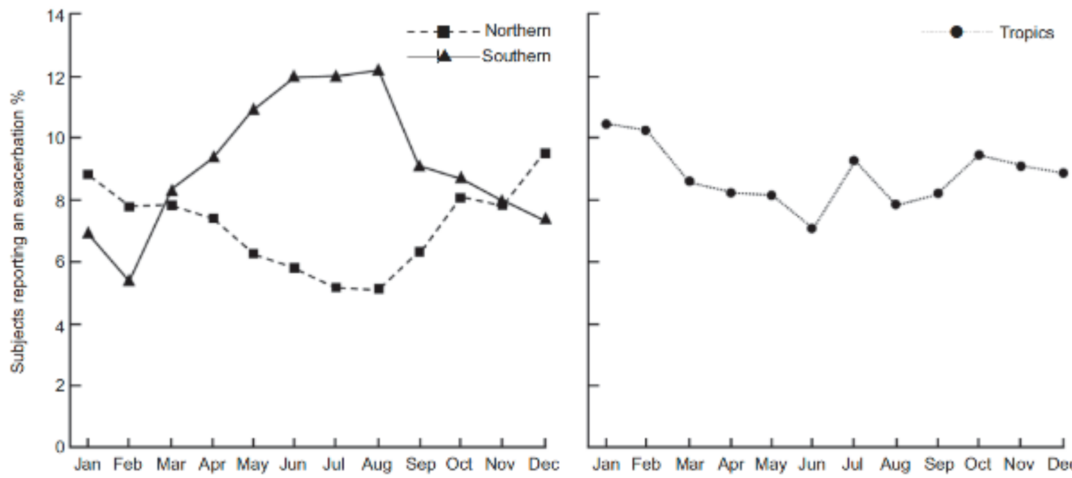
One of the first studies to examine the meteorological effects on COPD patient outcomes was by Mann et al. (1993). Fourteen patients completed an outpatient PR program in New England, Connecticut, USA and were asked to record their daily respiratory status during the spring and summer of 1991. Mann et al. (1993) cross-analyzed the effect of meteorological data (temperature, humidity, cloud cover, frontal change, barometric pressure, precipitation, wind velocity, ozone level, pollen count) on the respiratory status of the patients. The National Weather Centre in Windsor Locks (16 km away from New England) supplied meteorological data. The following variables were measured: morning dyspnea, daytime dyspnea, PEF, mood, and presence of lower respiratory tract infection (LRI). Mann et al. (1993) tested daily meteorological conditions and LRI frequency individually (and in combination) to see if they were predictors of daily mean values of morning and daytime dyspnea, PEF, and mood. The results found that in the spring, only precipitation affected the respiratory status by increasing morning and daytime dyspnea. In spring, other meteorological factors were not associated with changes in mood and PEF. In the summer, more meteorological factors were associated with poorer outcomes. High temperature, an increase in barometric pressure, and increased LRI frequency predicted an increase in morning dyspnea. High temperature and increase in barometric pressure also predicted reduced PEF. There was no association with mood or daytime dyspnea in the summer.

Jehn et al. (2013) developed a home-based tele-monitoring system and assessed the effects of heat stress (> 25 °C) on clinical and functional status in COPD patients in Berlin, Germany. They conducted a randomized controlled trial with 62 COPD patients from June 1st to August 31st in 2012. Patients were divided into two groups: tele-monitoring group and control group. In the tele-monitoring group, individuals did a daily assessment of clinical status with the CAT, daily lung function tests, and weekly 6MWT in their home-based environment. After completing the tests, the data was transmitted via a mobile network to the Charité University Hospital's study center. The patients were required to complete all the measurements in the morning within two hours of inhalation of their bronchodilators. Both groups received usual care based on set guidelines for the treatment and management of COPD. There was a baseline examination, and regular follow-up visits at three, six, and nine months for both groups. These visits consisted of a detailed medical history, current medication, duration of disease, co-morbidities, physical examination, height, quality of life, spirometry test, CAT, 6MWT, and number of visits to their primary care physician or lung specialist. Results found that during heat stress (summer), participants in the tele-monitoring group showed a significant reduction in lung function and exercise capacity (6MWT performance), compared to the control group. Significantly fewer tele-monitoring patients suffered exacerbations in comparison to the control group patients. After the nine months follow up, the tele-monitoring group had fewer exacerbations, shorter hospital stays, and fewer specialist consultations than the control group. In addition, the tele-monitoring group had a significant improvement in clinical status (CAT score), and 6MWT from baseline to the 9-month follow up. The control group worsened in clinical status, showed no significant change in the 6MWT, and both groups had no change in lung function. Tele-monitoring was found to reduce the risk of exacerbations during the summer with an improvement in clinical and functional status, and reduced frequency of exacerbations and healthcare utilization throughout the year.

Jenkins et al. (2012) published one of the only studies that examined the impact of seasons on COPD exacerbation frequency in multiple regions worldwide. They did a secondary data analyses of a large three-year multi-centred randomized controlled trial (comparing different inhaled medications) in 42 countries with a total of 6112 participants: Northern regions (4849 participants [Canada, China, 26 Eastern and Western European countries, and the USA]), Southern regions (622 participants [Argentina, Australia, Brazil, Chile, New Zealand, and South Africa]) and the Tropics (641 participants [Hong Kong, Malaysia, Mexico, Philippines, Singapore, Taiwan, and Thailand]). In the Northern regions, summer is from June to August and winter from December to February; however, it is reversed in the Southern regions (the Tropics experience hot and humid weather year-round). Exacerbations were defined as worsening of symptoms requiring systemic corticosteroids and/or antibiotics (moderate) or requiring hospital admission (severe). Results found a two-fold increase in exacerbations in the Northern and Southern regions during the winter months compared to summer (Figure 2.4). This association was not observed in the Tropics since the temperature is relatively constant at 18°C. This study had a large sample size, but there were smaller number of participants in the Southern and Tropics regions in comparison to the Northern region. The potential mechanisms behind why exacerbations were increased in the winter were not speculated on in this study.

Figure 2.4

Number of patients reporting an exacerbation in Northern, Southern, and Tropics Regions (Jenkins et al., 2012)



Several studies examined the correlation between local weather data and COPD hospitalizations. Ferrari et al. (2012) conducted a retrospective analysis of meteorological factors (air pressure, humidity, solar radiation, temperature, and wind speed) from the European Centre for Medium-Range Weather Forecast, on daily ambulatory care visits (due to COPD) between 2006 and 2007 in Bavaria, Germany. The findings indicated that an increase in 1% of daily ambulatory care visits was associated with an increase in temperature, and an increase in air pressure. A decrease of 1% daily ambulatory care visits was associated with an increase in solar radiation and specific humidity. The variables of wind speed and humidity did not significantly affect ambulatory care visits. The exact mechanism about how the exposure of meteorological factors increased or decreased COPD morbidity was unclear.

Tseng et al. (2013) investigated the correlation between COPD exacerbation rates (Taiwan National Health Insurance registry data) and meteorological variables (daily temperature, daily relative humidity, daily barometric pressure, wind speed, and hours of sunshine) from the Taiwan Central Weather Bureau between January 1999 to December 2009. Tseng et al. (2013) found that a 1°C decrease in air temperature was associated with a 0.8% increase in exacerbations, and a 5°C drop increased the risk of exacerbations over the long-term effect (28-day average). Higher temperatures, higher barometric pressure, more hours of sun exposure, and lower humidity were associated with an increase in exacerbations. Hence, temperature (low and high) may be a potential risk factor for COPD exacerbations. Speculations on the mechanism of this association was not described.

Likewise, Monteiro et al. (2013) examined the relationship between the occurrence of cold episodes and hospital admissions for individuals with COPD in Porto, Portugal (November 2000 to March 2007). The Meteorological Observatory of Serra do Pilar provided climatic records. Cold episodes were defined as at least seven consecutive days with a minimum temperature below 5°C. The results found an increase in COPD admissions during winter by 59%, especially during cold episodes. The results are similar to Tseng et al. (2013), and ideas on the mechanism of cold episodes on hospital admissions were not described.

Zhao et al. (2019) investigated the correlation between COPD hospitalizations and weather conditions between 2000 and 2015 (Brazil) to determine if heat exposure was associated with COPD morbidity. The results from this case-crossover study demonstrated an increase in hospitalizations for every 5°C increase in daily mean temperature.

Sama et al. (2015) completed a cross-sectional survey examining environmental influences on: COPD exacerbations, respiratory symptoms, use of additional medication (antibiotics or steroids), actions taken (e.g., removing themselves from activities), and use of daily rescue medications. The study consisted of 167 clinically diagnosed patients with COPD from a medical group in Massachusetts, USA; each patient must have experienced at least one exacerbation within the 15-month study period. The questionnaire asked about daily living activities and chemical/non-chemical exposures associated with triggers of COPD symptoms, flare-ups or exacerbations. The influence of weather extremes was only one of many exposures in the questionnaire. However, this was the only study we could find that addressed the burden of different weather conditions. They found 78% of study participants were affected by both extremes of weather (hot/humid, cold/dry). Specifically, 81% of participants found it harder to breathe in hot/humid weather, and 67% in cold/dry weather. Also, 87% of participants acted in response to hot/humid weather and 75% in cold/dry weather by using medication to control their symptoms and removing themselves from such environments.

Ferrari et al. (2012), Jehn et al. (2013), Jenkins et al. (2012), Monteiro et al. (2013), Sama et al. (2015), Tseng et al. (2013), and Zhao et al. (2019), all demonstrated that both extremes of temperatures increased hospitalizations and exacerbations. Ferrari et al. (2012) found that an increase in solar radiation was associated with decreased ambulatory care, whereas, Tseng et al. (2013), found that more hours of sun exposure were associated with an increase in COPD exacerbations. The limitations of the studies by Ferrari et al. (2012), Jehn et al. (2013), Monteiro et al. (2013), Tseng et al. (2013), and Zhao et al., (2019) are related to the authors' use of local city-wide temperature data rather than individual temperature exposures. The authors did not control for exposure to air pollutants and did not consider indoor temperature. Furthermore, all of these studies were conducted in different parts of the world, making it difficult to generalize the results to individuals with COPD in North America, especially Canada. Although Mann et al. (1993) examined individual data rather than city-wide temperature data, they did have a small sample size, and the study is dated.

2.6 Summary

Overall, this literature review demonstrated that meteorological variables of temperature and humidity influenced the outcomes of individuals with COPD, including lung function, symptoms, exacerbations, and physical activity (Ferrari et al., 2012).

The influence of lower or decreasing temperatures (indoor and outdoor) encompass the majority of results, demonstrating associations with increased adverse respiratory symptoms (Donaldson et al., 1999; McCormack et al., 2016), reduced lung function (Donaldson et al., 1999; Lin et al., 2018; McCormack et al., 2016), lower health status (Miravitlles et al., 2003), increased use of rescue medications (McCormack et al., 2016), decreased physical activity (Furlanetto et al., 2017), increased exacerbations (Donaldson et al., 1999; Jenkins et al., 2012; Miravitlles et al., 2003; Tseng et al., 2013) and hospitalizations (Monteiro et al., 2013). A higher or increasing temperature was associated with increased ambulatory care visits (Ferrari et al., 2012) and hospitalizations (Zhao et al., 2019), increased exacerbations (Jehn et al., 2013; Werchan et al., 2018), reduced lung function (Jehn et al., 2013), lower health status (Werchan et al., 2018), and both increased physical activity (Balish et al., 2017; Furlanetto et al., 2017) and decreased physical activity (Jehn et al., 2013).

Lower or decreasing humidity levels were associated with increased exacerbations (Tseng et al., 2013); higher or increasing humidity with reduced ambulatory care visits

(Ferrari et al., 2012), and physical activity (Furlanetto et al., 2017). High or increasing air pressure was associated with increased ambulatory care visits (Ferrari et al., 2012) and exacerbations (Tseng et al., 2013). More hours of sun, or increased solar radiation, was associated with increased physical activity (Alahmari et al., 2015), decreased ambulatory care visits (Ferrari et al., 2012), and increased exacerbations (Tseng et al., 2013). Precipitation (rain) was associated with decreased physical activity in four studies (Alahmari et al., 2015; Balish et al., 2017; Furlanetto et al., 2017).

The geographical location of these studies included the UK (Donaldson et al., 1999; Osman et al., 2008; Seemungal et al., 1998), Germany (Ferrari et al., 2012; Jehn et al., 2013), Portugal (Monteiro et al., 2013), Spain (Miravitlles et al., 2003), Belgium (Furlanetto et al., 2017), Brazil (Furlanetto et al., 2017; Zhao et al., 2019), China (Lin et al., 2018), USA (Texas) (Werchan et al., 2018) and Taiwan (Tseng et al., 2013). Only two studies were conducted in environments similar to Canada: (Balish et al., 2017) across all of Canada, and (McCormack et al., 2017) in the USA (Massachusetts).

Most studies examined the association of temperature in a large geographical area (Alahmari et al., 2015; Balish et al., 2017; Donaldson et al., 1999; Ferrari et al., 2012; Furlanetto et al., 2017; Lin et al., 2018; McCormack et al., 2016; Monteiro et al., 2013; Zhao et al., 2019), rather than collecting individual temperature exposure data (Donaldson et al., 1999; McCormack et al., 2016; Osman et al., 2008). Some compared the influence of indoor temperature on COPD outcomes, rather than the impact of outdoor temperature (D'Amato et al., 2018; McCormack et al., 2016; Osman et al., 2008).

Finally, the studies described above were retrospective (Ferrari et al., 2012; Monteiro et al., 2013; Osman et al., 2008; Tseng et al., 2013; Sama et al., 2015; Zhao et al., 2019), or longitudinal observational designs (Alahmari et al., 2015; Balish et al., 2017; Donaldson et al., 1999; Furlanetto et al., 2017; Lin et al., 2018; McCormack et al., 2016) because weather is an exposure that is difficult to control prospectively. The risk of bias from confounders may be higher and may be difficult to ascertain weather-related inferences (e.g., temperature, humidity, sunlight) from seasonal (allergens), and air quality variables (particulates).

2.6.1 Rationale for Study

There is a lack of evidence describing both the burden of extreme weather conditions on individuals with COPD and the impact on important outcomes. Sama et al. (2015) found 78% of study participants were affected by both hot/humid and cold/dry weather. Their objective was to determine potential triggers for exacerbations, and what proportion of individuals avoided these triggers (with weather being an uncontrollable trigger). However, the weather was only *one* of several different exposure variables they investigated, and impact on outcomes was not assessed.

There is also a lack of research conducted in North America, making results difficult to generalize to individuals living in Canada. Only two studies were conducted in environments similar to Canada (Balish et al., 2017; McCormack et al., 2017). Balish et al. (2017) focused solely on how weather is related to steps/day in individuals with COPD, and McCormack et al. (2017) determined the effect of daily temperature on respiratory health outcomes (symptoms, lung function, rescue inhaler use). Both studies collected weather data from local stations instead of personal temperature data and had small sample sizes. Balish et al. (2017) conducted their study across five different Provinces (Nova Scotia, New Brunswick, Quebec, Saskatchewan, British Columbia). However, most of the measurements were recorded during the spring/summer seasons, and sample size decreased over time. In addition, Balish et al. (2017) recruited participants from PR programs; their cohort of participants may have been more active than the general COPD population. Researchers collected PA activity using pedometers, but intensity/difficulty of PA was not measured. McCormack et al. (2017) had a sample from one city (Baltimore, USA) which may make it difficult to generalize across a large geographical area like Canada. In addition, they did not measure influence of weather on physical activity.

The proposed research addresses these knowledge gaps by providing information on the Canadian prevalence of individuals with COPD affected by extremes of weather, and the potential impact on HRQoL/health status, respiratory symptoms, physical activity, frequency of rescue medication use, exacerbations, and healthcare utilization. This may provide further evidence on the challenges that individuals with COPD experience during different extreme weather conditions and guide them and clinicians regarding the management of important health outcomes.

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CHAPTER 3: A CROSS-SECTIONAL SURVEY ON THE EFFECTS OF TEMPERATURE AND HUMIDITY ON HEALTH OUTCOMES IN INDIVIDUALS WITH COPD: A PILOT STUDY

3.1 Abstract

3.1.1 Objectives. Extremes of temperature and humidity are associated with adverse respiratory symptoms, reduced lung function, and increased exacerbation amongst populations with Chronic Obstructive Pulmonary Disease (COPD). This study described the effects of temperature and humidity extremes on health outcomes, health status and physical activity, in individuals with COPD.

3.1.2 Methods. A pilot study of cross-sectional self-reported survey assessed extremes of temperature and humidity on health outcomes in 1) moderate or ideal (14 to 21°C, 30 to 50% relative humidity [RH]), 2) hot and humid (≥ 25°C, > 50% RH) and 3) cold and dry (≤ 5°C, < 30% RH). The survey included questions on health outcomes (respiratory symptoms, rescue medication use, exacerbations, healthcare utilization), health status (COPD Assessment Test [CAT]; higher score = worse health status), physical activity (PROactive daily physical activity in COPD questionnaire [D-PPAC]; lower score = poorer physical activity), and participant baseline and geographical demographics. Participants were ≥ 40 years, diagnosed with COPD or related chronic respiratory diseases, resided in Canada ≥ one year, and recruited from PR (and related) programs, through word of mouth, and social media. Participants with a CAT minimal clinical important different (MCID) ≥ 2-points were defined as "Responders" to the extreme weather conditions, compared to ideal/moderate conditions. Descriptive statistics, Repeated-Measures ANOVA (CAT, D-PPAC), Cochran's Q test for categorical dependent variables, along with post-hoc pairwise tests were performed using IBM® SPSS Statistics. P < 0.05 was considered statistically significant.

3.1.3 Results. A total of n = 37 participants were enrolled, mean (SD) age 64.5 (11.1) years, n = 23 (67.6%) female, smoking history 39.5 (25.6) pack per year. The number of responders to either extreme weather condition was 34 (94.4%), with the majority being negative responders: 23 (63.9%) and 26 (74.3%) for cold/dry and hot/humid weather, respectively. Health status was significantly different and clinically important between the three weather conditions ($p < 0.001$), with ideal CAT score (17.2 [7.8]) compared to hot/humid (22.4 [7.4] $p < 0.001$), and cold/dry conditions (21.4 [8.3], $p < 0.001$). Ideal condition D-PPAC total score (13.0 [3.1]), was significantly higher compared to hot/humid conditions 14.72 [3.9] ($p = 0.008$), and lower in the cold/dry conditions 12.2 [4.5] ($p = 0.364$). Ideal D-PPAC amount scores were significantly worse, and D-PPAC difficulty significantly better compared to both cold/dry and hot/humid conditions (D-PPAC amount 2.33 [1.96] and 2.17 [1.38] vs 4.39 [1.36], respectively; D-PPAC difficulty 10.06 (4.59) and 12.39 (4.04) vs 4.39 [1.36], respectively, both $p < 0.001$).

