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Environmental Factors Affecting Physical Activity Levels of Older Adults

Caitlin Wright,

Supervisor: MacDermid, Joy C., *The University of Western Ontario*
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Abstract

Many individuals worldwide, especially older individuals, do not achieve enough regular physical activity. Since falls increase with age, it is crucial to understand how environmental factors might contribute to physical activity. This thesis aimed to investigate the literature and empirical data to inform our understanding of how environmental factors might affect the physical activity and mobility of older adults. A systematic review evaluated 64 articles that investigated the relationship between greenspace, weather and season on physical activity levels of older adults aged 60 and older. Environmental factors studied included season, daylight, air quality, greenspace, and weather. Weather conditions include temperature, precipitation, wind, humidity, barometric pressure, and cloud cover. Greenspace, moderate temperatures, and longer daylight were associated with more physical activity. A sample of older adults extracted from the Canadian Longitudinal Study on Aging (CLSA) who had incurred a wrist fracture were evaluated to determine the relationship between precipitation, active living environment index, barometric pressure, relative humidity, temperature, sulfur dioxide, ozone, $PM_{2.5}$ and NO_2 on PASE levels. Regression analysis demonstrated that sulfur dioxide and the active living environment (ALE) index were correlated with a higher PASE score. Overall, this information should be considered by urban planners and landscape architects to design cities/towns that would encourage physical activity. This also has implications for health professionals in planning adaptive physical activity strategies in collaboration with older adults; and for policymakers to consider the potential impact of climate change on the physical activity levels of older adults in different communities.

Keywords

Physical Activity, Older Adults, Mobility, Greenspace, Weather, Season, Air Quality

Summary for Lay Audience

People over 65 sometimes have difficulty maintaining their physical activity levels. About half of people over 65 do not meet Canadian physical activity guidelines, and by age 74, only 28% do so. Since physical activity is an essential part of healthy aging, this research summarizes what is known in research studies that have been published about how environmental factors can be related to physical activity. The specific environmental factors studied included season, daylight, air quality, greenspace, and weather. Therefore, understanding how these environmental factors impact the physical activity levels of older adults will also provide insight into the implications on health this might have for the overall health of the general population. Healthcare professionals will be able to better educate patients on the importance of physical activity and allow them to provide modified activities based on factors that might prevent physical activity. Urban planners and policymakers may also use this information to help build or design facilities that support and encourage physical activity. Lastly, environmental design, as well as architecture, should focus on optimizing greenspaces and conservation efforts. These should all be considered when influencing increased physical activity levels in older adults.

Co-Authorship Statement

This dissertation includes two papers that will be submitted to peer-reviewed journal articles. Caitlin Wright is the primary author for both papers in data collection, analysis, and writing. Joshua Vincent assisted in data collection, data synthesis, trainee supervision, and editing and providing feedback for both chapters and throughout this dissertation. Dr Joy MacDermid (primary supervisor) supervised and was the principal applicant on the grant funding the project, helped codesign the research question and analytical plan as well as edited and provided feedback for this dissertation. Dr Jason Gilliland assisted in trainee supervision and provided feedback for both chapters. Sara Stretton assisted in writing and synthesizing data for Chapter 1.

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Chapter 1

1.0 Introduction

1.1 Importance of Physical Activity

The World Health Organization (WHO) defines physical activity as "any bodily movement produced by skeletal muscles that requires energy expenditure" (Bull et al., 2020). Physical activity includes exercise, sports, and other activities performed for occupation, leisure, and active transportation (Langhammer et al., 2018). Regular physical activity is crucial to living a long and healthy life. However, many individuals today often overlook the importance of physical activity and how this can affect us as we age (Galloway & Jokl, 2000). Physical inactivity can be defined as "an insufficient physical activity level to meet present physical activity recommendations" (Bull et al., 2020). Being physically inactive increases one's chance of developing an illness or disease and may lead to premature death (Warburton et al., 2006). Some common health consequences associated with physical inactivity include cardiovascular disease, diabetes, stroke, hypertension, osteoporosis, and certain types of cancer (Langhammer et al., 2018; Warburton et al., 2006). Types of cancer commonly associated with low physical activity levels include colon and breast cancer (Warburton et al., 2006). Physical activity also has positive benefits on bones, joints, and muscles (Galloway & Jokl, 2000). Another health concern that can arise from physical inactivity includes obesity (Shields & Tremblay, 2008; Warburton et al., 2006). Obesity has increased over 30 years (Twells et al., 2014). From 1985-2011 the obesity prevalence of adults in Canada increased from 6.1% to 18.3%, and prevalence continues to increase across all provinces (Twells et al., 2014). An individual is considered obese if their body mass index (BMI) equals or exceeds 30 kg/m2 (Villareal et al., 2004). A primary factor as to why obesity rates are increasing is because individuals are choosing to engage in constant sedentary behaviour or remain inactive, which leads to an increase in energy intake vs energy expenditure (Shields & Tremblay, 2008). Therefore, individuals with a less active lifestyle are at a higher risk of becoming obese (Villareal et al., 2004). Obesity can lead to many health issues. From around 1990-2010, there has been an increase from approximately 4.6 billion dollars to 7.1 billion dollars a year that Canada is spending on health issues related to obesity (Twells et al., 2014). When it comes to older adults, they must engage in regular physical activity because obese adults are known to have less muscle mass causing them to become frailer (Villareal et al., 2004). Physical activity also improves mental health (Langhammer et al., 2018). Symptoms of acute anxiety and panic attacks as well as depression, have been shown to improve when engaging in regular physical activity (Paluska & Schwenk, 2000).

Overall, physical inactivity is also known to be the cause of approximately 9% of premature deaths worldwide (Smith et al., 2019). Therefore, meeting physical activity guidelines is crucial to maintaining physical and mental health. If individuals continue to forgo physical activity and this issue is not addressed, it will continue to be of major concern for the population's overall health.

1.2 Physical Activity Guidelines

The most recent guidelines for physical activity released by the World Health Organization (WHO) were done in 2020. World Health Organization (WHO) 2020 guidelines on physical and sedentary behaviour state that physical activity levels differ based on age group (Bull et al., 2020). The different age categories that the guidelines address are categorized by children and adolescents (5-17), adults (18-64) and older adults (65+) (Bull et al., 2020). These guidelines also state, however, that physical activity guidelines differ between age groups (Bull et al., 2020). The recommended physical activity guidelines for adults (aged 18-64) include 150-300 minutes of moderate aerobic physical activity or 75-150 minutes of vigorous (high)-intensity physical activity per week (Bull et al., 2020). Muscle strengthening exercises should also be done two or more days a week, preferably at a moderate to vigorous intensity (Bull et al., 2020). The physical activity guidelines for older adults aged 65+ are much like those for adults. Guidelines state that older adults should engage in 150–300 minutes of moderate or 75–150 minutes of vigorous (high) aerobic physical activity per week (Bull et al., 2020). Older adults should also engage in varied multicomponent physical activity with a focus on balance and strength training (Bull et al., 2020). This is recommended to be done three or more days a week to help with overall function and lower the risk of falling (Bull et al., 2020). Guidelines also include recommendations concerning sedentary time; it is stated that for adults and older adults, sedentary time should be limited as higher amounts of physical activity are associated with determinantal health outcomes (Bull et al., 2020). Aiming to go over the recommended moderate-vigorous physical activity levels can help to prevent the health risks associated with engaging in higher amounts of sedentary behaviour (Bull et al., 2020).

Overall, the more consistent a person is with meeting these physical activity guidelines, the better it is for their physical and mental health (Warburton et al., 2006). Not following these guidelines will lead to a much quicker decline in musculoskeletal function due to aging but can often be reduced by regular physical activity and exercise (Galloway & Jokl, 2000). As a result, engaging in regular physical activity can also play a very important role in injury prevention as exercises can be done that focus on strength training, mobility, and balance (Galloway & Jokl, 2000; Bull et al., 2020).

1.3 Importance of Studying Physical Activity Influences of Older Adults

It is important to study older adults now and in years to come as the world's population is rapidly aging (He et al., 2015). In 2015, older individuals (≥65) made up approximately 8.5% of the world's population, and by 2050, this number is supposed to reach 16.7% of the world's population (He et al., 2015). Whereas the younger population (20-64) will only increase moderately (He et al., 2015). The percentage of the population younger than 20 is predicted to stay steady (He et al., 2015).

Older adults are also considered a vulnerable population as they tend to be at a higher risk of poor health (Aday, 1994). Aging is a natural phenomenon resulting from molecular and cellular damage over time (Berad et al., 2016). Even though we have no control over our age, there are steps and precautions we can take to live a longer and healthier life (Berad et al., 2016). The World Health Organization states that there shouldn't be any stereotypes regarding the "typical" older person, as we all age differently (Berad et al., 2016). This can depend on many different factors, including genetics, sex, as well as our physical and social environments (Berad et al., 2016). According to the world health organization, some 80-year old's have similar physical and mental capacities to those in their 20s (Berad et al., 2016). However, some individuals experience a rapid decline in physical and cognitive capacities at much younger ages (Berad et al., 2016).

One of the many precautions older individuals can take to live a healthier and longer life includes increased physical activity with a focus on strength training (McPhee et al., 2016). Continuing to engage in regular physical activity as you age can also allow you to be much more mobile and physically independent (McPhee et al., 2016). After the age of 40 is when it is most common to detect the deterioration of physiological systems (McPhee et al., 2016). However, an individual's lifestyle can significantly impact health as one ages (McPhee et al., 2016).

Another reason why older individuals can be more prone to fractures is that they have developed osteoporosis (Ettinger, 2003). Osteoporosis is most common in older adults, and regular physical activity is thought to be one of the only methods that might prevent fractures by preventing osteoporosis and limiting falls (Kannus, 1999). This is because physical activity can improve bone density and strength and muscle strength even for frail older individuals (Kannus, 1999). Exercise, which is a form of physical activity, can also reduce the risk of falling (Kannus, 1999). This is because it can improve coordination, balance, and reaction time (Kannus, 1999). Therefore, being physically inactive can also make older individuals much more susceptible to fractures or broken bones (Ettinger, 2003; Kannus, 1999). The second most fractured bone in the elderly, making up 18% of total fractures in the elderly population, are distal radius fractures (Levin et al., 2017). Distal radius fractures are also the most fractured upper extremity bone in women over 50 (Levin et al., 2017). The prevalence of fractures, including distal radius fractures, is increasing as the elderly population continues to increase (Levin et al., 2017). These fractures can vary in severity, and a low bone mineral density (BMD) can be a reason why distal radius fractures might be more severe or have a higher chance of occurring (Liporace et al., 2009). Another issue that can arise as you age and don't participate in regular physical activity includes sarcopenia (Langhammer et al., 2018). This can be defined as "low muscle mass in combination with low muscle strength and/or low physical performance" (Langhammer et al., 2018). Sarcopenia tends to be more common as you age; however, this can be prevented or improved by regular physical activity to build lean body mass (Langhammer et al., 2018). By older adults consistently meeting physical activity level requirements, this will allow for improvement in their overall physical fitness and improve their mobility and independence towards completing tasks as they age (Langhammer et al., 2018).