Frequency of exacerbations ($p = 0.002$), rescue inhaler use ($p = 0.05$) and hospitalizations ($p = 0.034$) were significantly different between each of the three weather conditions. The number of exacerbations in hot/humid (n = 30 [86%]), was significantly higher compared to ideal/moderate conditions (n = 21 [58%]), $p = 0.002$. There was no significant difference for family doctor visits ($p = 0.148$), respiratory specialist visits ($p = 0.761$), or ED visits ($p = 0.307$).

3.1.4 Conclusions. Study revealed a greater proportion of the participants were negatively affected by extremes of weather conditions. Health status worsened, physical activity decreased, and frequency of exacerbations and health utilization were higher in extremes of weather. Health status worsened and exacerbation rates increased in hot/humid compared to ideal conditions, but physical activity increased mainly due to decreased difficulty level. Future prospective studies should directly and objectively investigate different combinations of extreme temperature and humidity levels on symptoms and physical activity, include larger sample sizes, measure longer term impacts of weather, and measure the influence of confounding variables such as disease severity. In longer-term studies and/or clinical practice the CAT, D-PPAC and objective physical activity monitors can be used to determine responders and non-responders to extreme weather conditions.

3.2 Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory disorder and one of the top three causes of death worldwide (Halpin et al., 2019). In Canada, COPD is the fourth leading cause of death (Dang-Tan et al., 2015) and the Public Health Agency of Canada (2011) cites that in 2009-2010 about 4% of Canadians (772, 200) aged 35 years and older were diagnosed with COPD. In Canada, there is a substantial economic and humanistic burden from COPD. The average total cost per COPD patient ranges between $2,444 to $6,693 per annum, which rises as disease severity increases (Dang-Tan et al., 2015). Individuals with COPD have impacts on their quality of life, and around 45% experience pain (Dang-Tan et al., 2015). Symptoms significantly affect daily activities such as climbing stairs, doing housework, getting dressed, and sleeping (Chapman, & Kaplan, 2012). The major underlying cause of COPD are environmental factors, with smoking being the most significant (Dang-Tan et al., 2015). However, seasonal factors have been associated with worsening COPD symptoms (Werchan et al., 2018).

Global climate change has resulted in increases in the mean yearly ambient temperature, and frequency and intensity of variable weather conditions (McCormack et al., 2017). The effects of these changes on the health of individuals with COPD are poorly understood in research (Jehn et al., 2013). As the lungs are exposed to the environment, it is important to determine how temperature and humidity affect the lung function of individuals with COPD (Hansel et al., 2016).

Previous literature has examined the effects of temperature and humidity on COPD health outcomes (Ferrari et al., 2012). Lower temperatures have been associated with increases in adverse respiratory symptoms, reduced lung function, lower health status, increased use of rescue medication, decreased physical activity, and increased exacerbations and hospitalizations (Donaldson et al., 1999; Furlanetto et al., 2017; Jenkins et al., 2012; Lin et al., 2018; McCormack et al., 2016; Miravitlles et al., 2004; Monteiro et al., 2013; Tseng et al., 2013). Increased temperatures have been associated with increased hospitalizations and exacerbations, reduced lung function, and increased and decreased physical activity levels (Balish et al., 2017; Ferrari et al., 2012; Jehn et al., 2013; Werchan et al., 2018; Zhao et al., 2019). Additionally, lower humidity levels were associated with increased exacerbations (Tseng et al., 2013), and higher humidity levels associated with reduced ambulatory care visits and lower physical activity levels (Ferrari et al., 2012; Furlanetto et al., 2017).

There is a lack of evidence describing both the burden of extreme weather conditions on individuals with COPD, and the impact on important outcomes. Sama et al. (2015) completed a cross-sectional survey examining environmental influences in individuals with COPD in Massachusetts, USA. They found 78% of study participants were affected by hot/humid and cold/dry weather, with 81% finding it harder to breathe in hot/humid weather, and 67% in cold/dry weather. However, weather was only one of several different exposure variables they investigated (and the impact on outcomes was not assessed). There is also a lack of research conducted in North America, making results difficult to generalize to individuals with COPD living in Canada. One study conducted across Canada focussed only on physical activity (Balish et al., 2017), and another conducted in Northwestern USA collected information on respiratory symptoms, exacerbations, and rescue inhaler, but focussed on cold temperatures only (McCormack et al., 2017).

The primary objective of this study was to determine what proportion of individuals with COPD were affected by extremes of weather (hot/humid and cold/dry) in terms of health status and respiratory symptoms. The secondary objective of this study was to determine the associations between extremes of weather and health status, respiratory symptoms, physical activity, frequency of exacerbations, rescue inhaler use, and healthcare utilization in individuals with COPD. We hypothesized that approximately 75% of participants would report being affected by either extreme of weather conditions, and both extremes of weather conditions would be associated with lower health status, higher adverse respiratory symptoms, decreased physical activity, increased rescue inhaler use, and increased healthcare utilization. We based our hypothesis on the results of the cross-sectional self-reported survey conducted by Sama et al. (2015). The study found that 78% of the subjects are affected by environmental triggers that influences COPD outcomes. This study is the first step to describe the effects of extreme weather conditions for individuals with COPD in Canada and may inform future weather-related management strategies for those living with COPD.

3.3 Methods

3.3.1 Study Design and Exposure

A cross-sectional self-reported survey was developed to assess the effects of temperature and humidity on health status, respiratory symptoms, physical activity, frequency of exacerbations, rescue inhaler use, and healthcare utilization in individuals with COPD. The survey consisted of closed-ended multiple-choice and open-ended questions and was completed anonymously online (SurveyMonkey® platform, San Mateo, California), telephone, or by mail. Due to COVID-19 pandemic restrictions, we were unable to conduct our survey in person. Individuals who completed the survey received compensation for their time ($20 gift card).

Participants were asked to recall answers from the most recent year (including all four seasons), not including restrictions due to COVID-19. Two individuals with COPD (Quebec) collaborated on this research study by contributing to the protocol, survey, and interpretation of the results.

The survey assessed the outcomes in three weather conditions:

- Moderate or "ideal" conditions (14 to 21°C and approximately 30 to 50% relative humidity)
- Cold and dry conditions ($\leq$ 5°C and < 30% relative humidity)
- Hot and humid conditions ($\geq$ 25°C and > 50% relative humidity)

3.3.2 Research Questions

Primary Research Question. What proportion of individuals with COPD are affected by extremes of weather (hot and humid, cold and dry) with respect to health status and respiratory symptoms (e.g., cough, phlegm, tightness of chest, breathlessness, and frequency of exacerbations)?

Secondary Research Question. What are the associations between extremes of weather and health status, respiratory symptoms, physical activity, frequency of exacerbations, rescue inhaler use, and healthcare utilization in individuals with COPD?

3.3.3. Hypotheses

Primary Research Question Hypothesis. We hypothesized that approximately 75% of participants will report being affected by either hot/humid weather and cold/dry weather conditions.

Secondary Research Question Hypothesis. We hypothesized for individuals with COPD, both extremes of weather conditions (compared to ideal conditions) would be associated with:

1. lower health status,
2. higher adverse respiratory symptoms,
3. decreased physical activity,
4. increased rescue inhaler use, and
5. increased healthcare utilization.

3.3.4 Outcome Measures

The CAT (Jones et al., 2009) was used in our survey to assess both symptoms and health status. Questions included cough, phlegm, tightness of chest, breathlessness, activity limitation at home, confidence leaving home, sleep, and energy (Jones et al., 2009). Each question uses a 0 to 5-point scale; a total score ranges from 0-40. Higher overall scores represent worse health status. The minimum clinically important difference (MCID) of the CAT is 2 points (a meaningful change in an outcome, for a specific group of participants [Wacker et al., 2016]).

The PROactive daily physical activity in COPD questionnaire (D-PPAC) (Gimeno-Santos et al., 2015) was incorporated into our survey to assess physical activity for each weather condition. This tool has been used to assess the influence of weather-related variables on physical activity in France (Vaidya et al., 2020). Questions address the frequency of walking, the number of outdoor chores completed, difficulty getting dressed, avoiding activities, breathlessness, tiredness, and break frequency during physical activity (Gimeno-Santos et al., 2015). Each question uses a 0 to 4-point scale; total scores normally range from 0 to 37. Because we did not measure step count and vector magnitude units, scores in this study ranged from 0 to 28. We also calculated sub-scores, D-PPAC amount (frequency of walking + number of outdoor chores completed) and D-PPAC difficulty (difficulty getting dressed + avoiding activities + breathlessness + tiredness + break frequency during physical activity). For the total and sub-scores, a lower score indicates poorer physical activity (lower amount, higher difficulty). The D-PPAC uses both vague quantifiers (none at all, rarely, sometimes, frequently, all the time) and a numeric rating scale. We used vague quantifiers instead of asking individuals to rate their physical activity on a scale due to the ambiguity of what each number represented. This is contrary to the CAT, which outlines what each number on the scale represents. The MCID for the D-PPAC amount score is 6 points, and the D-PPAC difficult score is 4 points (Garcia-Aymerich et al., 2021).

The CAT and the D-PPAC are both valid and reliable tools that demonstrate strong internal consistency and test-retest reliability showing the ability to measure the construct it intended to measure (Gimeno-Santos et al., 2015; Jones et al., 2009).

Frequency of exacerbations, rescue inhaler use, healthcare utilization (doctor visits, emergency department, hospitalizations), and response actions to the weather conditions were determined through categorical multiple-choice questions. For example, answer choices for frequency included: “3 or more times per day,” “1 or 2 times per day,” “2 or 3 times per week.” Answer choices for actions taken included: “I removed myself from the weather condition,” “I avoid going outside,” and “I go to a different geographical location.”

The end of the survey included items to describe our study population and identify potential confounders to weather exposure (Steiner et al., 2015 and Bourbeau et al., 2019). This included questions on:

a. *demographics* (age, sex, living arrangement, marital status, education, employment status, income),
b. *daily activity and symptoms* (modified Medical Research Council dyspnea scale (mMRC) [Mahler & Wells, 1988], attendance in PR and self-management program, International Physical Activity Questionnaire Short Form (IPAQ) [Craig et al., 2003], respiratory medications),
c. *exacerbation related* (frequency, hospital admissions, vaccination history),
d. *co-morbidity* (co-morbidity history, weight loss, fracture history),

e. *prognostic indicators* (smoking status, home oxygen use, continuous positive airway pressure (CPAP) or bilevel ventilation use, edema, primary diagnosis, and duration), and

f. *environmental* (type of community, city size, rainfall).

The mMRC dyspnea scale grades the effect of breathlessness on daily activities (Mahler & Wells, 1988) by measuring perceived respiratory disability (any restriction or lack of ability to perform an activity considered normal; Medical Research Council, 2016). The scale is graded from 0 to 4, with higher scores indicating more breathlessness (Mahler et al., 2009). The mMRC scale is a valid and reliable tool (Mahler et al., 2009; Natori et al., 2016) that has been used to predict COPD-related hospitalizations and exacerbations (Natori et al., 2016).

The IPAQ is an instrument designed to analyze physical activity data in adults 18 to 65 years old (Craig et al., 2003). Although many individuals with COPD are 70 years and older, the IPAQ is still considered a reasonable measurement of physical activity and demonstrates strong test-retest ability and validity (Liao et al., 2014). We used the short version questionnaire that consisted of seven items on time spent (frequency, days per week; and duration, time per day) walking, in vigorous and moderate intensity activity, and in sedentary activity (Craig et al., 2003). The IPAQ estimates physical activity levels as either a continuous or cateogorical variable (Liao et al., 2014) – we scored the IPAQ both ways. As a continuous variable, the physical activity is computed by weighting each type of activity by its energy requirements defined as MET-minutes (metabolic equivalents; Craig et al., 2003). We reported the combined total physical activity = Walking + Moderate + Vigorous MET-min/week scores. Healthy individuals typically engage in 1.5-2 hours of physical activity daily, equating to a minimum of 3000 MET min/week (IPAQ Research Committee, 2004). The median MET min/week for individuals with COPD has been found to be as low as 149 and as high as 12,159 (the range consists of moderate to vigorous activity values; Andersson et al., 2015; Inal-Ince et al., 2014). As a categorical variable, physical activity is divided into three categories: inactive, minimally active, and HEPA active (health enhancing physical activity; a high active category) (IPAQ Research Committee, 2004).

The full questionnaire was only provided in English, and can be found in Appendix B.

3.3.5 Participant Recruitment

Inclusion criteria included: individuals 40 years and older (COPD Foundation, 2020), diagnosed with COPD according to the Canadian Thoracic Society criteria (having an FEV1/FVC ratio < 0.7) by a physician (Balish et al., 2017), any disease severity (mild, moderate, severe, very severe), residing in Canada for at least one year (not including times related to COVID-19), and capable of providing informed consent. Exclusion criteria included: individuals less than 40 years old, not diagnosed or primarily diagnosed with COPD or any related chronic respiratory disorders, residing outside of Canada or less than one year in Canada (to ensure individuals have experienced all seasons of the year), and those unable to provide consent.

Due to poor response rate, we decided to include individuals that reported diagnoses of other chronic respiratory-related diseases or disorders, including asthma, sleep apnea, interstitial lung disease, or lung cancer. We acknowledge these diseases/disorders differ from COPD; however, it is common for all of these disorders to overlap with COPD (Lambert & Dransfield, 2016; Malhotra et al., 2018), and we believed this limitation could be counteract by the increased in sample size which will contribute to the study's internal validity. We also collapsed chronic bronchitis, bronchiectasis, and emphysema under COPD as these diseases either fall under the COPD family or are similar in lung function and symptomology (lung inflammation, increased mucus production and problems breathing, coughing, and frequent infections [Kim & Criner, 2013; Nielsen et al., 2015]).

We recruited individuals from PR programs, through patient advocacy groups (e.g., Breathe: The Lung Association – Fitness for Breath programs, The Lung Health Foundation), professional respiratory organizations (e.g., Canadian Society of Respiratory Therapists, Canadian Thoracic Society), using snowball sampling techniques, and with the use of social media (e.g., Twitter [Wasilewski, Stinson, Webster, & Cameron, 2019]). Due to the COVID-19 pandemic, we were unable to visit PR programs in person to recruit participants. Individuals with COPD are immune-compromised, and as a result, most of the PR, education, and support programs available to them were cancelled or moved to an online format. The original plan was conducting the survey in person and displaying our poster at different institutions. We had to rely on program coordinators to spread the word about our study; we contacted them by phone, email, and social media to share our survey with their patients.

3.3.6. Sample Size

Originally, our sample size was based on Sama et al. (2015), as this was the only study found to report prevalence. Assuming that 78% of the subjects in the population were affected by extremes of weather, and an expected response rate of 87%, the study would require a sample size of 304 to estimate the expected proportion with 5% absolute precision and 95% confidence (Dhand & Khatkar, 2014). If we selected a random sample of 304 from the sampling population and determine that 78% of subjects were affected by extremes of weather, we would be 95% confident that between 73% and 83% of subjects in the population are affected by extremes of weather (Dhand & Khatkar, 2014).

3.4 Data Analysis

3.4.1 Primary Objective Data Analysis

To determine the number of study participants affected by hot/humid and/or cold/dry extreme weather conditions, we defined individuals as "responders". Responders were individuals whose CAT score was at least 2 points different (MCID) compared to the moderate "ideal" weather condition score. Negative responders (worsened health status) had CAT scores ≥ 2-points, while positive responders (better health status) had CAT scores ≤ 2-points compared to the ideal/moderate CAT score.

The data analysis consisted of descriptive statistics, including means and standard deviations (SD) for continuous variables, median and interquartile range (IQR) for skewed data, and counts and percentages for nominal variables. For open-ended questions, text summaries describing overarching themes were completed.

3.4.2 Secondary Objective Data Analysis

We conducted a comparison of the means within the three different weather conditions, using a Repeated-Measures ANOVA for interval data (CAT, D-PPAC). For categorical dependent variables we collapsed the categories into "yes" or "no" (exacerbations, rescue inhaler use, healthcare utilization) and performed a Cochran's Q test. Due to the limited sample size, we were not able to adequately adjust for potential confounders. We would have conducted a logistic regression for the categorical dependent variables if we had a full sample size. For significant Repeated-Measures ANOVA or Cochran's Q results, we performed Bonferroni corrected pairwise post-hoc tests. We used IBM® SPSS Statistics for the statistical analyses. A p-value < 0.05 was considered significant ($p < 0.017$ for post-hoc pairwise tests).

3.5 Research Ethics Approval

Ethics approval was obtained from Ontario Tech University (REB #: 16029).

3.6 Results

We started recruitment and opened our survey on September 16th, 2020, and closed our survey on December 11th, 2020. We contacted a total of 267 COPD PR programs in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Newfoundland and Labrador, Nova Scotia, and Prince Edward Island. After leaving voicemails/messages, and sending emails, 29 coordinators agreed to share our survey with their patients. They did this by word of mouth when interacting with COPD patients in appointments, on their social media/website, and emailed/handed out our survey poster.

On Twitter, we tagged COPD organizations such as The Lung Health Foundation, Canadian Thoracic Society, Canadian Lung Association, Canadian Society of Respiratory Therapists, The Respiratory Therapy Society of Ontario, COPD Canada, The Canadian Respiratory Research Network, and College of Respiratory Therapists of Ontario. Out of the 37 tagged, six organizations retweeted our tweet.

When we opened the survey, we publicly shared the link over social media and with the PR program's coordinators. This resulted in over 400+ responses, which we suspected were from spambots and/or individuals seeking the $20 gift card. Bots are fake participants that have been programmed to complete multiple responses in a matter of minutes (Simone, 2019). The motive behind using bots to complete online surveys may have been to receive the incentive ($20 gift card) or to skew research findings for malicious reasons (Simone, 2019). The survey was subsequently closed, and after a review of the data, this resulted in 12 legitimate responses. It is probable we missed legitimate or included illegitimate responses. However, we were very conservative in the decisions for legitimacy by including data more characteristic of chronic lung disease (e.g., age, smoking duration, diagnoses, and co-morbidities), or if sensible open text comments were provided.

Prior to re-releasing the survey, changes were made. First, specific questions required responses: age, what actions they took in each weather condition (open-ended), current physical activity levels (numerical response), primary diagnosis, and COPD duration. We also asked participants to state their age at two different points in the survey to ensure they matched. Once the survey was complete (and if done online), respondents were required to email us and provide the approximate date and time of completion before receiving compensation. Finally, we did not publicly share the survey link; individuals contacted us if they were interested, and we sent a link to them, or a phone call was arranged. This new approach yielded 25 additional responses to add to our final dataset of n = 37 (online n = 31, phone n = 5, mail n = 1). It is difficult to assess the response rate of the survey because it is unknown how many individuals with COPD were aware of the survey. However, given the multiple recruitment strategies used, and shift of focus on the COVID-19 pandemic, it is likely the response rate to this survey was very low.

Overall, we had 3 incomplete surveys, and 5 surveys with missing answers.

Incomplete Surveys:

- n = 1 did not complete the survey at all
- n = 1 completed up until the healthcare utilization questions in the Hot/Humid Condition
- n = 1 did not complete the demographic questions

Missing Answers:

- n = 1 did not complete the Hot/Humid CAT questions
- n = 1 did not complete both the IPAQ and the pneumococcal vaccine questions
- n = 1 did not complete COPD duration question
- n = 2 did not complete the income question

3.6.1 Participant Characteristics

Out of the 37 participants that responded to the survey, n = 29 (78.4%) participants reported COPD as their primary diagnosis, with the balance identifying asthma (11 [29.7]), sleep apnea (4 [10.8]), interstitial lung disease (2 [5.4]), or lung cancer (1 [2.7]). The mean (SD) age was 64.5 (11.1), and 23 (67.6%) were female. The mean (SD) of chronic lung disease duration was 12.4 (11.2) years. Table 3.1 to 3.5 provides additional details.

The primary comorbidities identified were bone disease 10 (27%), cardiovascular diseases 7 (18.9%), and diabetes 5 (13.5%). Mean (SD) BMI was in the "overweight" range (Health Canada, 2019) at 27.77 (8.35) kg/m^2. The majority lived with their spouse/partner 15 (44.1%) or lived alone 11 (32.4%), and 19 (55.9%) of individuals were married/common law. Most participants either attended college/vocational school 15

(44.1%) or had some university training 11 (32.4%). Eighteen (52.9%) of participants were retired, and there was an approximately equal distribution of income across the < $25,000 to > $65,000 ranges (Table 3.2).

With respect to physical activity and dyspnea (Table 3.3), 79.4% (n = 27) were minimally active (based on the IPAQ), with a mean (SD) MET minutes per week of 3688.8 (3306.6). Most individuals identified themselves as mMRC Grade 1 (n = 13 [37.1%]) dyspnea level (I get short of breath when hurrying on the level or walking up a slight hill), or Grade 2 (n = 12 [34.3%]) dyspnea level (I walk slower than people of the same age on the level because of breathlessness or have to stop for breath when walking at my own pace on the level) (Table 3.3).

In terms of potential confounding variables, the majority of participants were former smokers 25 (71.4%), with 6 (17.1%) current smokers. The majority of participants took short-acting beta-agonists 30 (81.1%), and/or combination inhalers 27 (73.0%). Nineteen (54.3%) experienced an acute exacerbation in the last year, 27 (77.1%) and 18 (52.9%) had their influenza and pneumococcal vaccinations (respectively), and 22 (62.9%) attended PR within the last year. In terms of community characteristics, 14 participants (41.2%) live in urban communities, 16 (47.1%) in communities with a large population size (≥ 100,000 people), and 27 (79.4%) in communities with precipitation some days of the month (Table 3.4). Questions on geographical location were not included in the survey. However, open-text comments and phone/mail interviews revealed that n = 13 were from Ontario, n = 3 from British Columbia, n = 2 from Quebec, n = 1 Alberta, n = 1 New Brunswick, n = 1 Nova Scotia, and n = 16 unknown.

Table 3.1

Participant Characteristics

Characteristics	Value
Age (years), N = 34	
Mean (SD)	64.53 (11.07)
Median (IQR)	66.50 (14.25)
Gender, N (%)	
Female	23 (67.6)
Male	11 (29.7)
Primary Respiratory Diagnosis*, N (%)	
COPD	29 (78.4)
Asthma	11 (29.7)
Sleep Apnea	4 (10.8)
ILD	2 (5.4)
Lung Cancer	1 (2.7)
Respiratory Disease Duration, N = 34	
Mean (SD)	12.40 (11.18)
Median (IQR)	9.75 (17.00)
Comorbidities, N (%)	
Bone Disorder	10 (27.0)
Cardiovascular Diseases	7 (18.9)
Diabetes	5 (13.5)
Neuropsychiatric Disorders	4 (10.8)
Cancer	3 (8.1)
Congestive Heart Failure	3 (8.1)
High Cholesterol	2 (5.4)
PAD	2 (5.4)
Cirrhosis	1 (2.7)
Complex Migraines	1 (2.7)
Coronary Heart Disease	1 (2.7)
DVT	1 (2.7)
GERD	1 (2.7)
Musculoskeletal Disorders	1 (2.7)
Pulmonary Embolism	1 (2.7)
BMI (kg/m^2), N = 34	
Mean (SD)	27.77 (8.35)
Median (IQR)	27.50 (9.20)
Smoking History, N (%)	
Former Smoker	25 (71.4)
Current Smoker	6 (17.1)
Never Smoked	4 (11.4)
PPY	
Mean (SD)	39.5 (25.6)
Median (IQR)	39.5 (29.8)

Total sample size N = 37. BMI: Body Mass Index, COPD: chronic obstructive pulmonary disease, DVT: Deep Vein Thrombosis, GERD: Gastroesophageal Reflux Disease, ILD: Interstitial Lung Disease, IQR: interquartile range, PAD: Peripheral Artery Disease, PPY: Packs smoked per year, SD: standard deviation.

*Some individuals identified more than one primary respiratory diagnosis.

Table 3.2

Participant Demographics

Participant Demographics	Value
Living Arrangement, N (%)	
Lives with spouse/partner	15 (44.1)
Lives alone	11 (32.4)
Lives with children	5 (14.7)
Lives with roommates	2 (5.9)
Lives with parents/guardians	1 (2.9)
Marital Status, N (%)	
Married/Common Law	19 (55.9)
Divorced/Separated	7 (20.6)
Single/Never Married	5 (14.7)
Widowed	3 (8.8)
Level of School, N (%)	
College or vocational school	15 (44.1)
Any university training	11 (32.4)
Highschool or less	7 (20.6)
Any postgraduate training	1 (2.9)
Employment Status, N (%)	
Retired	18 (52.9)
Disability	7 (20.6)
Full-Time	4 (11.8)
Self-Employed	4 (11.8)
Not employed	1 (2.9)
Household Income, N (%)	
< $25,000	7 (21.9)
$25,001-$45,000	8 (25.0)
45,001-$65,000	8 (25.0)
> $65,000	9 (28.1)

Total sample size N = 37.

Table 3.3

Physical Activity and Dyspnea Baseline Measurements

Measurements	Value
Responders, N (%)	34 (94.4)
IPAQ level of physical activity, N (%)	
Inactive	2 (5.9)
Minimally Active	27 (79.4)
HEPA Active	5 (14.7)
Total METs minutes, N = 37	
Mean (SD)	3688.8 (3306.6)
Median (IQR)	2099.5 (1264.6-6824.3)
MRC Scale, N (%)	
Grade 0	2 (5.7)
Grade 1	13 (37.1)
Grade 2	12 (34.3)
Grade 3	7 (20.0)
Grade 4	1 (2.9)

Total sample size N = 37. HEPA: health enhancing physical activity; a high active category, IPAQ: International Physical Activity Questionnaire, IQR: interquartile range, MET: Metabolic equivalent of task, MRC: Medical Research Council, SD: standard deviation. Grade 0: I only get breathless with strenuous exercise, Grade 1: I get short of breath when hurrying on the level or walking up a slight hill, Grade 2: I walk slower than people of the same age on the level because of breathlessness or have to stop for breath when walking at my own pace on the level, Grade 3: I stop for breath after walking about 100 years (91 meters) or after a few minutes on the level, Grade 4: I am too breathless to leave the house or I am too breathless when dressing (Grade 4 represents worse breathlessness).

Table 3.4

Community Characteristics

Community Characteristics	Value
Community, N (%)	
Urban	14 (41.2)
Suburban	11 (32.4)
Rural	9 (26.5)
Population Size, N (%)	
Large (≥ 100,000)	16 (47.1)
Medium (30,000-99,999)	8 (23.5)
Small (1,000-29,999)	10 (29.4)
Precipitation Level, N (%)	
Most days of the month	1 (2.9)
Some days of the month	27 (79.4)

Few days of the month	4 (11.8)
Very few days of the month	2 (5.9)

Total sample size N = 37.

Table 3.5

Interventions Received and Health Utilization

COPD Related Variables	Value
Respiratory Medications, N (%)	
SABA	30 (81.1)
Combination Inhalers	27 (73.0)
LABA	12 (32.4)
Corticosteroid Pills	7 (18.9)
Antibiotics	6 (16.2)
Nebulizer	3 (8.1)
Mucolytics	2 (5.4)
P-4 Inhibitors	1 (2.7)
Vaccines, N (%)	
Influenza	27 (77.1)
Pneumococcal	18 (52.9)
O_2 Therapy, N (%)	14 (40)
CPAP or NIV, N (%)	6 (17.6)
Acute exacerbation in last year, N (%)	19 (54.3)
ER visits in last year, N (%)	10 (28.6)
Bone Fracture in last year, N (%)	3 (8.6)
Swelling (ankles, legs, feet), N (%)	13 (37.1)
PR Attendance, N (%)	22 (62.9)
Self-Management Education Program, N (%)	13 (37.1)

Total sample size N = 37. CPAP: Continuous positive airway pressure therapy, ER: Emergency Room, LABA: Long-acting beta-agonists, NIV: Non-invasive ventilation, P-4 Inhibitors: Phosphodiesterase-4 Inhibitor, PR: Pulmonary Rehabilitation, O_2: Oxygen, SABA: Short-acting beta-agonists.

3.6.2 Influence of Extreme Weather Conditions

Primary Objective: Proportion Affected

The number of positive or negative responders to either extreme weather condition (compare to ideal) was 34 (94.4%), with 26 (72.2%) in cold/dry, and 30 (85.7%) in hot/humid weather. Out of the 34 responders, 22 (66.1%) responded to both weather conditions; 4 (11.1%) to only cold/dry conditions; 8 (22.2%) to only hot/humid conditions. The majority were negative responders with 23 (63.9%) and 26 (74.3%) for cold/dry and hot/humid weather, respectively (Table 3.6).

The MCID values for the D-PPAC were published after this study was completed (Garcia-Aymerich et al., 2021), and not considered part of the original responder criteria. Very few participants reached the 6-point MCID (decrease or increase) for the D-PPAC amount score in any weather condition. For the D-PPAC difficulty score, 11 (29.7%) reached the 4-point MCID in cold/dry conditions (8 [21.6%] less difficulty), and 19 (51.4%) in hot/humid conditions (18 [48.6%] less difficulty), in comparison to ideal conditions (Table 3.6).

We also calculated the MCID between the two extreme conditions, cold/dry versus hot/humid weather. The proportions of responders who reached the CAT and/or D-PPAC MCIDs was similar to comparisons with ideal conditions. The number of responders (CAT score) from cold/dry to hot/humid weather conditions was 26 (72.2%), where 16 (44.4%) worsened (Table 3.7).

Secondary Objective: Health Status

The mean (SD) CAT score was significantly different between the three weather conditions ($p < 0.001$), Table 3.9. Ideal health status (17.2 [7.8]) was significantly higher compared to hot/humid (22.4 [7.4] $p < 0.001$), and cold/dry conditions (21.4 [8.3], $p < 0.001$). Additionally, the two extremes of weather resulted in clinically important decreases in health status as both went beyond the MCID of two points (over four points).

Secondary Objective: Physical Activity

The mean (SD) D-PPAC total score significantly differed between each weather condition ($p < 0.001$), Table 3.8. Post hoc tests revealed a significant increase in overall physical activity in the hot/humid conditions, 14.72 (3.9) compared to ideal conditions, 13.00 (3.1), $p = 0.008$. There was a decrease in physical activity in the cold/dry conditions 12.2 (4.5) compared to the ideal conditions but was not statistically significant ($p = 0.364$). There was also a significant difference between D-PPAC total score in hot/humid versus cold/dry conditions ($p < 0.001$).

The sub-scores for the D-PPAC scores had different results compared to the D-PPAC total score. The mean (SD) D-PPAC amount score was *significantly worse in both* cold/dry (2.17 [1.38]) and hot/humid (2.33 [1.96]), compared to ideal conditions (4.39 [1.36]), $p < 0.001$. The D-PPAC difficulty score was *significantly better in both* cold/dry at 10.06 (4.59), hot/humid at 12.39 (4.04) compared to ideal conditions, 8.61 (3.60), $p < 0.001$. There was no difference in either D-PPAC amount or difficulty score between cold/dry and hot/humid conditions.

Secondary Objective: Exacerbations and Health Utilization

Overall, exacerbations and health utilization were higher in extremes of weather, however frequency of exacerbations ($p = 0.002$), rescue inhaler use ($p = 0.05$) and hospitalizations ($p = 0.034$) were significantly different between each of the three weather conditions, Figure 3.1, and Table 3.8. The only significant pairwise post-hoc result was the number of exacerbations between ideal/moderate and hot/humid conditions, $p = 0.002$. In ideal/moderate conditions n = 15 (42%) did not have an exacerbation, and n = 21 (58%) did have an exacerbation. In hot/humid conditions, n = 5 (14%) did not have an exacerbation, and n = 30 (86%) did have an exacerbation.

Table 3.6

Proportion of Participants Reaching the Minimal Clinical Important Difference for the CAT and D-PPAC: Ideal vs Cold/Dry and Ideal vs Hot/Humid Weather Conditions (N=37)

MCID Variable	Ideal vs. Cold/Dry, N (%) Total Worse | Better		Ideal vs. Hot/Humid, N (%) Total Worse | Better	
CAT (2 points)*	26 (72.2)		30 (85.7)	
	23 (63.9)	3 (8.3)	26 (74.3)	4 (11.4)
D-PPAC amount (6 points)	1 (2.7)		3 (8.1)	
	1 (2.7)	0 (0)	3 (8.1)	0 (0)
D-PPAC difficulty (4 points)	11 (29.7)		19 (51.4)	
	3 (8.1)	8 (21.6)	1 (2.7)	18 (48.6)
CAT and/or D-PPAC (amount or difficulty)	27 (73.0)		31 (83.8)	
	24 (64.9)	5 (13.5)	29 (78.4)	8 (21.6)

*Responders. Missing n = 1 (n = 2 for CAT hot/humid)

Table 3.7

Proportion of Participants Reaching the Minimal Clinical Important Difference for the CAT and D-PPAC: Cold/Dry Compared to Hot/Humid Weather Conditions (N = 37)

MCID Variable	**Cold/Dry vs. Hot/Humid, N (%)** **Total** **Worse | Better**	
CAT (2 points)	26 (72.2)	
	16 (44.4)	10 (27.8)
D-PPAC amount (6 points)	0	
	0	0
D-PPAC difficulty (4 points)	12 (32.4)	
	1 (2.7)	11 (29.7)
CAT and/or D-PPAC (amount or difficulty)	31 (83.8)	
	26 (70.3)	11 (29.7)

*Responders. Missing n = 1 (n = 2 for CAT hot/humid)

Table 3.8

Weather Conditions and Outcomes

Variable	Ideal Conditions	Hot/humid Conditions	Cold/dry Conditions	p-value
CAT[a]	n = 36	n = 35	n = 36	**P < 0.001**
Mean (SD)	17.2 (7.8)	22.4 (7.4)	21.4 (8.3)	
Median (IQR)	17.5 (12.5)	22.0 (14.0)	21.5 (13.8)	
D-PPAC total[b]	n = 36	n = 36	n = 36	**P < 0.001**
Mean (SD)	13.0 (3.1)	14.7 (3.9)	12.2 (4.5)	
Median (IQR)	13.0 (4.5)	15.0 (4.8)	12.0 (4.5)	
D-PPAC amount [c]	n = 36	n = 36	n = 36	**P < 0.001**
Mean (SD)	4.4 (1.4)	2.3 (2.0)	2.2 (1.4)	
Median (IQR)	4.0 (2.0)	2.0 (2.0)	2.0 (2.0)	
D-PPAC difficulty[d]	n = 36	n = 36	n = 36	**P < 0.001**
Mean (SD)	8.6 (3.6)	12.4 (4.0)	10.1 (4.6)	
Median (IQR)	9.0 (4.8)	13.0 (5.8)	9.5 (5.8)	
Exacerbations[e], N (%)				**P = 0.002**
No	15 (41.7)	5 (14.3)	7 (19.4)	
Yes	21 (58.3)	30 (85.7)	29 (80.6)	
Rescue inhaler use, N (%)				P = 0.05
No	12 (33.3)	7 (20.0)	7 (19.4)	
Yes	24 (66.7)	28 (80.0)	29 (80.6)	
Family doctor visit, N (%)				P = 0.148
No	32 (91.4)	27 (77.1)	27 (75.0)	
Yes	3 (8.6)	8 (22.9)	9 (25.0)	
Respiratory specialist, N (%)				P = 0.761
No	31 (86.1)	28 (80.0)	30 (83.3)	
Yes	5 (13.9)	7 (20.0)	6 (16.7)	
ED visit, N (%)				P = 0.307
No	34 (94.4)	30 (85.7)	30 (83.3)	
Yes	2 (5.6)	5 (14.3)	6 (16.7)	
Hospitalization, N (%)				P = 0.034
No	35 (97.2)	31 (88.6)	29 (80.6)	
Yes	1 (2.8)	4 (11.4)	7 (19.4)	

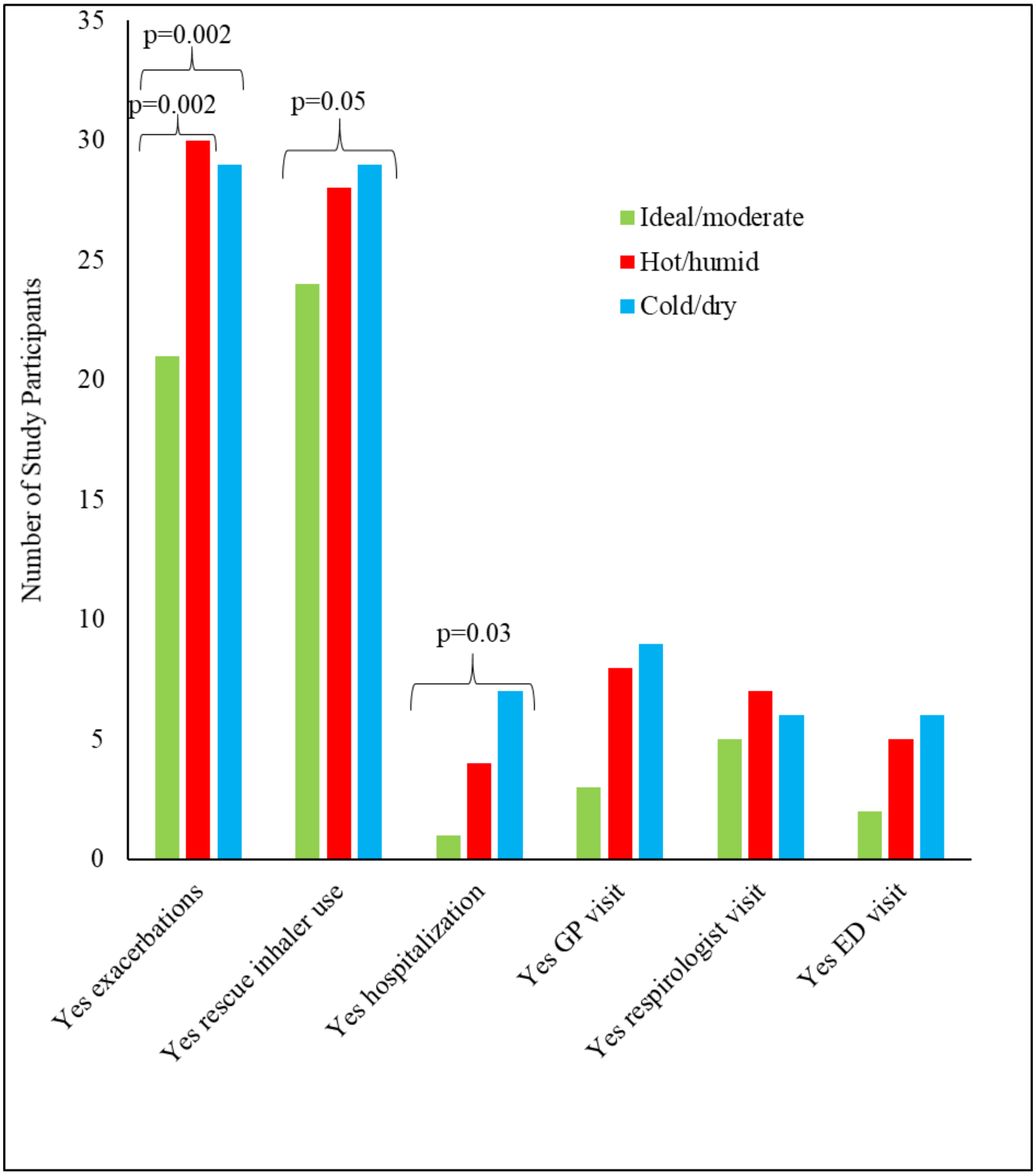
Total sample size N = 37. CAT: COPD Assessment Test, D-PPAC: Daily-PROactive Physical Activity in COPD, ED: Emergency Department, IQR: interquartile range. SD: standard deviation, Mild exacerbation = no change in prescribed medications, Moderate exacerbation = required prescribed antibiotic and/or oral corticosteroid, Severe exacerbation = required a hospital admission or emergency department visit. Higher CAT scores represent worse health status. Lower D-PPAC scores represent worser physical activity.