1.4 Environmental Factors Influencing Physical Activity Levels

Overall, it is very important that individuals of all age groups meet daily physical activity requirements (Galloway & Jokl, 2000). However, many factors might influence one's decision to participate in physical activity. While conducting a preliminary search, it was observed that many studies were done on factors that might influence physical activity levels in younger individuals, including children, adolescents, and young adults. However, a limited number of studies in comparison were done that specifically focused on older adults. Therefore, it is important to aim our focus towards better understanding how environmental factors impact older adults' physical activity levels. Environmental factors focused on include season, daylight, air quality, greenspace, and weather. Weather conditions included temperature, precipitation, wind, and humidity.

Season is known to influence weather conditions over a longer period (months), so it is important to understand how seasonal variation might influence physical activity levels. It is expected that outdoor physical levels vary based on season and weather. Another important factor to consider when considering season is day length. Hours of daylight are known to differ with season and geographical location. As a result, considering how physical activity behaviours might differ depending on day length will be beneficial.

Previous studies outline that longer days and warmer weather typically correlate with increased physical activity (Tucker & Gilliland, 2007). However, it is important to understand what factors (if any) impact physical activity decisions for older adults most. Weather is known to vary on its own day-to-day but is also influenced by season. Therefore, looking at the impacts of both weather and season will allow for a better understanding of how these certain environmental factors can influence one's decision on participating in physical activity on a day-to-day basis as well as understand how this can be affected over a longer period (e.g., months). Weather conditions include temperature, precipitation, wind, humidity, barometric pressure, and cloud cover.

Air quality is another environmental factor that will be examined in relation to the effects on physical activity. It is important to focus on air quality as several factors influence it, including anthropogenic emissions that can cause health concerns (Kinney, 2008). However, natural weather and climate variables can also impact air quality, including temperature, humidity, wind speed, wind direction, and vertical atmospheric mixing height (Kinney, 2008).

Greenspace is another factor that will be focused on in relation to how it might influence the physical activity levels of older adults. Greenspace encompasses forests, parks, streams, and rivers (Wolch et al., 2014). Evidence proves the more greenspace a neighbourhood has, the more health benefits this provides to humans as well (Richardson et al., 2013). It has also been shown that greenspace can be linked to higher levels of physical activity leading to better physical health and improved overall mental health (Richardson et al., 2013). It has also been shown that people living in neighbourhoods with more greenspaces had a lower risk of poor mental health and cardiovascular disease (Richardson et al., 2013). Evidence suggests that areas with more greenspaces have lower overall morbidity and mortality rates (Richardson et al., 2013). Therefore, understanding the influence of greenspace on older individuals will allow for a better understanding of how one's proximity or access to greenspace might impact their physical activity levels.

1.5 Impact of Climate Change as a Mediator of the Relationship Between Weather and Mobility

Climate change is an issue of high concern in our society today because it is a major threat to our natural environment and human health. Weather events due to climate change include increased frequency or impact of extreme adverse weather (Mirza, 2003). Examples include heat waves or cold waves, droughts, extreme storms, and tropical cyclones (Mirza, 2003). Unfortunately, scientists have stated that our world is rapidly changing and is much different today than in 2010 (Levin, 2019). In 2010 the International Energy Agency (IEA) stated that there will be a 6°C of warming by the end of the century (Levin, 2019). In 2010 the average global temperature was 0.88°C, over pre-industrial levels and by 2019, it was approximately 1.1°C, over pre-industrial levels (Levin, 2019). The past decade has also been associated with extreme weather events, including heat waves, fires and hurricanes, as well as reaching record levels of rainfall and flooding (Levin, 2019). Extreme or adverse weather events are increasing in many locations worldwide (Mirza, 2003). It is also important to look at how the implications of climate change now and in the future are of particular concern based on geographic location.

Another environmental factor that is also a common factor associated with climate change is air quality. Even though natural phenomena can impact air quality, air quality has been rapidly decreasing worldwide due to human activity. Not only is this harming our environment, but this has implications for human health (Landrigan, 2017). It is predicted that in 2015 alone, 6.4 million people died due to the effects of air pollution (Landrigan, 2017). Since 1990, the number of deaths from extreme air pollution increased, especially in rapidly growing and industrialized areas (Landrigan, 2017). Health complications that air quality is known to cause include issues to the cardiovascular system, heart attacks, strokes, rhinitis, tuberculosis, respiratory illnesses, and different types of cancers, including lung cancer (Landrigan, 2017; Ammons et al., 2021). Prolonged exposure to poor air quality can potentially harm any individual; however, some people might be at a higher risk than others (O'Neil et al., 2012). For example, underlying health concerns, genetics, race, gender, lifestyle, and socioeconomic position can influence an individual's physical state and susceptibility to the harmful effects of air pollution (O'Neil et al., 2012). As a result, air quality was the climate factor that had the most influence on individuals' physical activity could be due to their certain perceptions of air quality (O'Neil et al., 2012). Factors influencing one's outlook on air quality can depend on one's socioeconomic position, race, income, and education level (O'Neil et al., 2012). Also, individuals who view themselves as healthy and at low risk of developing disease or cancer might not be as concerned about the health implications of air quality compared to those who suffer from health conditions (Ammons et al., 2021). It is important that teachers, healthcare workers and other community leaders educate individuals on air quality. This would make individuals more mindful about how to take care of their health better and make them aware of how important it is to do our best to lower the number of pollutants that go into the atmosphere.

Another important factor to address when discussing climate change is the presence of greenspace. It is important to note that urbanization is a significant issue contributing to global warming and climate change (Govindarajulu, 2014). Lack of green space is a by-product of urbanization and is a factor of climate change as it can lead to an increase in poor air quality, increased atmospheric temperate and affect the health of water sources (Govindarajulu, 2014). Greenspace is also considered one of the most cost-effective practices a city could do to preserve biodiversity, mitigate the effects of climate change, and aid in disaster risk management (Govindarajulu, 2014). It would benefit urban planners and foresters to help plan and develop guidelines for greenspace in cities (Govindarajulu, 2014). Conserving greenspace would benefit the environment significantly and help mitigate climate change factors (Govindarajulu, 2014).

Climate change is expected to continue to progress in the future, and as a result, the environmental changes associated with climate change could have implications on physical activity levels and, as a result, could impact older adults' mobility. Understanding climate change and how it will impact weather/climate conditions worldwide in years to come will also allow us to predict how older adults' physical activity levels might be affected. This information will also be useful when considering how to encourage physical activity levels in the future.

1.6 Overview of Canadian Longitudinal Study on Aging

In the second study, a regression analysis was done using the data that had been previously collected. This study was done to determine how environmental factors affect the physical activity levels of older adults from the Canadian Longitudinal Study on Aging (CLSA) who previously sustained a wrist fracture. Information from this database was collected between 2010 and 2015 (Canadian Longitudinal Study on Aging, 2023). Overall, there were over 50,000 individuals that were recruited and provided information (Canadian Longitudinal Study on Aging, 2023). The first follow-up was done from 2015-2018, and the second follow-up was completed between 2018-2021 (Canadian Longitudinal Study on Aging, 2023). Individuals aged 45-85 were recruited and followed until 2033 or until they pass away (Canadian Longitudinal Study on Aging, 2023). Focusing on those aged 45+ is beneficial as this will allow us to identify what factors affect aging. This database aims to find ways to help us live long and well, as well as understand why some people age in a healthy fashion while others might not (Canadian Longitudinal Study on Aging, 2023). Therefore, it will be beneficial to see which environmental factors affect physical activity levels in older individuals within the CLSA, specifically those who have previously sustained a wrist fracture.

1.7 Purpose of Study

Today an increasing number of adults do not meet physical activity guidelines, and sedentary behaviour continues to increase. It is crucial to think about why this might be and how this issue can be prevented in the future. Although studies have been done on factors affecting physical activity levels, a limited number of studies have specifically focused on how environmental factors affect physical activity levels, especially in older adults. This is an important age group to focus on as an increasing number are approaching old age. It is also important to study this topic as physical activity levels tend to decrease in association with increasing age. As mentioned previously, older individuals are also at a higher risk of health issues. However, studies have shown that many health issues can be prevented by engaging in a healthy and active lifestyle, including regular physical activity. Therefore, it is crucial to understand how to promote physical activity levels in older adults now and into the future.

Many factors can play a role in one's decision to participate in physical activity and can vary from person to person. One of these factors includes our surrounding environment. Some studies have been done on how certain environmental factors might impact physical activity levels in individuals. However, few studies have been done on how environmental factors affect physical activity levels in older adults. This information will allow for a more in-depth understanding of how environmental factors affect the older population and how policymakers, health professionals, urban planners and foresters can plan to offset any influences that future climate change might have on physical activity levels. This information will also provide suggestions for future research.

Overall, this thesis aims to identify environmental factors that affect physical activity levels with a focus on older adults. Objectives include 1) to provide insight into the current state of the evidence on the effects that environmental factors have on physical activity levels of those 60 years of age and older, 2) to investigate the relationship between environmental factors and mobility indicators on those who previously sustained a wrist fracture in the Canadian Longitudinal Study on Aging (CLSA) (45+).

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Chapter 2

The Impacts of Environmental Factors on Physical Activity in Older Adults: A Systematic Review

Caitlin Wright[1,2], Joshua Vincent[1,4], Sara Stretton[1,2], Joy MacDermid[1,2,3], Jason Gilliland[1,5,6,7]

[1] School of Health and Rehabilitation Sciences, University of Western Ontario, London, Ontario, Canada

[2] Roth│McFarlane Hand and Upper Limb Centre, St. Joseph's Hospital, London, Ontario, Canada

[3] School of Physical Therapy, University of Western Ontario, London, Ontario, Canada

[4] School of Rehabilitation Science, McMaster University, Hamilton, Ontario, Canada

[5] Department of Geography and Environment, University of Western Ontario, London, Ontario, Canada

[6] Department of Paediatrics, University of Western Ontario, London, Ontario, Canada

[7] Department of Epidemiology and Biostatistics, University of Western Ontario, London, Ontario, Canada

2.0 Abstract

Background: The number of people around the world reaching old age is drastically increasing and many older adults do not achieve enough regular physical activity to achieve the recognized health benefits. Current literature suggests that certain environmental factors can affect an individual's decision to participate in physical activity, however limited research has focused on how environmental factors affect the physical activity levels of older adults.

Objectives: This systematic review was conducted to reveal the current state of the evidence on the effects that environmental factors have on physical activity levels of those 60 years of age and older.

Methods: Articles were identified through electronic database searches in MEDLINE, PsycINFO, Embase, Cumulative Index to Nursing and Allied Health Literature (CINAHL) and SCOPUS. A total of 64 studies matched the specific inclusion criteria and these studies were published between January 2010-November 2022. Natural environmental factors studied in previous research included greenspace, weather, daylight/solar radiation, season, and air quality. Data was extracted on specific weather conditions including temperature, precipitation, humidity, windspeed, and atmospheric pressure.

Results: Overall, there was a strong correlation between increased greenspace, moderate-warm weather and longer hours of daylight having a positive association with the physical activity levels of older adults. Hot temperatures, colder temperatures, high humidity, high windspeed and poor air quality were negatively associated with the physical activity levels of older adults. Physical activity levels were consistently lower in the winter and highest in the spring or summer depending on temperature.

Conclusion: Policy makers, urban planners, and health care professionals should all be aware of how these environmental factors might affect physical activity levels. This information will also be important to be aware of when implementing physical activity interventions.