[a]ideal vs hot/humid, p = 0.0005; ideal vs cold/dry, p = 0.0000. [b]ideal vs hot/humid, p = 0.008; hot/humid vs cold/dry, p = 0.00002. [c]ideal vs hot/humid, p < 0.001; ideal vs

cold/dry, $p < 0.001$. [d]ideal vs hot/humid, $p < 0.001$; ideal vs cold/dry, $p < 0.001$. [e]ideal vs hot/humid, $p = 0.002$

Figure 3.1

Healthcare Utilization Between Conditions



Secondary Objective: Actions Taken during Extreme Weather and Open-Ended Responses

During ideal conditions, the majority of participants reported they took no actions, 21 (56.8%). Whereas, in cold/dry conditions, 15 (40.5%) reported they avoided going outside or stayed indoors, 9 (27.0%) took no actions, and 7 (18.9%) limited the amount of time outside or used medications to cope with the weather condition. During hot/humid conditions, the majority of participants (27 [73.0%]) avoided going outside or stayed indoors. At the end of the survey participants were invited to elaborate on how specific weather conditions affected them, and actions they took in response to them. The themes identified were comments on strategies used and problematic conditions.

Strategies Used

Within this theme, we uncovered various strategies that individuals would use to cope with extreme weather conditions: avoiding conditions, using medication/oxygen therapy, and other strategies (Table 3.9, 3.10, 3.11). Some of the strategies themselves caused issues, in addition to the extreme weather condition. For example, air conditioning (AC) on a high setting would trouble participant's lungs because of the dust and necessitate the use of an air filter. Based on the comments, it appears that hot and humid weather was more problematic in comparison to cold and dry. This corroborates with our other results: more participants were negative responders to hot/humid (74.3%) compared to cold/dry weather (63.9%), and the amount and difficulty level of physical activity decreased in both weather conditions.

Table 3.9

Avoided Conditions

Conditions	Direct Quotes
Ideal	• "No actions taken, enjoyed this weather" • "Avoided going outside, except when necessary" • "Only when allergies are acting up then will go inside during nice weather"
Cold/Dry	• "Avoided going outside, especially when it is cold and windy" • "Avoid almost all outdoor exertion" • "Dress warmer" • "Stayed inside and ventured out if not avoidable"
Hot/Humid	• "Avoided going outside, take it easy when it is hot and humid" • "Try to sit out for short periods of time for fresh air" • "Stayed indoor during hot days"

Table 3.10

Using Medication/Oxygen Therapy

Conditions	Direct Quotes
Ideal	• "Limited time outside to early mornings and evenings, always used oxygen" • "Used inhaler"
Cold/Dry	• "Made sure to use rescue inhaler before leaving the house" • "Rest and used inhaler or medication" • "Increase use of corticosteroid and rescue inhalers"
Hot/Humid	• "Rest and used inhaler" • "Only very early mornings would spend much time outside, once it gets hot must be in a cool area on my oxygen sporadically" • "Stayed inside most of the day, used 2 different inhalers and made sure house was cool, went out in the evening when it was cooler and went to the beach"

Table 3.11

Other Strategies

Conditions	Direct Quotes
Ideal	• "Did not have to do much in this condition, would have to stop every 5 minutes but continued; did this until it got cold" • "Love this weather the best, if short of breath, sit for a bit then catch breath and continue"
Cold/Dry	• "On cooler days, did not need to use oxygen, did breathing exercises and go at a slower pace" • "Came back to Saint John from Saskatoon, it is dry and cold there, moist and cold here" • "Used a scarf/mask to limit breathing in cold air"
Hot/Humid	• "Went out during the cool part of the day or evening, used AC and fans" • "Tried to stay in coolest easily accessible place" • "Hot and humid weather is the worst, limited outside to early mornings only, used central air all the time" • "Lucky enough to have a cottage, but it gets very hot, and I feel the humidity, go for a swim as often as I can and as close to bedtime as possible" • "Stayed indoors with low AC cause too much cold bothers lungs, go in car to mall or visit family and friends; sir under a deep shade tree, except if humidity too high, don't do this either because breathing is hampered" • "Do stuff in the morning, using fans inside, moving room to room, not going for a walk outside it is too hot, got an air filter machine to clean the air, the AC is also problematic; coughing more and can't breathe, the humidity is really bad"

Problematic Conditions

Some participants elaborated on which weather condition was most problematic to them, and what they would do to cope (Table 3.12). Hot and humid weather appeared problematic, and some preferred the dry air instead. Also, cold conditions were not just associated with low levels of humidity; in some jurisdictions such as British Columbia and New Brunswick, cold weather was associated with higher levels of humidity.

Table 3.12

Problematic Conditions

Direct Quotes
"Moderate/ideal conditions-cool weather; with 40-45% humidity is ideal for me to garden or walk. The higher the temperature rises from 70, and the more humidity, the more difficult for me to breathe and function."
"Avoided the outside, remove yourself from the weather condition, tried to decrease the time as much as possible, would avoid buying groceries if it was too cold, the cold would tear my lungs, when it gets dark I get tired, in the cold conditions experience more higher humidities in BC than dryer air, dry air more preferable."
"I avoided going outside it when was too hot, and the hot is more problematic than cold, take the dog for a walk in the morning when it is cooler, take him out at night when it cooled down."
"As the disease progresses, I find Warm/Humid more difficult than Cool/Dry."
"I just want to add that I do find high heat, extreme cold and humidity play a very big factor in my overall health which was why I was interested in participating."
"Moderate to hot and humid weather is a big factor to my breathing, relief comes from central air and doing breathing exercises. BIPAP machine has helped greatly with energy level. I'm new at having COPD, so still learning and any information would be greatly appreciated."
"If too much rain I am gone to much heat I am done, mild temps clear sky's no problem"
"Very definite decrease in quality of life during extreme heat & humidity."

3.7 Discussion

This study, using a cross-sectional survey, examined the effects of extremes of temperature and humidity (cold/dry and hot/humid) on health outcomes in individuals with COPD living in Canada. Overall, we found (in 37 individuals with COPD), 94.4% of participants had a clinically important response in their health status, to cold/dry and/or hot/humid extremes of weather. This number exceeds our original hypothesis of 75% but is similar to the proportion that had a clinically important *decrease* in their health status, with 63.9% in cold/dry and 74.3% in hot/humid. In addition, these numbers are similar to the study by Sama et al. (2015), where 78% of study participants had adverse effects on their symptoms in both extremes of weather, with 81% in hot/humid weather, 67% in cold/dry weather.

Both extremes of weather conditions resulted in lower health status, and increased healthcare utilization (exacerbations, rescue inhaler use, and hospitalizations). The number of exacerbations was higher in hot/humid weather compared to ideal/moderate conditions. However, for rescue inhaler use and hospitalizations, there were no significant pairwise differences between weather conditions (i.e., ideal/moderate versus cold/dry, ideal/moderate versus hot/humid). There was no significant impact of weather type on family doctor and respiratory specialist visits, or ED visits. It is likely our study sample size was underpowered to detect a response across the three different weather conditions, and for pairwise comparisons. We found overall physical activity was lower in cold/dry conditions but increased in hot/humid conditions. The amount of physical activity, and the difficulty level was educed in both cold/dry and hot/humid conditions.

3.7.1 Cold/Dry Weather Conditions

In cold/dry weather conditions, we found that participants experienced a lower health status in comparison to ideal conditions. Our findings correlate with Miravitlles et al. (2004) who found that worse health status was observed in the winter rather than the spring and summer seasons.

In terms of physical activity, our study found an association between cold/dry conditions and lower physical activity (amount and difficulty level). We did not collect data on the types of activities, but we believe during cold/dry conditions participants decreased the amount of activity, along with doing activities that were less vigorous (hence the decrease in difficulty). These results align with Alahmari et al. (2015), who observed that colder weather was associated with a lower daily step count. Thorpe et al. (2014) explored, in COPD patients, the barriers and enablers of participation in physical activity following hospitalization. They found that some patients reported they would not leave their house because very cold weather caused excess coughing and sneezing. Other patients said the cold air made it difficult to breathe and resulted in shortness of breath. This is similar to the open-text feedback we received in our survey. For example, one participant commented, "I will go outside as little as possible. I wear a scarf around my face to limit the breathing in of cold air." Likewise, another participant commented, "Made sure to use rescue inhaler before leaving the house. Always had a scarf over my mouth and nose." With respect to intensity of activity in different weather conditions the literature does support our association of decreased level of activity (difficulty) in colder conditions. Hoaas et al. (2019) conducted a cross-sectional study to determine if there were differences in physical activity levels between Norwegian, Danish, and Australian people with COPD, and if the variations in physical activity levels were due to the seasons (winter, spring, summer, autumn). Physical activity was measured using SenseWear Armband; total energy expenditure (kJ), number of daily steps, awake sedentary time, light and moderate to vigorous intensity physical activity were recorded. Participants walked more and increased their level of physical activity during summer in comparison to the other cooler seasons.

The decrease in health status and physical activity in cold/dry weather may be due to a number of reasons. First, several studies have identified 18°C as a potential threshold of indoor temperature below which adverse health effects may occur (Jenkins et al., 2012; Jevons et al., 2016; Keatinge & Donaldson, 2001; World Health Organization, 2007).

These adverse health effects include increases in blood pressure and risks of blood clots (Jevons et al., 2016), and increase in susceptibility to lung infections and vulnerability to the common cold (Monteiro et al., 2013). With respect to physical activity, colder temperatures may lead to increased bronchoconstriction (Koskela et al., 1996), which has been associated with decreased physical activity (Donaldson et al., 2012).

3.7.2 Hot/Humid Weather Conditions

In hot/humid conditions, there was an association with lower health status and higher adverse respiratory symptoms (exacerbations). Previous research has found similar results. Werchan et al. (2018) observed a relationship between exacerbation triggers and health status using the CAT score. Their results found that 13.1% of participants reported hot and humid weather as an uncontrollable trigger and were associated with lower health status. Mann et al. (1993) found in the summer, high temperatures predicted an increase in morning dyspnea and reduced PEF. Tseng et al. (2013) also found that higher temperatures were associated with an increase in exacerbations.

Our study found that hot/humid conditions were associated with higher overall physical activity, compared to ideal conditions. This was mainly due to the decrease (improvement) in the level of difficulty, as the amount (like in cold/dry) of physical activity was significantly lower. This is in contrast to Balish et al. (2017) who found that an increase of 10°C was associated with 316 more steps over seven days when participating in PR in Canada. Our results also contrast with Furlanetto et al. (2017) who observed COPD patients' physical activity in Brazil and Belgium. They found that a 1°C rise in temperature increased the time spent being active by 1.4 minutes in Belgium patients and 6.0 minutes in Brazil patients. Like our study, these researchers also found for every percentage increase in humidity, the active time decreased by 1.03 minutes (Furlanetto et al., 2017). In addition, Miyamoto et al. (2018) and Sugino et al. (2012) used triaxial accelerometry to measure physical activity in individuals with COPD and observed a significant decrease in physical activity duration and intensity on rainy days. In the prior section, the Hoaas et al. (2019) study was described, concluding individuals with COPD had increased levels of physical activity in warmer weather conditions. In these studies, increases in PA in higher temperatures may have occurred because participants engaging in PR may have been more active than those who did not participant in PR (Sewell et al., 2010), and/or cold environments caused more negative effects compared to warmer ones e.g., COPD exacerbations (Jenkins et al., 2012; Koskela et al., 2007). We could not find studies supporting our results; decreased physical activity intensity (difficulty) in hot/humid conditions. It is recommended that both the amount and magnitude of physical activity be measured when investigating the impact of different extremes of weather conditions for individuals with COPD (Hecht, 2009).

The pathophysiological mechanisms of the association between heat exposure and exacerbation of COPD symptoms (to the extent that hospitalization was required) are not well understood (Zhao et al., 2019). The mechanism of heat exposure may induce cytokine release resulting in inflammatory responses, causing hyperventilation (Malik et al., 1983; Michelozzi et al., 2009). Hyperventilation then triggers acute bronchoconstriction and dyspnea in individuals with pre-existing COPD (Anderson et al., 2013; Sprung, 1980; White, 2006). Lin et al. (2018) speculated that higher temperatures could induce bronchoconstriction (Anderson & Daviskas, 2000) and elevate concentrations of biological aerosols, which can cause inflammatory and allergic responses in the respiratory tract (Collaco et al., 2011).

3.7.3 Cold/Dry and Hot/Humid Weather Conditions

This study did not show significant differences in in rescue inhaler use, family doctor and respiratory specialist visits, hospitalizations, or ED visits either across the three weather conditions, or in the post-hoc pairwise comparisons. This is likely due to the small sample size, as previous research by McCormack et al. (2017), found a 5.5°C decrease in daily minimum outdoor temperature was associated with an increase in the use of rescue inhalers. Similarly, Monteiro et al. (2013) found during "cold episodes," which are seven consecutive days below 5°C, there was an increase in COPD admissions by 59%. Ferrari et al. (2012) found that an increase in 1% daily ambulatory care visits was associated with increased temperature and air pressure. A decrease of 1% daily ambulatory care visits was associated with an increase in solar radiation and specific humidity. Likewise, Zhao et al. (2019) observed an increase in hospitalizations for every 5°C increase in daily mean temperature.

The majority of participants reported worse outcomes in the extreme weather conditions, however a minority of participants' health status *improved* with 3 (8.3%) positive responders in cold/dry, and 4 (11.4%) positive responders in hot/humid conditions. Previous research has found similar results with improved health status in hot/humid conditions. Miravitlles et al. (2004) found spring/summer seasons was associated with better health status scores, in comparison to winter, which may be due to the lower rate of exacerbations observed in spring/summer months. We were unable to find research to support improvements in health status in cold/dry conditions. Describing this group's characteristics and focusing on why they had health status improvements in these weather conditions will be useful for future research and clinical practice.

3.7.4 Open-Text Feedback: Potential Strategies

Based on the open-text comments, potential strategies to cope with extreme weather conditions were identified. Air conditioning may be a helpful strategy but can also be problematic because small particles like pollen, mold, and pollutants can get trapped in the filters and then released into the air. Using an air filtration system and low flow air conditioning that is regularly cleaned (to limit indoor air pollution from dust) could help individuals cope with hot and humid conditions (D'Amato et al., 2018; Jiang et al., 2016; Vijayan et al., 2015).

Another strategy that participants suggested is to use a scarf or mask to limit breathing in cold air. Scarves or masks may help filter the air and hold or "trap" heat and moisture as an individual exhales (Koskela, 2007), preventing congestion and airway epithelial damage due to cold temperatures (Koskela et al., 1996).

In previous research, it was observed that humidifiers may also help individuals with breathing as it is associated with fewer exacerbations (Ferrari et al., 2012; Rea et al., 2010). Rea et al. (2010) conducted a study to investigate if long-term humidification therapy could improve health outcomes in individuals with COPD (compared to regular care). Humidification therapy significantly reduced exacerbations and improved quality of life scores and lung function, compared to regular care. Authors speculated that long-term humidification therapy might cause a decrease in airway inflammation and may lead to improved outcomes through lung mucociliary clearance (Hasani et al., 2008).

Study participants mentioned using medication or oxygen therapy to help with certain conditions. Others took breaks between physical activity to decrease the stress on their lungs. Hence, optimizing medications and oxygenation status, together with reducing the amount and difficulty of activities may help individuals stay active without feeling fatigued in extreme weather conditions. Another strategy that could be used is to engage in PR. PR has been shown to help individuals train their lungs and skeletal muscles, in order to handle moderate to high levels of physical activity (and avoid the adverse effects of being sedentary; Balish et al., 2017; Hoaas et al., 2019).

3.7.5 Confounding Variables

For weather related outcomes, the risk of bias from confounders is high, making it challenging to ascertain weather-related inferences (e.g., temperature, humidity, sunlight) from seasonal (allergens) and air quality variables (particulates) (Ferrari et al., 2012; O'Shea et al., 2007). In our study, we were unable to adequately adjust for confounding variables due to our small sample size. Our participants were mostly female (68%), had significant smoking history (mean 40 pack years), used oxygen therapy or CPAP/NIV (58%), attended PR (63%) or self-management education programs (37%). In addition, the mean (SD) age was 64.5 (11.1), and BMI in the "overweight" range (Health Canada, 2019) at 27.77 (8.35) kg/m^2. Nineteen (54.3%) participants experienced an acute exacerbation in the last year. The majority lived with their spouse/partner 15(44.1%) or lived alone 11 (32.4%), and 18 (52.9%) were retired.

These variables may have impacted our results. First, smokers (former or current) have been found to be more susceptible to colder temperatures because they may have increased vascular response in lower temperatures (Näyhä & Hassi, 1995; Saumet &

Dittmar, 1985), which may increase risk of stroke and myocardial infarction (Elwood et al., 1993; Stout & Crawford, 1991). Osman et al. (2008) observed that in lower temperatures, individuals who were smokers were more likely to have their symptomatic health status adversely affected compared to non-smokers. Jenkins et al. (2012) conducted a study to determine the seasonal impact on COPD exacerbation frequency and found a higher exacerbation rate in winter than in summer. Their results observed that older age, lower BMI, lower FEV1, and a history of prior exacerbations significantly increased the risk of exacerbations. Similarly, Zhao et al. (2019) found in higher temperatures, older individuals ($\geq$ 75 years old, both males and females) experienced an increase in hospitalizations. Kenney et al. (2014) found that older individuals experience a greater exacerbation risk due to the social and working factors of living alone, being confined to their home, and poor social contact.

Overall, future research describing the impact of important confounders during various weather-related conditions will help inform different management strategies and goals for individuals with different COPD severities and phenotypes.

3.8 Strengths and Limitations

3.8.1 Strengths

Our study is one of the few that assessed the effects of temperature and humidity on health outcomes in individuals with COPD living in Canada. Our study used objective measures (CAT and D-PPAC) that were reliable and valid (Craig et al., 2003; Gimeno-Santos et al., 2015; Jones et al., 2009; Liao et al., 2014; Mahler & Wells, 1988; Mahler et al., 2009; Natori et al., 2016) and defined positive and negative responders (Garcia-Aymerich et al., 2021; Liao et al., 2014; Wacker et al., 2016) to weather extremes. We utilized good recruitment strategies, despite the challenges associated with the COVID-19 pandemic. Our sample had representation from various parts of Canada from different communities of large, medium, and small population sizes.

We conducted the survey using a multi-modal method (online/phone/mail) and took several steps to minimize potential biases or errors when designing the survey (described below) (Dillman et al., 2014). One of the main reasons for using a multi-modal method was to improve timeliness. We wanted to give all options available since we had to collect data within two to three months in the hope of achieving the best response rate. This approach also minimizes the challenges with accessibility, since individuals with COPD may not have had access to the internet or had access to computer technology (Dillman et al., 2014). To minimize measurement errors, we endeavoured to use the same question, wording, and visual formats across all modes e.g., printing the online version of the survey for participants answering by mail. We also acknowledge the limits of consistency between modes e.g., unavailability of drop-down menus in paper surveys, more opportunities to express feelings and opinions during phone interviews. In addition, with paper and online surveys, detailed instructions were provided, and it was clearly indicated that participants could skip any question they do not want to answer. Future research should include multi-modal survey methodology to enhance response rate but should also assess if each modality is reliable.

3.8.2 Limitations

The primary limitation of this study was the sample size (proposed initially at 300), which affected generalizability and our ability to control for confounders. Our study was also retrospective and may have suffered from recall bias and/or under- or overestimations. Individuals were asked to recall their symptoms, physical activity, exacerbations, rescue inhaler use, and hospitalization utilization during different weather conditions from a year in the past and, during pre-COVID-19 times. We used ideal conditions as a baseline for the health status before a change in weather, which may also cause recall issues. Some individuals may have answered based on the time they completed the survey, when they could not attend PR or leave their house due to COVID-19 risks and restrictions. Also, since the study was conducted in the fall/wintertime, this may have influenced recency bias.

Our survey was anonymous, and since our data was affected by bots, results from the first dataset (n = 12) and second dataset (n = 25) may have differed. We did in fact find the total CAT score in the first cohort was significantly lower (better health status) compared to the second cohort. Given the small sample size, this may have been due to random error. However, it is probable this cohort had less severe COPD, or did not have COPD (most of these individuals did not come from PR programs). Future research should incorporate consistent approaches to recruitment, ways to confirm a COPD diagnosis, and stratification by disease severity.

This study did not collection information on ethnicity. We could not find literature describing the influence of ethnicity and different weather conditions on respiratory related outcomes. Ethnicity may play a role as rain significantly decreased active time by 22 minutes in individuals with COPD living in Belgium but had no significant effect in Brazil (Furlanetto et al., 2017); and there were regional differences in the magnitude of weather effects between North and South Bavaria (Ferrari et al., 2012). It is difficult to determine if these outcomes were due to geographical location and/or ethnicity. Previous research on healthy individuals in a climactic chamber, found ethnicity differences in thermal preferences (based on personal comfort); individuals of Asian descent consistently preferred higher temperatures compared to those of Western and Middle European descent (Havenith et al., 2020). Future research could further explore this by assessing the same weather extremes (actual or artificial) on individuals with COPD of various “biological” ethnicities.

Our study was open to individuals across Canada, but this may be a limitation as the weather in individual provinces differs. For example, British Columbia experiences cold and humid weather based on participant text feedback, and in our study, we only assessed cold and dry weather conditions. In addition, we likely did not have any French-speaking participants because we did not have the resources to translate the survey. We also recruited mostly from PR programs. Our sample may not be generalizable to the entire COPD population in Canada due to these limitations, however this study serves a pilot-study to provide important implications for future research studies.

3.9 Future Research

To determine the impact of weather on outcomes to individuals with COPD, understanding the influence of other factors (confounders) is required. Using prospective designs, such as cohort studies, with larger sample sizes would be a good next step. It would be valuable to note the severity of COPD in individuals and obtain a confirmed COPD diagnosis. Also, piloting a study and using consistent recruitment techniques and data collection methods can promote study reliability. To enhance sample size, utilizing patient advocacy groups such as COPD Canada, and home healthcare organizations is strongly recommended. In addition, targeting individual geographical regions rather than all together, is recommended, especially given the vast geographical area of Canada. We recommend using objective measurements to identify responders to extreme weather conditions. Based on this study using both the CAT and D-PPAC (amount and difficulty) is recommended, as both were impacted by the extreme weather conditions. Collecting objective measures of physical activity quantity, and magnitude, are also recommended. Studies should consider both spectrums of temperature and humidity together, such as hot and cold temperatures with high and low humidity. Other meteorological factors could also be considered, such as barometric pressure (Ferrari et al., 2012), solar radiation or hours of sunshine (Ferrari et al., 2012; Tseng et al., 2013), and/or wind speed (Ferrari et al., 2012).

Another innovative research approach is to use a Climatic Chamber where changes in temperature, relative humidity, wind, and solar radiation are possible. In previous literature it was found that air pollution reduced physical activity, increased adverse respiratory symptoms, and reduced pulmonary function (Alahmari et al., 2015). Also, air pollution was associated with COPD exacerbations and mortality, and poor quality of life (Hansel et al., 2016). Since it has similar effects to temperature and humidity extremes, it is difficult to determine which is the primary cause behind the effects on health outcomes. Using a climatic chamber decreases the confounding impact of outdoor air quality variables. This may help identify the direct effects of these weather conditions, but also allow for tests of specific interventions.

The experiences of individuals with COPD in different weather conditions, using a qualitative approach, should be considered, especially considering the varied open-text responses in this study (most participants worsened, but some improved) and past research (Balish et al. 2017; McCormack et al. 2017; Miravitlles et al. 2004).

Finally, future research should involve the development and evaluation of management and coping strategies to help alleviate adverse symptoms and the limitations for individuals with COPD in extreme weather conditions.

3.10 Conclusion

This study showed that individuals with COPD living in Canada may be negatively affected by both extremes of hot/humid and cold/dry conditions. Sixty-four percent (n = 23) negatively responded to cold and dry conditions, and 74% (n = 26) to hot and humid conditions. This negative response was associated with decreased health status, decreased physical activity (amount and difficulty level), and increases in exacerbations, rescue inhaler use, and hospitalizations. It is imperative to develop preventative and management programs to help individuals with COPD cope with different weather conditions. These may include optimizing medications and oxygenation status, avoidance strategies, and pulmonary rehabilitation. This is especially important given COPD is one of the top three leading causes of death, and climate change has resulted in more and more extremes of weather conditions.

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CHAPTER 4: GENERAL DISCUSSION

4.1 General Discussion

Chronic obstructive pulmonary disease (COPD) is a progressive respiratory disease and is currently one of the three leading causes of mortality in the world (GOLD, 2020). Individuals with COPD suffer from exacerbations or significant worsening of respiratory symptoms leading to a negative impact on their quality of life, decreased lung function, and physical activity (Inal-Ince et al., 2014; Werchan et al., 2018). As the lungs are the portal organ of the environment (Jehn et al., 2013), temperature and humidity affect individuals' lung function (Hansel et al., 2016). However, there is a lack of evidence to support this claim, and the underlying reasons are not known. By determining the relationship between weather and COPD outcomes, it may help the future management of COPD.

The principal goal of this research was to assess the influence of temperature and humidity on COPD outcomes (respiratory symptoms, frequency of rescue medication use, exacerbations, healthcare utilization), health status, and physical activity in individuals with COPD using a cross-sectional self-reported survey. We assessed three weather conditions to determine the effect on COPD outcomes: moderate or ideal, hot and humid, and cold and dry. We had two objectives for our study: to determine the proportion of individuals with COPD affected by extremes of weather on their health status and respiratory symptoms, and to determine the associations between extremes of weather and health status, respiratory symptoms, physical activity, frequency of exacerbations, rescue inhaler use, and healthcare utilization in individuals with COPD. We hypothesized that 75% of participants [based on Sama et al. (2015)] would report being affected by either extreme of weather conditions and that both extremes of weather conditions would be associated with lower health status, higher adverse respiratory symptoms, decreased physical activity, increased rescue inhaler use, and increased healthcare utilization.

Our study found that the majority of participants responded to either type of extreme weather, as hypothesized. In comparison to ideal conditions, participants had worse health status (CAT score), and decreased physical activity (D-PPAC score) in both amount and difficulty level in cold/dry and/or hot/humid conditions. Frequency of exacerbations, rescue inhaler use, and hospitalization increased in both extremes of weather compared to ideal conditions. There was no significant difference between weather conditions for family doctor visits, respiratory specialist visits, and ED visits.

When conducting the surveys, we had the opportunity to complete the survey with some individuals over the phone. We believe most of them wanted to elaborate on the difficulties they faced with extreme weather conditions (more than participants who completed the online version). We discovered different themes for individuals' comments such as using multiple strategies to cope with weather extremes and which extremes of weather were most problematic. For example, many participants stated they avoided the condition and stayed indoors. Some would use medication or oxygen therapy and use air conditioning to help cope with the weather. Air conditioning seemed to help with high temperatures but may also be problematic since dust get trapped and may affect their breathing even more. There were multiple combinations of temperature and humidity that were challenging to deal with and differed from individual to individual. The majority of participants expressed that hot and humid weather conditions were more challenging than cold and dry. Two participants preferred dry air with cold temperatures. This was interesting because we hypothesized that dry humidity in cold temperatures would be problematic for individuals.

We did not meet our anticipated sample size of 300 due to COVID-19 restrictions, which weakened our inferences, and prevented an adequate analysis of confounding factors. The majority of our participants participated in PR, were former or current smokers, overweight according to their BMI, experienced an acute exacerbation in the last year, mostly retired, used O_2 therapy/CPAP/NIV, and lived in medium to large, populated communities. Future research should investigate specific influences of all relevant confounders.

Our study's strengths were that we utilized objective measures (CAT and D-PPAC) that were reliable and valid to assess the effects of temperature and humidity on COPD outcomes (Craig et al., 2003; Gimeno-Santos et al., 2015; Jones et al., 2009; Liao et al., 2014; Mahler & Wells, 1988; Mahler et al., 2009; Natori et al., 2016). We also defined negative and positive responders to the extreme weather conditions (Garcia-Aymerich et al., 2021; Liao et al., 2014; Wacker et al., 2016) according to the minimally clinical important difference of the CAT. Our study also consisted of a variety of participants from different regions across Canada. In terms of limitations, the COVID-19 pandemic contributed significantly to our survey's low response rate as we were unable to recruit individuals directly. Our study also suffered from recall bias as some individuals may have found it challenging to recall situations pre-COVID-19 times, and inaccurately estimated their answers to survey questions. In addition, although we recruited a variety of individuals throughout Canada, certain weather conditions may not apply to all regions.

Overall, future research should include prospective studies (such as randomized crossover or non-randomized comparisons) with larger sample sizes, various combination of weather variables (to mimic specific geographical regions) and consider important confounders. We anticipate our research will help develop management and coping strategies for individuals with COPD, living in different extreme weather conditions.

4.2 Dissemination

With this research, we anticipate other researchers, practitioners, the public, patients/consumers, and policymakers/government could benefit. Our results provide information on the prevalence of individuals with COPD affected by weather extremes, which weather extremes are most problematic, which outcomes are most affected, and other challenging weather-related conditions and outcomes not previously identified.

Due to the inconsistencies and gaps in the evidence, we believed it was essential to include the knowledge and opinions of individuals with COPD. We collaborated with two COPD patients Mr. Ben Bowles and Ms. Pauline Anderson. Partner engagement with our project was ongoing during the process of formulating the proposal and survey. Both individuals helped with patient recruitment and interpretation of the data. Both Mr. Bowles and Ms. Anderson both stated that it “was about time” this type of research was completed.

Our End of Grant strategy is to generate awareness and interest, share knowledge, inform decision-making, inform researchers, and facilitate policy change (CIHR, 2015). We will publish our research in a peer-reviewed publication and present it at relevant academic and health conferences. We will also present this information at various PR (and related) programs, and through patient advocacy groups.

4.3 Summary & Conclusions

Temperature and humidity are found to affect COPD outcomes, specifically health status, physical activity, exacerbations, rescue inhaler use, and healthcare utilization. It is anticipated there will be an increase in the number, duration, and intensity of extreme weather occurrences, especially heat waves, and warmer areas affected by colder temperatures (Jehn et al., 2013). The effects of temperature and humidity on COPD outcomes may be unavoidable. This may result in worsening clinical status and deteriorating quality of life in individuals with COPD (Jehn et al., 2013). Previous research has found that regular physical activity may increase exercise tolerance, reduce dyspnea, fatigue, and improve quality of life in individuals with COPD (Coventry & Hind, 2007). It may reduce health care costs by decreasing healthcare utilization. As COPD is one of the top three causes of mortality worldwide (GOLD, 2020), it is essential to help these individuals by developing non-pharmacological management programs, and adaptation strategies during extreme weather conditions.

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APPENDICES

APPENDIX A.1 SYNTHESIS MATRIX OF LITERATURE REVIEW ARTICLES

	Donaldson et al. (1999).	McCormack et al. (2017)	Ferrari et al. (2012)
Country	England	USA	Germany
Date	1999	2017	2012
Purpose	Determined if a decrease in environmental temperature increases morbidity from COPD.	Investigated individuals with COPD during the cold season to determine the effect of daily temperature on daily symptoms, lung function, and rescue inhaler use.	Assess various meteorological factors on health status of COPD patients; frequency of ambulatory visits to pneumologists/primary care physicians in Bavaria, Germany.
Variables (Independent/Dependent)	Daily lung function and symptom data collected over 12 months from 76 COPD patients living in East London and related to outdoor and bedroom temperature. Meteorological data: meteorological office had three-hourly temperatures, daily average windspeed and one-hourly relative humidity data, temperature and relative humidity were averaged to give daily mean values.	Daily symptoms, lung function, and rescue inhaler use with daily temperature.	Ambulatory care visits compared to meteorological data (solar radiation, air pressure, wind speed); analyzed results of the model at the European Centre for Medium Range Weather Forecast.
Confounding Variables	Did not specify confounding factors.	Age, sex, education, visit and % predicted FEV1 measured at enrolment or pack years of smoking, ethnicity.	Did not specify confounding factors.
Subjects	Patients were attending an outpatient clinic at the London Chest Hospital. Moderate-Severe COPD and had FEV1, baseline spirometry and arterial blood gas measurements carried out.	Patients over the age of 40; former smokers.	Data provided by Association of Statutory Health Insurance Physicians in Bavaria: visits to a primary care physician or pneumologist in 2006 and 2007.

Study Design	Longitudinal Study - questionnaire	Longitudinal study – assessed at 3 points	Study design: retrospective analysis of ambulatory care visits with COPD in Bavaria, Germany between Jan 2006-Dec 2007
Sample Size	76	84	~25 million visits
Themes	Meteorological variables - three-hourly temperature, daily average windspeed and one-hourly relative humidity data, temp and relative humidities & lung function: FEV1, baseline spirometry and arterial blood gas.	Temperature (indoor temperature, nitrogen dioxide, outdoor temperature, humidity, pollution) and lung function (spirometry tests), symptoms (BCSS scale)	Meteorological variables - solar radiation, air pressure, wind speed.
Main Findings	Fall in outdoor or bedroom temperature was associated with increased frequency of exacerbation and decline in lung function. Forced expiratory volume in one second (FEV1) and Forced vital capacity (FVC) fell by a median of 45 mL and 74 mL respectively between warmest and coolest week of the study. Falls in lung function were small; may be sufficient to compromised patients with COPD who have marked airflow obstruction (may make them more susceptible to infections) Could not explain by changes in relative humidity or windspeed since there no consistent relationships between this and lung function.	5.5°C decrease in daily minimum outdoor temperature was associated with an increase in rescue inhaler use, a 0.17-point increase in BCSS score (increase in respiratory symptoms), and a mean reduction of 38 mL and 26 mL in morning and evening FEV1, respectively. Daily indoor temperature was found to not significantly affect COPD outcomes, except when the temperature was below 21°C, i.e., lower indoor temperature was associated with a higher BCSS score. Variables of humidity and indoor nitrogen dioxide concentration did not impact the outcomes.	North vs. South Bavaria: north significant influence of variables wind speed and humidity 1% increase of daily consultations associated with change of 0.72 K temperature, 209.55 log surface pressure in Pa, decrease of 1% daily consultations with 1,453,763 Ws m^2 solar radiation. Solar radiation and humidity had negative impact on ambulatory visits.

How does study relate to other studies/important notes	This study found that common cold symptoms (such as nasal congestion) were related to the fall in temperature in winter. Cold temperature may cause increased peripheral vasoconstriction and shunt blood centrally and reduce lung capacity. Inhalation of cold air can cause post-exertional bronchoconstriction. Since patients with COPD already have a largely fixed airflow obstruction unlikely, they will show significant bronchoconstriction because of cold on airways. This study investigated the effect of indoor temperature in COPD patients; they are found to be more housebound because of their COPD.	Individuals were susceptible to the effects of cold temperature exposure, despite spending limited time outdoors.	These studies are finding a correlation with weather data and hospital admissions.
Strengths/Weaknesses/ Limitations	This study suggests that cold weather-related reduction in lung function and an increase in exacerbations may contribute to the high cold-related morbidity in COPD patients, but the mechanism was unknown. Data from fixed monitoring sites than individual data. Small sample size.	The interpretation of the results is unclear since it is difficult to separate the effects of temperature changes from other seasonal factors.	They found a correlation but the exact mechanism by which the exposure to these factors increase/decrease risk of morbidity remain unclear Bavaria is relatively small in relation to meteorological dimensions – found significant regional differences in the influence of meteorological factors.