Keywords: Physical Activity, Older Adults, Greenspace, Weather, Season, Air Quality

2.1 Introduction

Unfortunately, across the globe an increasing number of individuals are not meeting the recommended physical activity guidelines outlined by the World Health Organization (Bull et al., 2020). Physical activity is essential to support physical fitness, physical health, and mental health (Warburton et al., 2006). According to the World Health Organization (WHO), physical activity is defined as “any bodily movement produced by skeletal muscles that require energy expenditure,” and physical inactivity can be defined as “an insufficient physical activity level to meet present physical activity recommendations” (Bull et al., 2020). Being physically inactive is known to increase one’s chance of developing an illness, or disease as well as may lead to premature death (Warburton et al., 2006). Exercise as well as some everyday activities can be considered physical activity and can be performed at mild, moderate, or high levels of intensity (Bull et al., 2020). The World Health Organization (WHO) outlines that physical activity guidelines differ between age groups (Bull et al., 2020). The recommended physical activity guidelines for adults aged 18-64 is 150-300 minutes of moderate aerobic physical activity or 75-150 minutes of vigorous (high)-intensity physical activity per week (Bull et al., 2020). The physical activity guidelines for older adults aged 65+ include 150–300 minutes of moderate or 75–150 minutes of vigorous (high) aerobic physical activity per week (Bull et al., 2020). There is also an emphasis towards focusing on strengthening exercises in the older adult age group (Bull et al., 2020). Overall, the more a person meets these physical activity guidelines, the better it is for their physical and mental health (Warburton et al., 2006).

It is known that over the past 25 years, obesity has been of particular concern as it is seen as an increasing issue across all age groups (Shields & Tremblay, 2008). Obesity rates are increasing because individuals are choosing to engage in constant sedentary behaviour or remain inactive which leads to an increase in energy intake vs energy expenditure (Shields & Tremblay, 2008). Therefore, individuals who live a less active lifestyle are at a higher risk for obesity (Villareal et al., 2004). As a result, individuals who lead an inactive lifestyle are more susceptible to developing, type 2 diabetes, respiratory illnesses, cancer, osteoporosis, cardiovascular disease, and depression (Gaetano, 2016). It is especially important with older adults that they engage in regular physical activity because obese adults are known to have less muscle mass causing them to become frailer (Villareal et al., 2004). If individuals continue to forgo physical activity and this issue is not addressed, it will continue to be of major concern for the overall health of the population (An et al., 2018).

2.1.1 Physical Activity and Natural Environmental Factors

This systematic review will focus on how environmental factors impact physical activity levels of older adults, as well as addressing factors associated with climate change and global warming. Some environmental factors expected to impact an individual in terms of daily physical activity decisions include variation in weather conditions including temperature, precipitation, wind levels and humidity (Tucker & Gilliland, 2007). Seasonality is also known to affect weather conditions as well as day length (Tucker & Gilliland, 2007). Since the influence of environmental factors can be observed over shorter periods of time or longer periods of time (e.g., season) this systematic review will look at how older adults' physical activity levels might change depending on weather conditions and season depending on geographic location.

Other environmental factors included in this systematic review include air pollution as well as the impacts of greenspace on physical activity levels. Air pollution and lack of greenspace commonly due to increased urbanization are examples of factors that have led to the overall warming of the earth's overall atmospheric temperature (Karl, 2009). The Intergovernmental Panel on Climate Change (IPCC), states that climate change can be defined as ''any change in climate over time whether due to natural variability or as a result of human activity" (Pielke, 2005). Climate change also refers to the overall impacts that affect the earth as a result of these contributors and some of these include an increase in extreme weather conditions including extreme rain (including hurricanes), droughts, forest fires as well as glacier melting (Karl et al., 2009). Some impacts of climate change that directly affect humans include the shortage of freshwater, the higher spread of diseases due to higher temperatures, and increased poverty due to an increase in the prevalence of natural disasters and extreme weather conditions (Karl et al., 2009). Therefore, it is crucial to understand and outline how issues that arise from climate change might influence people's decision to go outside and participate in exercise or other forms of physical activity (Karl et al., 2009).

The reason why this is an issue and important to address in this review is because when air quality decreases, it is usually recommended to avoid vigorous outside activities (An et al., 2018). It is also recommended that individuals stay inside as much as possible when the air quality is particularly bad (An et al., 2018). This is because prolonged exposure to poor air quality is known to lead to a decrease in overall lung function, increase in blood pressure, or other impacts on one's cardiovascular and respiratory systems (An et al., 2018). Therefore, individuals might look at the air quality and decide that they are not going to exercise or even go outside that day to protect themselves from health effects associated with prolonged exposure to air pollutants (An et al., 2018). However, this can still be affecting their health over time if they are not engaging in regular physical activity. In many areas around the world that greatly suffer from poor air quality (e.g., China and India) this can be of concern when it comes to physical activity (An et al., 2018). Understanding how air quality might change in the future as well as how this issue might affect climate is crucial when it comes to air quality management but also the health of individuals all around the world.

Another important factor discussed in this systematic review includes greenspace. Some examples of green space include forests, parks, gardens, streams, and rivers (Wolch et al., 2014). Greenspace is important as it can help preserve natural ecosystems, and habitats (Wolch et al., 2014). Overall, greenspace provides many benefits to the overall health of the environment (Wolch et al., 2014). Some examples include improved air quality, noise control, temperature regulation and groundwater replenishing (Wolch et al., 2014). Previous literature has shown that the more greenspace a neighbourhood has, the more health benefits this provides to humans, including improved health and reduced morbidity (Richardson et al., 2013). People living in neighbourhoods with more green space have been found to have a lower risk of poor mental health, and cardiovascular disease (Richardson et al., 2013). Therefore, it is important to understand the impacts of greenspace that might affect physical activity levels in older adults.