	Tseng et al. (2013)	Monteiro et al. (2013)	Zhao et al. (2019)
Country	Taiwan	Portugal	Brazil
Date	2013	2013	2019
Purpose	Aims of study: investigate meteorological variables in relation to exacerbation rates of COPD and potential protective effects of vaccination or inhaled medicine on COPD patients.	Purpose of the study is to examine the relationship between occurrence of cold episodes and excess hospital admissions for COPD in Porto, Portugal (Nov to March 2000-2007). Daily morbidity count performed for COPD admissions during the period. Had climatic records from Meteorological Observatory of Serra do Pilar	Heat exposure has been related to increased morbidity and mortality for several health outcomes, but unknown for COPD.
Variables (Independent/Dependent)	Used National Health Insurance registry data from Jan 1, 1999 to Dec 1, 2009, all patients 40 years or older who had diagnosis of exacerbation of COPD and meteorological variables from Taiwan Central Weather Bureau were analyzed; case crossover study design to investigate the association between COPD exacerbation and meteorological variables.	Daily morbidity count performed for COPD admissions during the period, had climatic records from Meteorological Observatory of Serra do Pilar.	Data on hospitalizations for COPD in Brazil and weather conditions were collected from 1642 cities during 2000-2015.
Confounding Factors	Age, sex, date of admission, date of discharge, date of visit, up to 5 discharge diagnoses or 3 outpatient visit diagnoses, comorbidities, also asked of patient prescriptions, names of prescribed drugs, dosage, duration,	Did not specify confounding factors.	Collected data on hospitalizations for COPD (4 geographical areas), sex, 3 age groups (0-64, 65-74, > 75) date of admission, and primary diagnosis.

	total expenditure [no statistical significance in age, sex, health care costs]		
Subjects	Crossover study design in Taiwan, Jan 1, 1999 to Dec 1, 2009; 16,254 cases	Did not specify how many people they studied, but it was from Nov-March from 2000-2007.	Hospitalization data, did not specify how many people.
Study Design	Case-crossover	Case-crossover	Time stratified case-crossover
Sample Size	16,254 cases	N/A	N/A
Themes	Meteorological variables (average daily ambient temperature, daily maximum ambient temperature, daily minimum ambient temperature, average daily relative humidity, average daily barometric pressure, maximum wind speed, and total hours of sunshine on each day).	Cold spells (according to indices).	Temperature: heat exposure on COPD hospitalizations (association).
Main Findings	1 degree C decrease in air temperature associated with 0.8% increase in exacerbation rate 5 degree C decrease in mean temperature, cold temperature had a long-term effect on exacerbation of COPD. Elderly patients and those who did not receive inhaled medication tended to suffer an exacerbation when mean temp dropped 5-degree C. Higher barometric pressure, more hours of sun, lower humidity, associated with increase in COPD exacerbation.	Used difference indices to define cold spells. Found that there is an excess of COPD admissions during winter, mainly with cold spells. Depends on duration (# days of cold spell), intensity (relationship between temperature and time), lag period (time difference between cold episode and body's reaction to that event via. symptoms) and adaptation capacity (human body adjusting to thermal environment).	Results: OR of hospitalization was 1.05 for every 5-degree C increase in daily mean temperature. Effects stronger in late hot season compared to early. Effect greater in those 75 years or older. In Brazil, exposure to ambient heat was positively association with hospitalization for COPD.

	Two-fold increase in the COPD exacerbation rate in winter.		
How does study relate to other studies/important notes	This study: barometric pressure had positive correlation with exacerbation, but humidity and sunshine negatively associated. Increased humidity may eliminate the risk of triggering a COPD exacerbation, long-term humidification therapy significantly reduced exacerbation days, increased time to first exacerbation and improved lung function, quality of life.	From preventative standpoint – want to contribute to having a measure in place to create an efficient warning system suited to each regional local climate or teaching patients how to respond to extreme temperatures.	Underlying mechanisms for heat exposure on COPD patients: heat-induced release of cytokines may result in inflammatory response and respiratory distress, dissipating body heat through hyperventilation may trigger dynamic hyperinflation and dyspnoea in patients with pre-existing COPD, inhaling hot air may trigger acute bronchoconstriction of airway.
Strengths/Weaknesses/ Limitations	Limitations: did not include exposure to air pollutants, indoor temperature, SES, temperature exposure of the individuals.	Limitations: influence of COPD co-morbidities (presence of history of asthma or TB), concentration of atmospheric pollutants, along with wind, smog, SES can affect the aggravation of COPD.	Limitations: used grid temperature data rather than individual exposures, may underestimate relationship between ambient heat and COPD hospitalization. Unable to control for air pollution.

	Balish et al. (2017)	Furlanetto et al. (2017)	Osman et al. (2008)
Country	Canada	Brazil & Belgium	UK
Date	2017	2017	2008
Purpose	Unknown whether daily variation in weather (temperature, snow, rain) impacts PA (objectively measured) in COPD patients. Also want to determine whether demographic or	Purpose: seasonal changes in physical activity in daily life (PADL) with COPD patients living in regions of the world with contrasting weather variations have not been yet investigated.	Want to determine if the health status of patients with COPD are associated with maintaining the level of warmth in their homes.

	clinical characteristics moderate these relationships.		
Variables (Independent/Dependent)	COPD patients completed a questionnaire and wore a pedometer for 7 days at baseline, end of PR and at 3 and 9 months after completing PR. Compared to daily weather info from environment Canada using local airport weather station at each study that patients were recruited from (for the specific days patients wore pedometer).	Longitudinal, prospective and observational study, patients from Brazil and Belgium wore SenseWear Armband for 7 days in summer and 7 days in winter. Data was matched with weather information. Median temperature 11 degree C in Belgium and 21 degree C in Brazil.	Home warmth and health status of patients with COPD.
Confounding Variables	Self-reported social environment questionnaire: age, gender, annual income, BMI, FEV1 predicted.	Age, lung function, gender, functional exercise capacity, level of education (factors they collected: personal data [marital status, living alone, education level, work status], smoking, comorbidities, medical history, exercise training history).	Self-reported smoking status, marital status, age, patient data reviewed by hospital physician within past 2 years & recorded diagnosis of COPD, # of prior admissions for COPD, lung function measurements collected, FEV1 predicted, social deprivation [postcodes, car ownership, household overcrowding, head of household social class, male unemployment], measured health with SGRQ & EQ VAS.
Subjects	Sampled 189 patients from diverse geographical areas (diff PR programs across Canada) and assessed patients 4 times over a 1-year period.	Jan. to Sept. 2013, 24 patients from Belgium and 27 patients from Brazil Simultaneous assessment during winter in Belgium and summer in Brazil. Simultaneous re-assessment during	148 patients collected data of living room and bedroom temp measured at 30-minute intervals over 1 week between end of October 2004 and mid-May 2005, health status measured with St. George questionnaire and EuroQol (mailed to them), outdoor temp provided by Meteorological office.

		summer in Belgium and winter in Brazil. Collected weather data from each national meteorological institute. Measurements: spirometry, 6MWT, COPD assessment test and modified Medical Research Council scale Questionnaire.	Compared patient lung function measurements from physician from clinical records.
Study Design	Longitudinal, observational	Longitudinal, observational	Cross-sectional observational study
Sample Size	189	24 + 27	148
Themes	Meteorological variables: temperature, snow, rainfall and physical activity - steps/day.	Meteorological variables: mean temperature, minimum temperature, maximum temperature, precipitation, relative humidity and duration of daylight. Physical activity: spirometry, 6MWT	Home warmth and health status of patients with COPD, temperature with symptoms.
Main Findings	Daily mean temperature and total daily rainfall (not snowfall) independently predicted steps/day controlling for demographic and clinical covariates in 189 patients in PR. Increase of 10 degree C associated with 316 more steps (may be because cold air exacerbates COPD symptoms), rainfall 10 mm 175 less steps. Those with higher income had more steps/day on warmer days.	Patients in Brazil and Belgium decreased their active time in winter compared to summer and reduction was more pronounced in Brazil. Mean, max., and min. temperature, daylight duration, and relative humidity were significantly related to active time. Patients with COPD decrease their PADL in winter (even in region with milder climatic variation). Humidity had effect of PA: every % increase in humidity, active time decreased with mean minutes.	Used descriptive statistics for temperature monitoring results, parametric and non-parametric/least square multivariate regression analysis. 14 degree C outdoor threshold association with increases in respiratory mortality, median LR temp at 5 pm was 21degrees C and 8 patients had 5 pm LR temp below 18 degrees C and two had below 14 degrees C. Found that symptomatic health status of COPD patients is associated with maintaining guideline warmth in their homes during cold months, patients with fewer days with 21 for at least 9h had worse

			respiratory symptom scores.
How does study relate to other studies/important notes	To better establish relationship between weather and steps/day; replications of weather on PA in COPD populations needed, larger samples from more diverse geographic areas and repeated throughout the year to include seasonal variation within the sample.	The hypothesis that regions with less pronounced summer-winter variations in climatic conditions would present lower variability in PADL was rejected (refer to results in beginning). 1 degree C rise in temperature increased the time spend active by 1 minute in Belgium patients and 6 minutes in Brazil patients; may be duration of precipitation instead of amount could be strongly related to physical activity and explain the decrease in PA.	WHO recommends that living areas in homes should be maintained at a temperature b/w 18 to 24 degrees C. Perception of home as cold is related to poor self-related health and increased respiratory symptoms. Suggests that home indoor warmth influences respiratory health status and that 21 degrees C for 9h index is useful indicator of whether indoor warmth is sufficient for health.
Strengths/Weaknesses/ Limitations	Relied on self-reported step counts from a pedometer; did not rule out errors from reading the step count, or measure the intensity of time spent in PA. Which is what we hope to achieve in our study. Also, weather data was taken from stations close to where the PR program was located, the distance varied across patients and could be bias of how weather and PA are related. Future research could have GPS to provide more accurate relationship.	This information of PADL based on one center cannot be generalized to entire COPD population. Limitations: small number of patients, differences in PA between summer and winter not detectable using moderate intensity of PA as a threshold, lack of data on air pollution.	No previous study has shown direct relationship between objectively measured indoor hours of warmth and respiratory health status, little relationship of indoor to outdoor - did not track the effect of changes in outdoor temperature on COPD health. Future perhaps look at physiological mechanisms and how indoor temperature and smoking habits may mediate effects of outdoor temperature on mortality and morbidity during winter.

	Sama et al. (2015)	O'Shea et al. (2007)
Country	USA - Massachusetts	Australia
Date	2015	2007
Purpose	Want to determine the environmental triggers of COPD exacerbation.	Exercise is an important treatment for COPD patients but factors influencing adherence have been examined infrequently. Explores adherence factors to a progressive resistance exercise program for persons with COPD.
Variables (Independent/Dependent)	Environmental triggers and COPD symptoms.	Persons with COPD enrolled in a 12-week trial of progressive resistance exercise, invited to participate in 2 semi-structured qualitative interviews exploring program adherence.
Confounding Variables	Age, ethnicity, smoking history, sex, regular home O2 and nebulizer use, post-bronchodilator, patients had to have at least 1 antibiotic prescription 3 years prior and 1 exacerbation, no other lung disease.	BMI, disease severity, age, long term oxygen therapy, smoking history, rehabilitation history.
Subjects	167 clinically confirmed patients who participated in a COPD management program in medical group practice. Used a survey to ask about specific daily activities and associated chemical exposures likely to be irritating to the respiratory system and asked if exposure to these activities bothered their breathing, avoided them, or took additional medications to treat their symptoms.	22 patients interviewed at the conclusion of the intervention; 19 patients completed a second interview. Adherence was facilitated by expected outcomes, self-motivation, supervision, group support.
Study Design	Cross-sectional survey	Qualitative – grounded theory
Sample Size	167 patients; received response from 145.	22
Themes	Temperature and COPD symptoms.	Physical activity - adherence factors.
Main Findings	Developed questionnaire into 3 sections: PA, chemical exposures, and non-chemical triggers of COPD Data analysis by calculating prevalence ratios comparing the frequency of reporting a particular exposure as bothersome in one group vs. comparison population.	Short term: environmental – weather major environmental barrier, hot and cold weather, seasonal weather patterns (did not go into detail). Long-term: cold weather show to induce increased bronchoconstriction in COPD patients. Need of strategies for maintaining or adapting exercise performance in

	More than half of patients reported that certain common dusty activities (sweeping, vacuuming, dusting) and exposures to cigarette smoke, wood smoke, vehicle exhaust, cleaning prod, perfume affected breathing.	relation to weather changes may be important to overcome weather barriers.
How does study relate to other studies/important notes	Did claim that spending time in hot weather or humidity and cold air or cold weather did influence breathing and acted in response to the exposure.	N/A
Strengths/Weaknesses/ Limitations	Limitation - not studying clinical exacerbation but rather self-reported irritation of breathing and need for rescue medication.	Strengths: examined from perspectives of participants in short term and long term. Limitations: bias between interviewer and participant.

	Spence et al. (1993)	Mann et al. (1993)	Hsieh, et al. (1970)
Country	England	England	Indiana, USA
Date	1993	1993	1970
Purpose	Study examined the effect of breathing cold air on exercise tolerance and perception of breathlessness	Determine if meteorological conditions affect the respiratory status of individuals with chronic lung disease	Determine if gas exchanged is affected at rest and with exercise by airflow resistance alterations during cold air breathing in COPD patients (with history of sensitivity to cold air)
Confounding Variables	Gender, age, FEV1, FRC	Primary respiratory diagnosis, smoking history, oxygen therapy	Age, body surface area, vital capacity, FRC, TLC
Variables (Independent/Dependent)		Meteorological conditions & lung function: Daily meteorological conditions and LRI frequency were tested individually and in combination as predictors of daily mean values of morning & daytime dyspnea, PEFR and mood	Effects of temperature on gas exchange at rest and while exercising
Subjects	19 participants with stable COPD exercised of a cycle ergometer breathing either room or cold air (-13 degrees C)	14 participants who completed outpatient PR in greater Hartford area (New England) asked to record	9 patients with cold air sensitivity studied at rest and during treadmill exercise breathing room temp and – 12 degree C air

	Breathlessness assessed by Borg scaling; asking how breathless are you?	daily during spring and summer of 91' the following: Morning dyspnea, daytime dyspnea, PEFR (peak respiratory flow rate), mood, presence of lower respiratory tract infection (LRI)	
Study Design	Cross-sectional experimental study	Cross-sectional observational study	Cross-sectional experimental study
Sample Size	19	14	9
Themes	Temperature (cold air) on COPD symptoms when exercising	Meteorological conditions on lung function	Temperature on gas exchange on rest and exercise
Main Findings	Peak performance improved when breathing cold air; cold air reduces breathlessness in COPD inducing relative hypoventilation. Maximal exercise level achieved was higher breathing chilled air. Exercise produced a small increase in FEV of breathing room air and increase (not significant) greater in chilled air. Participants reported less breathlessness at the end of the work load when breathing chilled air.	Spring: Only meteorological factor that was associated with resp. status is rainfall (precipitation) - Directly related to increased morning and daytime dyspnea - Not related to changes in mood or PEFR Summer: Meteorological factors of high temperature, rise in barometric pressure, and increased LRI freq. predicted increased morning dyspnea High temp and rise in barometric pressure predicted reduced PEFR Not related to changes in mood or daytime dyspnea	7/9 patients more distressed during cold air breathing no significant differences in heart rate, O2 consumption and arterial blood PO2 and PCO2 between room temp and -12 degrees C air at rest/exercise
How does study relate to other studies/important notes	Breathing cold dry air can provoke bronchoconstriction in susceptible asthmatics, but some clinicians	Correlation of meteorological variables on individual participants recorded data vs	Airway resistance increases as temperature decreases, previous studies found that air cooled to -20 degrees C resulted in

	state that breathing cool air will ease breathing.	hospitalizations/exacerbation	increase in airway resistance
Strengths/Weaknesses/ Limitations	A lot of limitations to this study, not a lot of participants so it not generalizable, conflicting evidence in the literature, this is a dated article		One of the first articles, not enough patients to generalize, needed more research at this point

	Lin et al. (2018)	Thorpe et al. (2014)	Alahmari et al. (2015)
Country	China	Australia	England
Date	2018	2014	2015
Purpose	Evaluated association between temp. variations and daily fluctuations in pulmonary function in COPD patients	Explore from the perspectives of COPD patients the barriers and enablers of participation in PA following hospitalization for COPD	How climate and atmospheric pollutants affects physical activity in COPD patients
Confounding Variables	Individual-level confounders were collected at enrollment, including age, body mass index, education (level 1: illiteracy or elementary school; level 2: middle school; level 3: college; level 4: graduate), and smoking (status and pack-years). To account for possible influences associated with disease severity at baseline, collected information on the classifications of (GOLD). Collected air pollutant data	Age, gender, ethnic background	Age, sex, medical history, smoking history, FEV1 measurements, BMI / separated weekend and weekdays in analysis, should've looked at air pollution - but impractical to look at individual exposures
Variables (Independent/Dependent)	Linear mixed-effect model combined with distributed lag model to estimate cumulative effects of temp on morning/evening pulmonary function	Qualitative descriptive design, semi-structured phone interviews with 28 adult COPD patients who were admitted to the hospital with a	73 stable COPD patients, recorded on daily diary cards of worsening of respiratory symptoms, peak expiratory flow rate (mini-Wright meter), hours spend

	tests (PFTs); peak expiratory flow (PEF) and forced expiratory volume in 1-s (FEV1)	primary diagnosis of exacerbation of COPD	outside their home and number of steps taken per day; recorded on pedometer; Used daily data for atmospheric PM10 and ozone from Air quality information archive in London, and daily weather data from London Heathrow from British Atmospheric Data Archive Also completed daily COPD Assessment Test questionnaire
Subjects	Time-series panel study of 28 male COPD patients with repeated daily lung function measurements from Dec 2012- May 2013 in Shanghai, China	28 adult COPD patients who were admitted to the hospital with a primary diagnosis of exacerbation of COPD Between March-Nov 2011 in Adelaide, South Australia	73 stable COPD patients in London; 1995-March 2013; longitudinal observation
Study Design	Time-series panel	Qualitative descriptive	Cross-sectional observational study
Sample Size	28	28	73
Themes	Effects on temperature (morning/evening) on lung function (PFT, FEV1)	Physical activity - barriers and enablers	Meteorological variables - air pollution, ozone, weather data. Physical activity. Lung function: symptoms, peak expiratory flow
Main Findings	Association between daily mean temp and PEF were inverted U-shape; both low and high temp significantly reduced morning and evening PEF - No apparent association observed between temp and FEV1	Environment: Weather; seasonal weather patterns some patients said that if it gets too cold they will not leave their house, cold weather cause the cause of pneumonia and hospital admission (another patient said that cold weather makes me sneeze and cough a lot) weather has detrimental effect on breathing, cold	Colder weather below 22.5-degree Celsius reduced daily step count by 43.4 steps day per degree C, activity lower on rainy than dry days and on overcast days vs. sunny Higher ozone levels decreased activity during the whole week and at weekends PM10 reduced activity (not during weekend)

		air made it difficult to breath or cause a shortness of breath Some patients said that there was a limitation in PA because of pollen and dust	
How does study relate to other studies/important notes	PFT are essential for the diagnosis and management of COPD; decrease in lung function can lead to an acute exacerbation - identification of risk factors leading to lung dysfunction can help protect individuals from an acute exacerbation There is inconsistency in studies of the association between temperature and lung function; some suggested that higher temp could reduce lung function, while others reported reverse findings Previous studies have associated temp with lung function among COPD patients in either cold or warm seasons but not in both	Outcome of the study: important that health professionals acknowledge that there are barriers to physical activity and PR Hospital admission can create an opportunity for implementation of interventions promoting PA which can in turn reduce hospital readmission and decrease morbidity and mortality	Correlation with weather data on individual reported data//Importance of this study is that COPD patients already have a reduced exercise capacity due to limited airflow limitation; further reductions of activity due to weather may worsen muscular de-conditioning (common in inactive COPD patients)
Strengths/Weaknesses/ Limitations	Limitations: Ambient temperature were obtained from fixed monitoring sites rather than individual level measurements (something we hope to reduce); may lead to underestimation of ambient temp	Limitation of this study is that there were only 28 patients and this was in Australia, not generalizable - Pt were older, mostly male, exclusion factors: non-English speaking people, excludes some	Unable to assess the intensity of the physical activity Measuring with pedometers – some people did not wear it everyday, some were lost, broken for ex Measured climate exposure as a whole instead of to each individual