This systematic review will provide insight into the current state of the evidence on the effects of environmental factors on physical activity in older adults. It will also highlight specific environmental factors related to climate change and how physical activity might be affected in the future. This information can help health professionals determine how various environment related barriers to physical activity might affect certain patient populations. This will allow health professionals to modify patient activities in a manner to mitigate the effects of these environmental related factors. This study can also have implications for policy by providing stakeholders with information on the various environmental and climate change factors that would impact their recommendation for physical activity levels for individuals. It can also inform policy makers to plan for infrastructure modifications and/or new infrastructure to promote physical activity. Therefore, it is important to determine and gain a better understanding of how environmental factors might positively or negatively affect physical activity levels in older adults.

2.2 Methods

A systematic review was chosen for this study as systematic reviews are typically used to collect international evidence that is relevant to the research question (Munn et al., 2018). This systematic review was done to critically appraise and synthesize the results of existing literature on how environmental factors affect the physical activity levels of older adults as well as identify areas for future research. A protocol for this review was registered with Open Science Framework (https://osf.io/j6rdt/).

2.2.1 Eligibility Criteria

Articles were included if they met the following eligibility criteria: 1) evaluated at least one of the targeted environmental factors and its relationship to physical activity; 2) included individuals aged 60 years and older or disaggregated results for individuals 60 years or older; 3) included healthy individuals that had no known pre-existing health conditions; 4) was published in English; 5) published between Jan 1, 2010– Nov 23rd, 2022. Exclusion criteria included studies of clinical or athletic populations.

2.2.2 Databases and Search

All articles used in this systematic review were retrieved from a total of five electronic databases, which included MEDLINE (Ovid), PsycINFO (Ovid), Embase (Ovid), Cumulative Index to Nursing and Allied Health Literature (CINAHL) and SCOPUS. A librarian was consulted to determine which databases to search as well as determine key words to develop a search strategy that would ensure a compressive and wide range search of the literature (See Table 1). The literature search portion for this systematic review was done on November 23rd, 2022. A filter was applied to adjust for studies to be included between 2010-2022 as the weather has rapidly changed in the last decade (Sibitane et al., 2022). A second filter was also used to include studies written in English. Handsearching was also done to ensure all relevant articles were included.

Key Concepts	**Older Adults**	**Physical Activity**	**Environmental Factors**
Key Words	Aged Geriatric* Older adult* Senior*	Exercise Fitness Physical activit* Physical fitness Sport*	Air pollution Air quality Climate Climate change Global warming Greenhouse effect Greenspace

			Seasonal change Weather

Table 1: Note that key concepts were combined using "AND" while key words were combined using "OR"

2.2.3 Selection of Sources

After searches were conducted in each of the databases, articles were then uploaded into COVIDENCE which is used as a screening and data extraction tool. Once search yields were uploaded into COVIDENCE, duplicate articles were automatically deleted. Articles were then screened by title and abstract, followed by a full-text review of the articles (CW). Once this process was completed a second reviewer (JV) looked over the articles that were excluded to ensure no articles were missed. This was done to determine whether articles met the inclusion and exclusion criteria. Any uncertainty of whether an article should be included was resolved by discussion to reach a consensus between two authors (CW and JV).

2.2.4 Data Extraction Process

Before data extraction began, the data extraction sheet template was agreed upon by consensus of three authors (CW, JV, JM). Data extracted from each of the studies included author, type of study, study population (total number of participants and their age), location of study participants, type of physical activity that was being measured, and results of the study. Data extraction was done by one reviewer (CW) and reviewed by a second reviewer (JV) and a third reviewer (SS). The results from each study that was included in the data extraction table only included the results provided for those specifically aged 60+, as some studies also included results for individuals in younger age groups.

2.2.5 Critical Appraisal

Two reviewers (CW and JV) independently completed a critical appraisal of the 64 articles using the Mixed Methods Appraisal Tool (MMAT) Version 2018 (Hong et al., 2018). This tool allowed for the appraisal of both qualitative and quantitative studies that were included in this systematic review. Reviewers (CW and JV) compared individual quality assessments and agreed on each quality score of each article (See Tables 20 and 21). Any initial differences in the appraisal were resolved by consensus. Cohen's kappa statistic was used to determine agreement (k=0.82), which showed high agreement between reviewers.

2.3 Results

Search Yield: When conducting an initial search for this systematic review 4453 articles were retrieved. In MEDLINE 895 articles were retrieved, 271 articles from PsycInfo, 1,328 from Embase, 329 from CINAHL and 1,630 from Scopus. A total of 10 studies were imported from handsearching leaving 4463 studies imported for screening and 356 studies were assessed for full-text eligibility, leaving a total of 64 articles that met the inclusion criteria and were included in the systematic review (See Figure 1).