	Small sample size, and patient were enrolled in this study; findings may not be representative of general pop.	cultural and ethnic groups	

	Seemungal et al. (1998)	Miravitlles et al. (2004)	Werchan et al. (2018)
Country	London UK	Barcelona, Spain	Dallas, Texas
Date	1998	2004	2018
Purpose	The factors that affect severity and frequency on exacerbations and how this affects quality of life in individuals with COPD. [one of the first studies that looked at this phenomenon]	Evaluate exacerbations and their impact on the HRQoL of individuals with COPD.	Develop a psychometrically valid measure of perceived triggers of exacerbations in COPD patients (CETI)
Confounding Variables	Age, exacerbation group, MRC grade, past exacerbations, sex, symptoms	Age, BMI, smoking consumption, years of evolution of COPD, number of coexisting chronic conditions, COPD severity, dyspnea	Demographics (sex, age, marital status, race, occupation, education), medical history, diagnosis of COPD, oxygen use, history of comorbidities, smoking history, medications, exacerbation history
Variables (Independent/Dependent)	Exacerbations, Symptoms, Lung Function (PEFR), HRQoL (measured by St. George's Respiratory Questionnaire)	Lung function, exacerbations, HRQoL (measured by St. George's Respiratory Questionnaire)	Exacerbation triggers, COPD outcomes, HRQoL
Subjects	70 COPD patients (52 males, 18 female) for 1 year, attended the outpatient clinics in October 1995	336 COPD patients recruited from referral centers throughout Spain from 2-month period between Jan and Feb 1999, scheduled to attend four follow up visits at 6 month intervals over 2 years	Recruited 192 patients from local clinics and online to complete surveys of the CETI, demographic information, disease-specific info and the CAT: 53 item list of potential exacerbation triggers
Study Design	Cross-sectional observational study	2 year follow up study [cross-	Cross-sectional survey

		sectional observational]	
Sample Size	70	336	192
Themes	COPD exacerbations and HRQoL	Exacerbations and HRQoL	Exacerbations and HRQoL
Main Findings	Found that there were no differences in major symptoms or physiological parameters between reported and unreported exacerbations. At exacerbation, lung function decreased. The SGRQ total and component scores were significantly worse in individuals with frequent exacerbations. The findings suggest that patient quality of life is related to COPD exacerbation frequency.	Analysed data with descriptive statistics, differences between groups with t test or chi test, and repeated measures to see correlation within subjects (difference between patients with frequent and infrequent exacerbations in total SGRQ score), frequent exacerbations had a significant negative effect on HRQoL in patients with moderate COPD, those with severe COPD; exacerbations did not have an effect on HRQoL. They observed a significant and independent effect of seasonality. Worse HRQoL observed in winter season in comparison to spring/summer seasons (3 units lower (better) than winter - decrease in the number of exacerbations in the spring/summer compared to winter months)	Found that triggers were associated with COPD functionally status, exacerbation frequency, and healthcare utilization. Personal triggers related to dust, air pollution, smoking, and PA were most easily controlled. But reported that psychological factors, climate (13.1%), infection, respiratory symptoms, and sleep were more difficult to control. A higher perceived controllability is correlated with lower CAT scores indicating better health status.
How does study relate to other studies/important notes	This study can relate to our research because once we determine which temperatures and humidity's have	There was an aspect of seasonality observed in their results that supplements our research and feeds	Individuals who reported more climate related triggers had a poorer health status. The participants in this study were recruited

	a correlation with higher exacerbations, we can then determine whether HRQoL decreases during this time as well.	off Seemungal et al. (1998). Colder temperatures in the winter correlated with lower HRQoL and higher exacerbations during this time.	from a humid, subtropical area of the Southern part of US - often affected by extreme heat and air pollution during summer
Strengths/Weaknesses/ Limitations	No relation between hospital admission and COPD exacerbations, used self-reporting for lung function, exacerbations, and symptoms.	Individuals with severe COPD have an observed lower HRQoL which is why there was not a difference found. (Both groups of infrequent and frequent severe COPD had worse HRQoL at baseline but at end of follow up moderate COPD with frequent exacerbations had worse scores that those with severe COPD and infrequent exacerbations)	Strengths: recruitment of a sample that ranged in comorbidities, medical treatment, and indicators of impairment / Limitations: observed patient perceptions not actual exacerbation triggers, small portion of pt were online and self-reported their COPD without physical confirmation, and individuals may be less familiar with term exacerbation and may assume it means stronger symptoms

	Jehn et al. (2013)	Jenkins et al. (2012)
Country	Berlin, Germany	Australia
Date	2013	2012
Purpose	Developed a home-based tele-monitoring system to assess the effects of heat stress (> 25 degrees C) on clinical and functional status in COPD patients.	Impact of season on COPD exacerbation frequency
Confounding Variables	Age, gender, BMI, COPD medication, detailed medical history, duration of disease, comorbidities, physical examination, height	Age, smoking history, BMI, sex, treatment
Variables (Independent/Dependent)	Exacerbations, COPD outcomes, lung function, physical activity, hot temperature (obtained from local weather station)	Exacerbations, temperature, treatment: placebo, salmeterol, combo of salmeterol/fluticasone - for 3 years
Subjects	62 COPD patients from June 1st to August 31st of 2012 (32 days with heat stress)	3 year study conducted from Sept 2000 to Nov 2005 in 42 countries around the world: Northern regions (Canada, China, 26 Eastern and Western European countries, and USA) and the Southern region (Argentina, Australia, Brazil,

		Chile, New Zealand, and South Africa) and the tropics (Hong Kong, Malaysia, Mexico, Philippines, Singapore, Taiwan, and Thailand) [seasonal comparisons: Northern summer is June to August, and winter December to Feb, Southern is the reverse)
Study Design	Randomized control trial	Longitudinal international RCT
Sample Size	62	6112: 4849 N, 622 S, 641 T
Themes	Exacerbations, COPD outcomes, Temperature	Exacerbations, seasonal patterns - temperature
Main Findings	Divided groups into the Tele-monitoring group and control. Those in the TG group did the CAT test, daily lung function, and 6MWT. Analysed data with descriptive stats, differences using t-test and chi test. // During heat stress, the TG showed a significant reduction in lung function and exercise capacity (6MWT performance). Over the summer, significantly fewer TG patients suffered exacerbations compared to the control group patients. After 9 month follow up TG had fewer exacerbations compared to CG, shorter hospital stay and fewer specialist consultations. Significant improvement in clinical status at 9 M follow up whereas, CG worsened, improvement in 6MWT, and CG no significant change, and spirometry remained unchanged between both groups, but CAT score was significantly different for both groups.	Exacerbations in the northern and southern regions showed an increase in the winter months by two folds (not in the tropical countries - has a relatively constant temperature with mean of 18 degrees all year round), and exacerbation frequency was associated with older age, lower BMI, lower FEV1 and history of prior exacerbations. 38% of exacerbations were treated with antibiotics, 19% with systemic corticosteroids, and 43% with both - northern region more exacerbations in winter treated with antibiotics in comparison to summer, reversed for exacerbations treated with systemic corticosteroids, this was not seen in the southern region - perhaps due to smaller amount of patients
How does study relate to other studies/important notes	Tele-monitoring has been found to reduce the risk of exacerbations during the summer period - improves clinical and functional status of COPD patients over time and reduces the frequency of exacerbation and healthcare utilization during all periods of the year; beneficial to implement tele-monitoring in vulnerable patient groups during prolonged heat exposure	Factors contributing to this include increased exposure to viral infections, increased host susceptibility, greater time spent indoors, reduced PA, and temperature-related reduction in lung function
Strengths/Weaknesses/ Limitations	Limitations: collected weather data from local stations instead of individual effects, small study	There is statistical power to test for the differences due to region or risk factors (however small

	sample, cannot extrapolate findings those individuals who are not fully ambulatory - since they use oxygen therapy, or may have osteoarthritis or rheumatoid arthritis [this study truly relates to my study of how temperature affects COPD outcomes (lung function, symptoms, and physical activity)	amount of pt in southern and tropic regions)

APPENDIX B.1 SURVEY

OntarioTech UNIVERSITY

Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Information and Consent to Participate in a Research Study (pa

Name of Principal Investigator (PI): Mika Nonoyama, RRT, PhD

PI's contact number/email: 905-721-8668 ext. 5329, mika.nonoyama@ontariotechu.ca

Names(s) of Co-Investigator(s) and contact number(s)/email(s):

- Samantha Mekhuri, BSc(hon), MHSc(c): Samantha.mekhuri@ontariotechu.ca
- Caroline Barakat, MES, PhD: 905-721-8668 ext. 2173, caroline.barakat@ontariotechu.ca
- Winnie Sun, RN, PhD: 905-721-8668 ext. 5349, winnie.sun@ontariotechu.ca

Institutional affiliation: Faculty of Health Sciences, Ontario Tech University

External Funder/Sponsor: None

Introduction

You are invited to participate in a research study entitled "A Cross-sectional Survey on The Effects of Temperature and Humidity on Health Outcomes in Individuals with COPD". Please read the information about the study presented in this form. Throughout this page you will find the study purpose, procedure, benefits and risks, as well as your right to refuse to participate or withdraw from the study. Take as much time as you need to make your decision. Ask the Principal Investigator (PI) or other study team members to explain anything you do not understand, and make sure all of your questions have been answered before agreeing to consent. Before you make your decision, feel free to talk about this study with anyone you wish including your friends and family. Participation in this study is voluntary.

This study has been reviewed by the University of Ontario Institute of Technology (Ontario Tech University) Research Ethics Board #16029 on September 16, 2020.

CLICK "NEXT"

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OntarioTech UNIVERSITY

Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Information and Consent to Participate in a Research Study (page 2 of 5)

Purpose and Procedure:

Background and Purpose:

- Extremes of weather affect lung health because of the permanent exposure to the environment.
- Research has shown a relationship between extremes of humidity and temperature on shortness of breath, lung function, and may even influence the bad health effects of air pollution.
- There is little and/or inconsistent scientific evidence on how extreme weather affects people with COPD, the number of people affected, and specific types of Canadian weather conditions.
- You have been invited to participate in this study because you are 40 years or older, diagnosed with COPD by a physician, able to provided informed consent, and lived in Canada for at least one year (not including times related to COVID-19).
- We are interested in learning the effects of temperature and humidity on your quality of life, respiratory symptoms, physical activity, frequency of exacerbations, rescue inhaler use, and healthcare use. It is anticipated this important research will form the basis of future studies to determine the direct impacts of different weather extremes on COPD outcomes (in the Ontario Tech University climactic chamber), and how specific strategies may help with COPD management during these times.

Procedures:

- You will complete a survey that will include questions on your background health, quality of life, respiratory symptoms, physical activity level, frequency of exacerbations, rescue inhaler use, and healthcare use during three different weather conditions: 1) hot and humid, 2) cold and dry, and 3) moderate or "ideal" temperature and humidity.
- Background health questions will include your current physical activity and

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respiratory symptoms, comorbidities, primary respiratory diagnosis date, respiratory medications, and smoking history. In addition, we will ask questions about your age, sex, living arrangement, marital status, education, employment status, and income. This is to help us understand how the study results might differ for different characteristics.

- The survey will take around 20-30 minutes to complete.
- Surveys can be completed online, or using a paper version (mailed, telephone, or in-person). If you wish to complete a paper version of this survey please contact any member of the research team (see prior page).
- We anticipate having 304 individuals participate in this study.

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Information and Consent to Participate in a Research Study (page 3 of 5)

Potential Benefits:

- You may or may not directly benefit from participating in this study. However, your input and perspective will be of tremendous value.
- The results from the survey will enhance our awareness of extreme weather situations. Your input and perspectives may benefit society by enhancing our knowledge of how to manage COPD outcomes.

Potential Risk or Discomforts:

- We do not anticipate harm associated with participation in this study.
- You may feel uncomfortable with some of the questions as they may be sensitive in nature. If you feel uncomfortable, you may choose not to answer a question.
- Despite the survey being anonymous, and protections being in place, there is a small risk of unintentional release of personal information. Even though the risk of identifying you from the study data is very small, it can never be completely eliminated.

CLICK "**NEXT**"

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Information and Consent to Participate in a Research Study (page 4 of 5)

Use and Storage of Data:

- If the survey is completed on paper (telephone or in person), information will be transferred to an electronic Excel file. We will keep hard copy survey data in a locked filing cabinet, in a locked office at Ontario Tech University.
- Electronic data will be stored on a password-protected computer in an encrypted password-protected document on an Ontario Tech University issued laptop, with backup on the Ontario Tech University Google Drive.
- Following completion of the study, data will be kept for 5 years after the last publication of this study. Data will then be destroyed by deleting them from the computer and shredding documents.
- If you wish to receive gift card compensation and/or study results, your contact information (email or mailing address) will be required. In the former scenario, contact information will be destroyed immediately after compensation is provided. In the latter, contact information will be stored until the study is completed, and destroyed within one month of study completion. This contact information will be collected and stored separate from the survey data.
- All information collected during this study, including your contact information and survey data, will be kept confidential and will not be shared with anyone outside the study unless required by law. You will not be named in any reports, publications, or presentations that may come from this study.
- Study records identifying you may be inspected by representatives of The University of Ontario Institute of Technology (Ontario Tech University) Clinical Research Ethics Board for the purpose of monitoring the research.

Privacy and Confidentiality:

- Your privacy shall be respected. No information about your identity will be shared or published without your permission, unless required by law. Confidentiality will be provided to the fullest extent possible by law, professional practice, and ethical codes of conduct. Please note that

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confidentiality cannot be guaranteed while data is in transit over the Internet.

- The survey in this research study is anonymous, and will be assigned a "study number". In anonymous research, the information collected does not contain any personal identifiable information, and the risk of being able to connect data to you is very low.
- This research study includes the collection of demographic data which will be aggregated (not individually presented) in an effort to protect your anonymity. Despite best efforts it is possible that your identity can be determined even when data is aggregated
- Surveys completed online will use SurveyMonkey (https://www.surveymonkey.com). This platform complies with "Web Content Accessibility Guidelines" or WCAG (2.0), a global guideline for web accessibility. SurveyMonkey also meets "General Data Protection Regulation" or GDPR requirements. The Anonymous Responses collector option will be selected, which does not track and store identifiable participant information in survey results. Please note: SurveyMonkey does stores IP addresses, but deletes them after 13 months. Responses in SurveyMonkey are stored and accessed in the USA, and thus governed by USA laws.

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Information and Consent to Participate in a Research Study (page 5 of 5)

Voluntary Participation:

- Your participation in this study is voluntary and you may partake in only those aspects of the study in which you feel comfortable.
- You may decide not to be in this study, or be in the study now, and change your mind later.
- You may leave the study at any time without affecting your medical care, relationship with the institution, access to services, and credit for participating ($20 gift card).
- You will be given information that is relevant to your decision to continue or withdraw from participation. Such information will need to be subsequently provided.
- You may refuse to answer any question you do not want to answer, by skipping it.

Right to Withdraw:

- You have a right to withdraw from the study, and do not need to provide any reason(s). This can be done informing research personnel in person or on the phone, or by simply closing your internet browser.
- If completing the survey online, we will not be able to remove your data because it is anonymous. If you decide to withdraw while completing the survey in person or on the phone, you may request your data be removed at that moment. If you decide to withdraw after submitting the survey in person or by phone, we will not be able to remove your data because it is anonymous.
- Once results have been published or presented, it is difficult to withdraw data. However, when we publish and present study results, we will use aggregated data only.

Conflict of Interest:

- Researchers have an interest in completing this study. Their interests should not influence your decision to participate in this study.

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Compensation, Reimbursement, Incentives:

- You will receive a $20 gift certificate for compensating the time to complete the survey. If you enroll into the study and decide to withdraw from the study, you will still receive compensation for participation.
- Parking and postage will be provided if required.

Debriefing and Dissemination of Results:

- Once the study is complete, we will share the results with you if you choose to be informed. We will provide you with contact information if you have any questions or concerns.

Participant Rights and Concerns:

- Please read this consent form carefully and feel free to ask the researcher any questions that you might have about the study. If you have any questions about your rights as a participant in this study, complaints, or adverse events, please contact the Research Ethics Office at (905) 721-8668 ext. 3693 or at researchethics@ontariotechu.ca.
- If you have any questions or concerns during the research study, please contact Mika Nonoyama (mika.nonoyama@ontariotechu.ca or 905-721-8668 x 5329) or Samantha Mekhuri at samantha.mekhuri@ontariotechu.ca.

CLICK "NEXT" for consent options.

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Consent to Participate

* 1. **Please check all boxes below to acknowledge your consent**

I will receive a copy of this consent form for my own records.

- ☐ I have read and understood the subject information and consent form.
- ☐ I have had sufficient time to consider the information provided and to ask for advice if necessary.
- ☐ I have had the opportunity to ask questions and have had satisfactory responses to my questions.
- ☐ I understand that all of the information collected will be kept confidential and that the results will only be used for scientific objectives.
- ☐ I understand that my participation in this study is voluntary and that I am completely free to refuse to participate or to withdraw from this study at any time without changing in any way the quality of care that I receive.
- ☐ I understand that I may continue to ask questions in the future.
- ☐ I agree that authorized persons may have access to my personal health information as described in this consent document.
- ☐ I understand that there is no guarantee that this study will provide any benefits to me.
- ☐ I understand that I am not waiving any of my legal rights as a result of signing this consent form.
- ☐ I understand that I am giving free and informed consent to research participation by submitting this research consent form.