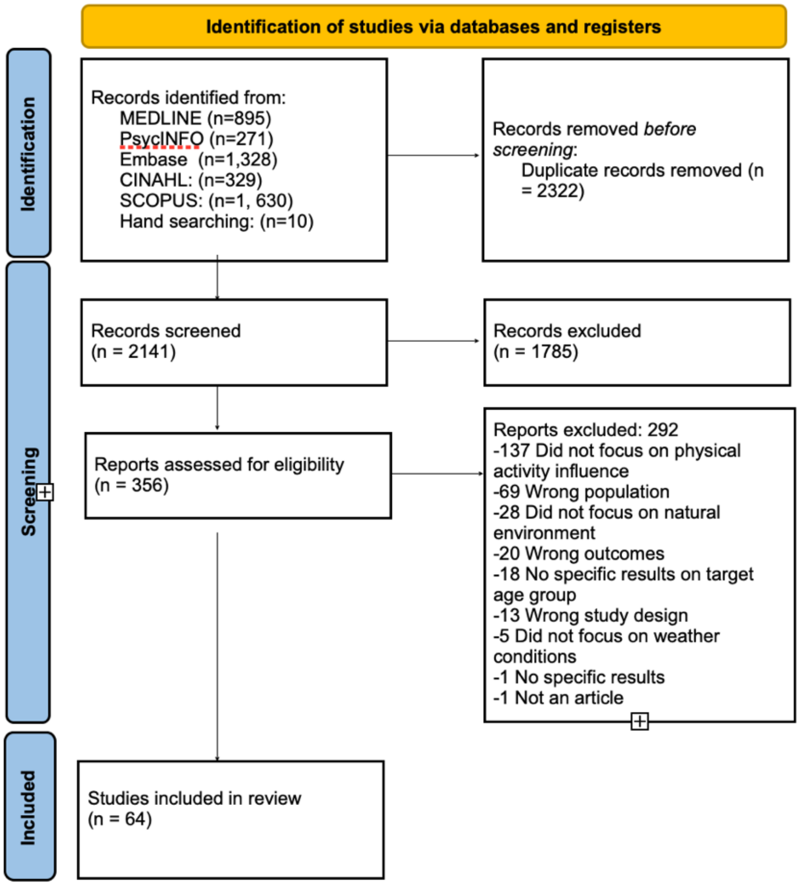

Figure 1. PRSIMA Flowchart

2.3.1 Effects of greenspace on physical activity of older adults

Among the included articles, 26 (40%) looked at the relationship between greenspace variables and physical activity. Four of these studies looked at greenspace in addition to other environmental factors. Most of these studies originated from Asia (n=12), most commonly China (n=11) (See Figure 2). There were three different types of physical activity assessed among the included articles: all physical activity (n=20), walking (n=5), and cycling (n=1). The relationship between physical activity and greenspace was synthesized qualitatively, and each is discussed below. The summary of these results can be seen in Tables 2 and 3 and the full results including all statistical data can be seen in Table 14 and Table 19.

2.3.1.1 Greenspace and physical activity. Greenspace and physical activity (general physical activity and walking) were assessed, and they all showed positive associations except one. Greenspace and general physical activity were assessed in 8 studies, and they found that accessibility to greenspace was positively associated with leisurely activities and increased physical activity time (Vich et al., 2021; Yu et al., 2021; Dalton et al., 2016). Greenspace, measured through normalized difference vegetation index (NDVI) also showed to increase the likelihood of physical activity in three studies (Zhou et al., 2020; Gong et al., 2014; Klompmaker et al., 2018); one study showed that only the second highest greenness neighbourhood was associated with regular physical activity (Huang et al., 2018); and the remaining study had no significant findings (Dadvand et al., 2016).

Greenspace and walking were assessed in 5 studies, they found through using a combination of accelerometer and GPS tracking that walking was positively associated with natural areas and the presence of outdoor fitness equipment (Zhai et al., 2020). Greenspace was associated with increased likelihood of walking in two studies (Lu 2018; Lu et. al., 2018); increased walking time in one study (Besser & Mitsova 2021); and a slower decline in walking over time in one study (Lin et al., 2020).

2.3.1.2 Greenspace attributes/other factors and physical activity. Greenspace attributes (proximity, aesthetic, and size) and physical activity (general and walking) were assessed in 8 studies and greenspace, weather, and physical activity were assessed in two studies. Proximity to greenspace and general physical activity were assessed in four studies. Proximity to greenspace was shown to increase the likelihood of physical activity in three studies (Machón et al., 2020; Miralles-Guasch et al., 2019; Yuen et al., 2019) and subjective proximity was shown to increase the likelihood of physical activity only among male participants in the remaining study (Dadvand et al., 2016). Greenspace aesthetic and general physical activity were assessed in three studies. Presence of water, different land types, and diversity of land use and habitats was associated with increased likelihood of physical activity in one study (Keskinen, 2018); presence and use of pathways were positively associated with physical activity in one study (Zhai et al., 2021); and percentage of greenspace land use diversity were positively associated with cycling in the remaining study (Wang et al., 2021). Size of greenspace and walking were assessed in one study, they found that size of greenspace was positively related to walking time (Zandieh et al., 2019). Lastly, weather, greenspace, and general physical activity were assessed in two studies. Both studies found that there was a negative relationship between greenspace physical activity and temperature and rain (Giehl et al., 2012; Vich et al., 2021).

2.3.1.3 Qualitative data and themes. There were five qualitative studies that identified themes (i.e., barriers, facilitators, and benefits) among greenspace and physical activity. Four studies reported barriers to participating in physical activity in greenspace (Adlaka et al., 2021, Leung et al., 2021, Van Cauwenberg et al., 201, Kou et al., 2021), two studies identified safety concerns as a common barrier (Adlaka et al., 2021; Kou et al., 2021). The remaining two studies both identified weather as a common barrier, one study specified rain and very hot weather and the other specified winter as a barrier (Leung et al., 2021; Van Cauwenberg et al., 2012). Three studies reported facilitators of physical activity in greenspace, all studies reported aesthetics as a common facilitator (Finlay et al., 2015; Kou et al., 2021; Leung et al., 2021). Other facilitator themes that were identified and unique include accessibility, amenities, sports facilities, walking/cycling facilities, safety, and warm/sunny weather. Lastly, the remaining study identified benefits of greenspace on physical activity, they identified that greenspace was seen as a facilitator to physical activity and improved health (Adlaka et al., 2021).

The included greenspace studies looked at various relationships between greenspace variables and physical activity. These studies commonly showed a positive relationship between greenspace and physical activity, although this relationship was mediated by weather, aesthetics, and proximity to greenspace. Studies commonly reported weather as both a facilitator and barrier to physical activity in greenspace; warm/sunny weather was associated with greater physical activity, while extreme or adverse weather conditions were associated with less physical activity. Similarly, greater greenspace aesthetics and closer proximity was associated with increased physical activity, while less aesthetically pleasing and further proximity to greenspace was associated with less physical activity.