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* 2. Do you consent to participate in this study?

- ◯ Yes
- ◯ No

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Optional Secondary Use of Research for future Research Purposes

* 3. Please check the two options below if you agree with the statements.

- [ ] I understand the possible need for secondary research uses of my research data for future research use and provide consent for the use of my data to be used in future studies.
- [ ] The research team has informed me that a separate Research Ethics Board (REB) application will be submitted for the secondary use of data for any future research purposes.

CLICK "NEXT" to start the survey.

You can exit the survey at any time, and finish it later.

Hover your mouse over words with an underline for further information and definitions.

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

* 4. How old are you today? Please state your answer as a number.

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Moderate "Ideal" Temperature and Humidity

This section will ask you to think back about your symptoms, physical activity, and background health history during a ***moderate or "ideal" temperature around 14-21°C and approximately 30-50% relative humidity.***

Moderate temperature refers to average temperature on a typical or "ideal" day, *not too hot or too cold.*

Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Symptoms: Moderate "Ideal" Temperature and Humidity

5. Think back about your symptoms during **moderate "ideal" conditions** and rank them on a scale from 0-5.

0 meaning you did not experienced these symptoms at all
5 meaning you experienced them all the time

	0	1	2	3	4	5
How often did you cough?	○	○	○	○	○	○
How often did you have mucus in your chest?	○	○	○	○	○	○
How tight did your chest feel?	○	○	○	○	○	○
How breathless were you walking up a hill or one flight of stairs?	○	○	○	○	○	○
How limited were you doing your activities at home?	○	○	○	○	○	○
How sound did you sleep at night?	○	○	○	○	○	○
How much energy did you have?	○	○	○	○	○	○

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6. Think back to your level of physical activity during **moderate "ideal" conditions on an average day.**

	None at all	Rarely	Sometimes	Frequently	All the time
How often did you walk outside?	○	○	○	○	○
How often did you do chores outside of the house?	○	○	○	○	○
How much difficulty did you have getting dressed?	○	○	○	○	○
How often did you avoid doing activities because of your lung problems?	○	○	○	○	○
How breathless were you in general during your activities?	○	○	○	○	○
How tired were you in general during your activities?	○	○	○	○	○
How often did you have to take breaks during your physical activities?	○	○	○	○	○

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Background Health History: Moderate "Ideal" Temperature and Humidity

7. How often did you experience an acute exacerbations during **moderate "ideal"** conditions?

- 1 or more mild exacerbation(s) [no change in prescribed medications]
- 1 or more moderate exacerbation(s) [required prescribed antibiotic and/or oral corticosteroid]
- 2 or more moderate exacerbation(s) [required prescribed antibiotic and/or oral corticosteroid]
- 1 or more severe exacerbation(s) [required a hospital admission or emergency department visit]
- None
- Other answer (please specify)

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8. How often did you use your rescue inhaler during **moderate "ideal"** conditions?

- 3 or more times per day
- 1 to 2 times per day
- 2 to 3 times per week
- Once a week or less
- Not at all
- Other answer (please specify)

9. How many times did you visit your family doctor during **moderate "ideal"** conditions?

- 0 to 1 time
- 2 to 3 times
- 4 to 5 times
- More than 5 times
- Other answer (please specify)

10. How many times did you visit your respiratory specialist during **moderate "ideal"** conditions?

- 0 to 1 time
- 2 to 3 times
- 4 to 5 times
- More than 5 times
- Other answer (please specify)

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11. How many times did you visit the emergency department during **moderate "ideal"** conditions?

- 0 to 1 time
- 2 to 3 times
- 4 to 5 times
- More than 5 times
- Other answer (please specify)

12. How many times were you admitted to the hospital during **moderate "ideal"** conditions?

- 0 to 1 time
- 2 to 3 times
- 4 to 5 times
- More than 5 times
- Other answer (please specify)

* 13. What actions did you take during **moderate "ideal"** conditions?
For example, you can state if you had to remove yourself from the weather condition, avoided going outside, went to a different geographical location.

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Cold Temperature and Dry Humidity

This section will ask you to think back about your symptoms, physical activity, and background health history during ***cold temperatures of less than 5°C and below 30% relative humidity.***

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Symptoms: Cold Temperature and Dry Humidity

14. Think back about your symptoms during **cold and dry conditions** and rank them on a scale from 0-5.

0 meaning you did not experience these symptoms at all
5 meaning you experienced them all the time

	0	1	2	3	4	5
How often did you cough?						
How often did you have mucus in your chest?						
How tight did your chest feel?						
How breathless were you walking up a hill or one flight of stairs?						
How limited were you doing your activities at home?						
How sound did you sleep at night?						
How much energy did you have?						

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15. Think back to your level of physical activity during **cold and dry conditions on an average day**.

	None at all	Rarely	Sometimes	Frequently	All the time
How often did you walk outside?	○	○	○	○	○
How often did you do chores outside of the house?	○	○	○	○	○
How much difficulty did you have getting dressed?	○	○	○	○	○
How often did you avoid doing activities because of your lung problems?	○	○	○	○	○
How breathless were you in general during your activities?	○	○	○	○	○
How tired were you in general during your activities?	○	○	○	○	○
How often did you have to take breaks during your physical activities?	○	○	○	○	○

Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Background Health History: Cold Temperature and Dry Humidity

16. How often did you experience an acute exacerbations during **cold and dry** conditions?

- 1 or more mild exacerbation(s) [no change in prescribed medications]
- 1 or more moderate exacerbation(s) [required prescribed antibiotic and/or oral corticosteroid]
- 2 or more moderate exacerbation(s) [required prescribed antibiotic and/or oral corticosteroid]
- 1 or more severe exacerbation(s) [required a hospital admission or emergency department visit]
- None
- Other answer (please specify)

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17. How often did you use your rescue inhaler during **cold and dry** conditions?

- ◯ 3 or more times per day
- ◯ 1 to 2 times per day
- ◯ 2 to 3 times per week
- ◯ Once a week or less
- ◯ Not at all
- ◯ Other answer (please specify)

18. How many times did you visit your family doctor during **cold and dry** conditions?

- ◯ 0 to 1 time
- ◯ 2 to 3 times
- ◯ 4 to 5 times
- ◯ More than 5 times
- ◯ Other answer (please specify)

19. How many times did you visit your respiratory specialist during **cold and dry** conditions?

- ◯ 0 to 1 time
- ◯ 2 to 3 times
- ◯ 4 to 5 times
- ◯ More than 5 times
- ◯ Other answer (please specify)

20. How many times did you visit the emergency department during **cold and dry** conditions?

- ◯ 0 to 1 time
- ◯ 2 to 3 times
- ◯ 4 to 5 times
- ◯ More than 5 times
- ◯ Other answer (please specify)

21. How many times were you admitted to the hospital during **cold and dry** conditions?

- ◯ 0 to 1 time
- ◯ 2 to 3 times
- ◯ 4 to 5 times
- ◯ More than 5 times
- ◯ Other answer (please specify)

* 22. What actions did you take during **cold and dry** conditions?
For example, you can state if you had to remove yourself from the weather condition, avoided going outside, went to a different geographical location.

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Hot Temperature and Humid Conditions

This section will ask you to think back about your symptoms, physical activity, and background health history during ***hot temperatures of higher than 25°C and above 50% relative humidity.***

Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Symptoms: Hot Temperature and Humid Conditions

23. Think back about your symptoms during **hot and humid conditions** and rank them on a scale from 0-5.

0 meaning you did not experience these symptoms at all
5 meaning you experienced them all the time

	0	1	2	3	4	5
How often did you cough?	○	○	○	○	○	○
How often did you have mucus in your chest?	○	○	○	○	○	○
How tight did your chest feel?	○	○	○	○	○	○
How breathless were you walking up a hill or one flight of stairs?	○	○	○	○	○	○
How limited were you doing your activities at home?	○	○	○	○	○	○
How sound did you sleep at night?	○	○	○	○	○	○
How much energy did you have?	○	○	○	○	○	○

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24. Think back to your level of physical activity during **hot and humid conditions on an average day.**

	None at all	Rarely	Sometimes	Frequently	All the time
How often did you walk outside?	○	○	○	○	○
How often did you do chores outside of the house?	○	○	○	○	○
How much difficulty did you have getting dressed?	○	○	○	○	○
How often did you avoid doing activities because of your lung problems?	○	○	○	○	○
How breathless were you in general during your activities?	○	○	○	○	○
How tired were you in general during your activities?	○	○	○	○	○
How often did you have to take breaks during your physical activities?	○	○	○	○	○

Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Background Health History: Hot Temperature and Humid Conditions

25. How often did you experience an acute exacerbations during **hot and humid** conditions?

- 1 or more mild exacerbation(s) [no change in prescribed medications]
- 1 or more moderate exacerbation(s) [required prescribed antibiotic and/or oral corticosteroid]
- 2 or more moderate exacerbation(s) [required prescribed antibiotic and/or oral corticosteroid]
- 1 or more severe exacerbation(s) [required a hospital admission or emergency department visit]
- None
- Other answer (please specify)

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26. How often did you use your rescue inhaler during **hot and humid** conditions?

- 3 or more times per day
- 1 to 2 times per day
- 2 to 3 times per week
- Once a week or less
- Not at all
- Other answer (please specify)

27. How many times did you visit your family doctor during **hot and humid** conditions?

- 0 to 1 time
- 2 to 3 times
- 4 to 5 times
- More than 5 times
- Other answer (please specify)

28. How many times did you visit your respiratory specialist during **hot and humid** conditions?

- 0 to 1 time
- 2 to 3 times
- 4 to 5 times
- More than 5 times
- Other answer (please specify)

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29. How many times did you visit the emergency department during **hot and humid** conditions?

- 0 to 1 time
- 2 to 3 times
- 4 to 5 times
- More than 5 times
- Other answer (please specify)

30. How many times were you admitted to the hospital during **hot and humid** conditions?

- 0 to 1 time
- 2 to 3 times
- 4 to 5 times
- More than 5 times
- Other answer (please specify)

* 31. What actions did you take during **hot and humid** conditions?
For example, you can state if you had to remove yourself from the weather condition, avoided going outside, went to a different geographical location.

Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Physical Activity Levels

This section will ask you about your **current** physical activity levels.

32. During the last 7 days, how much **time** did you spend **sitting** during a day?

Include time spent at work, at home, while doing learning work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

Hours

Minutes

33. During the last 7 days, on how many **days** did you **walk** for at least 10 minutes at a time?

This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

# of Days

34. How much **time** did you usually spend **walking** on one of those days?

Hours

Minutes

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35. During the last 7 days, on how many **days** did you do **moderate physical activities** like gardening, cleaning, bicycling at a regular pace, swimming, or other fitness activities.

Think only about those physical activities that you did for at least 10 minutes at a time. **Do not** include walking.

# of Days

36. How much **time** did you usually spend doing **moderate physical activitie**s on one of those days?

Hours

Minutes

37. During the last 7 days, on how many **days** did you do **vigorous physical activities** like heavy lifting, heavier garden or construction work, chopping woods, aerobics, jogging/running, or fast bicycling?

Think only about those physical activities that you did for at least 10 minutes at a time.

38. How much **time** did you usually spend doing **vigorous physical activities** on one of those days?

Hours

Minutes

39. **Which response best describes your shortness of breath?**

- ◯ I only get breathless with strenuous exercise
- ◯ I get short of breath when hurrying on the level or walking up a slight hill
- ◯ I walk slower than people of the same age on the level because of breathlessness or have to stop for breath when walking at my own pace on the level
- ◯ I stop for breath after walking about 100 yards (91 meters) or after a few minutes on the level
- ◯ I am too breathless to leave the house or I am breathless when dressing

40. Have you attended pulmonary rehabilitation **in the last year** (during non COVID-19 times)

- ◯ Yes
- ◯ No

41. Have you attended a pulmonary self-management education program (other than pulmonary rehabilitation) **in the last year** (during non COVID-19 times)?

- ◯ Yes
- ◯ No

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Overall Background Health History

This section will ask you about your **current** health status.

* 42. What was your **primary** respiratory diagnosis?

- ☐ Chronic Obstructive Pulmonary Disorder (COPD)
- ☐ Chronic Bronchitis
- ☐ Emphysema
- ☐ Bronchiectasis
- ☐ Asthma
- ☐ Idiopathic Pulmonary Fibrosis
- ☐ Pulmonary hypertension
- ☐ Sarcoidosis
- ☐ Lung Cancer
- ☐ Sleep Apnea
- ☐ Cystic Fibrosis
- ☐ Tuberculosis
- ☐ Asbestosis

Other answer (please specify)

* 43. How long have you had Chronic Lung Disease, after being diagnosed by a doctor?

Years

Months

44. What respiratory medication(s) do you currently use? Check all that apply.

- ☐ Short-acting Bronchodilator Inhalers (e.g. Atrovent, Airomir, Bricanyl Turbuhaler, Ventolin)
- ☐ Long-acting Bronchodilator Inhalers (e.g. Incruse Ellipta, Seebri Breezhaler, Spiriva Handihaler)
- ☐ Combination Inhalers (e.g. Combivent Respimat, Advair Diskus, Breo Ellipta, Symbicort Turbuhaler, Anoro Ellipta, Duaklir Genuair, Inspiolto Respimat, Ultibro Breezhaler, Trelegy Ellipta)
- ☐ Nebulizer (a device that turns medication into fine mist using mouthpiece/mask)
- ☐ Corticosteroid pills
- ☐ Antibiotics
- ☐ Phosphodiesterase-4 Inhibitors
- ☐ Mucolytics

Other answer (please specify)

45. Do you use oxygen therapy at home?

- ◯ No
- ◯ Only for activity
- ◯ Only for sleep
- ◯ 24 hours a day
- ◯ Other answer (please specify)

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46. Do you use continuous positive airway pressure (CPAP)?

- ◯ No
- ◯ Only for sleep
- ◯ During the day and during sleep
- ◯ Other answer (please specify)

47. Do you use bi-level non-invasive ventilation (NIV)?

- ◯ No
- ◯ Only for sleep
- ◯ During the day and during sleep
- ◯ Other answer (please specify)

48. What is your smoking history?

- ◯ Current every day smoker -> go to next question 48.
- ◯ Current some day smoker -> go to next question 48
- ◯ Former smoker-> go to next question 48
- ◯ Never smoked-> skip to question 50
- ◯ Other answer (please specify)

49. On average how many packs a day did, or do, you smoke(d)?

- ◯ 1/2 a pack per day
- ◯ 3/4 pack per day
- ◯ 1 pack per day
- ◯ 2 packs per day
- ◯ Other answer (please specify)

50. Age and smoking history. Please fill in the blanks below.

Age at first cigarette	
Age at last cigarette (leave blank if current smoker)	

51. How often did you have an acute exacerbation **in the last year**?

- ◯ No exacerbations
- ◯ 0 to 1 moderate exacerbation that did not require an emergency department visit or hospitalization
- ◯ more than 2 moderate exacerbations that did not require an emergency department visit or hospitalization
- ◯ 1 or more severe exacerbation(s) that required an emergency department visit or hospitalization

52. Did you require an emergency room visit and/or admitted to the hospital **in the last year?**

- ◯ Yes
- ◯ No

53. Did you receive the influenza vaccine **in the last year?**

- ◯ Yes
- ◯ No

54. Did you receive the pneumococcal vaccine **in the last year?**

- ◯ Yes
- ◯ No

55. What other health conditions do you have? Check all that apply.

- ☐ Cardiovascular diseases (e.g. Hypertension)
- ☐ Congestive heart failure
- ☐ Coronary heart disease
- ☐ Bone disorder (e.g. Osteoarthritis, Osteoporosis)
- ☐ Diabetes
- ☐ Musculoskeletal disorders
- ☐ Neuropsychiatric disorders (e.g. Anxiety, Depression)
- ☐ Neurological disorders (e.g. Alzheimer's disease, Dementia)
- ☐ Respiratory diseases (Other than COPD)
- ☐ None

Other answer (please specify)

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56. Have you had a bone fracture **in the past year**?

◯ Yes

◯ No

57. Do you have swelling in your ankles, legs, and feet?

◯ Yes

◯ No

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Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Demographics

* 58. How old are you today? Please state your answer as a number.

Years

59. What is your biological sex?

- Male
- Female
- Other answer (please specify)

60. What is your current height?

61. What is your current weight? Fill in one option.

Pounds

Kilograms

62. What type of community do you live in?

- City or urban community
- Suburban community
- Rural community
- Other answer (please specify)

63. Which of the following best describes your city/town's population size?

- Large (population 100,000 or greater e.g. Toronto, Calgary, Montreal)
- Medium (population 30,000 to 99,999 e.g. Peterborough, Kamloops, Fredericton)
- Small (population 1,000 to 29,999 e.g. Innisfil, Cochrane, Gander)
- Other answer (please specify)

64. How often does it precipitate (rain, snow) where you live?

- Most days of the month
- Some days of the month
- Few days of the month
- Very few days of the month
- Other answer (please specify)

65. What is your living arrangement?

- ◯ Lives alone
- ◯ Lives with spouse or partner
- ◯ Lives with children (with or without others)
- ◯ Lives with parents/guardians
- ◯ Other answer (please specify)

66. What is your marital status?

- ◯ Single or never married
- ◯ Married or common law
- ◯ Divorced or separated
- ◯ Widowed
- ◯ Other answer (please specify)

67. What is the highest degree or level of school you have completed?

- ◯ No schooling
- ◯ High school or less
- ◯ College or vocational school
- ◯ Any university training
- ◯ Any postgraduate training
- ◯ Other answer (please specify)

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68. What is your employment status?

- ◯ Full-time
- ◯ Part-time or casual
- ◯ Self-employed
- ◯ Student
- ◯ Disability
- ◯ Not employed
- ◯ Parental leave
- ◯ On leave
- ◯ Retired
- ◯ Other answer (please specify)

69. How much total combined income did all members of your household earn in the past 12 months?

- ◯ less than $25000
- ◯ $25001 to $45000
- ◯ $45001 to $65000
- ◯ greater than $65001
- ◯ Other answer (please specify)

Effects of Temperature and Humidity on Health Outcomes in Individuals with Chronic Obstructive Pulmonary Disease (COPD)

Further Comments and Thank You

70. Use this space if you have any comments or feedback on how extreme weather affects you (that was not addressed in this survey).

Use this space if you also have other general comments or feedback.

We appreciate the time and effort required to answer our questions completely and accurately. As a token of our appreciation, you can receive a $20 Tim Horton's gift card either by mail or email (depending on your preference).

Please email mika.nonoyama@ontariotechu.ca with the following information: 1) date and approximate time you completed the survey; and 2) Indicate if you would like to receive the study results.

This contact information will be stored completely separate from your survey answers to maintain the anonymity of your responses. Therefore, nobody will be able to link your name or address with your answers. Only one gift card per person and gift cards can only be mailed/emailed to locations within Canada. You can also opt not to receive the gift card if you prefer not to provide us with your name and mailing address.

If you do not wish to receive the study results and/or the $20 gift card, press " **DONE.**"

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