Table 2

Summary of Quantitative data on Greenspace

Relationship	Author(s) and year of publication	Results
Greenspace and general physical activity	*Yu et al., 2021*	Greenspace was positively associated with leisure activities
	Vich et al., 2021	Greenspace was associated with more physical activity time.
	Zhou et al., 2020	Greenspace increased the likelihood of physical activity
	Gong et al.,2014	

	Klompmaker et al., 2018	Greenspace increased the likelihood of physical activity.
	Dalton et al., 2016	Greenspace increased physical activity time
	Dadvand et al., 2016	There were no significant findings for surrounding greenspace and physical activity
	Huang et al., 2018	Greenspace was associated with regular physical activity only in the second highest greenness quartile neighbourhood
Greenspace and walking	*Lin et al., 2020*	Greener and sky view neighbourhoods were associated with a slower decline in walking
	Besser & Mitsova, 2021	Greenspace increased walking time
	Lu et. al., 2018	Greenspace increased likelihood of walking and walking time
	Lu 2018	Greenspace increased likelihood of walking but not walking time
	Zhai et al., 2020	Walking was positively associated with natural areas and the presence of outdoor fitness equipment
Proximity to greenspace and general physical activity	*Dadvand et al., 2016*	Subjective proximity to greenspace increased the likelihood of physical activity only among male participants
	Machón et al., 2020	Proximity to greenspace increased likelihood of physical activity

	Miralles-Guasch et al., 2019	
	Yuen et al., 2019	
Greenspace aesthetic and general physical activity	*Keskinen 2018*	Presence of water, different land types, diversity of land use, and habitat diversity increased likelihood of outdoor physical activity
	Zhai et al., 2021	Presence and use of pathways were positively associated with physical activity
	Wang et al., 2021	Greenspace aesthetics (percentage of greenspace land use and diversity) were positively associated with cycling
Size of greenspace and walking	*Zandieh et al., 2019*	Size of greenspace was positively related to walking time. There were no relationships found between closest or most attractive greenspace
Weather, greenspace and general physical activity	*Giehl et al., 2012*	There was a negative relationship between greenspace physical activity and temperature and rain.
	Vich et al., 2021	

Table 3

Summary of Qualitative data and themes on Greenspace

Relationship	Author(s) and year of publication	Results
Barriers of physical	*Adlaka et al., 2021*	Neighbourhood disorder and crime

activity greenspace	*Leung et al., 2021*	Weather (rain, very hot temperature)
	Van Cauwenberg et al., 2012	Weather (winter)
	Kou et al., 2021	Slopes, safety
Facilitators of physical activity in greenspace	*Kou et al., 2021*	Variation of natural elements, accessibility, amenities, sport facilities, maintenance/aesthetic, walking/cycling facilities, safety
	Finlay et al., 2015	Trees, flowers, shade, pristine natural features
	Leung et al., 2021	Weather (warm/sunny), natural environment, cleanliness, aesthetics
Facilitators of walking in greenspace	*Van Cauwenberg et al., 2012*	Aesthetics (parks, fields, woods, rivers, ponds), weather (spring/summer)
Benefits of greenspace	*Adlaka et al., 2021*	Greenspace as seen as a facilitator for physical activity and improved health

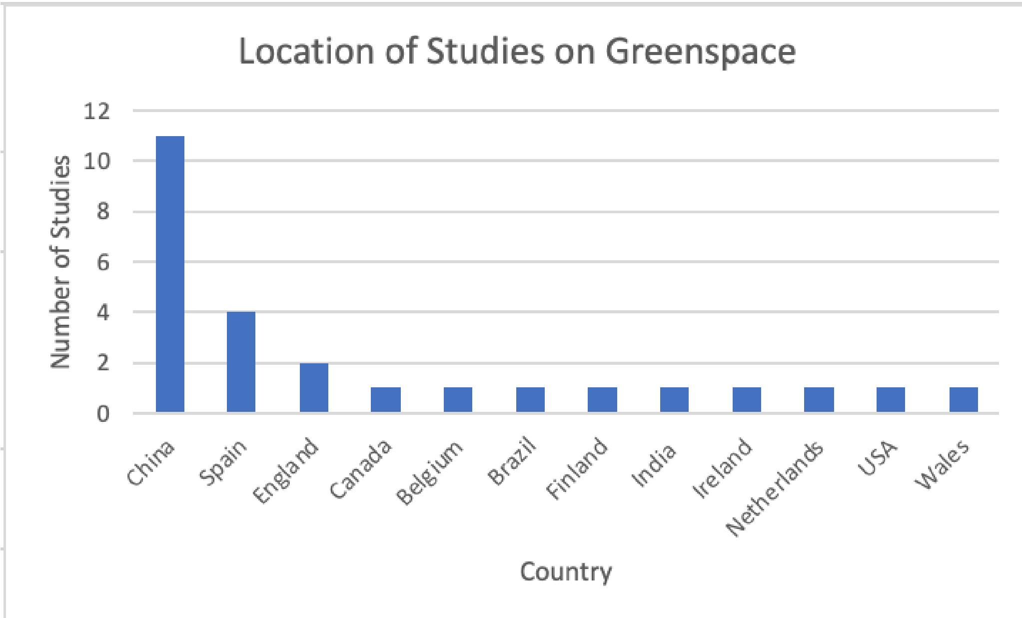

Figure 2. Chart showing the country of each study providing results on Greenspace.

2.3.2 Studies on Weather

Among the included articles, 29 (45%) looked at the relationship between weather and physical activity. From the studies looking at weather as well as other environmental factors there were 15 studies. The study design varied and among the included articles, 18 articles were quantitative studies, and 11 studies were qualitative. In some studies, multiple weather conditions were analyzed. Weather conditions addressed in these studies included, temperature (n=28), precipitation (n=19), humidity (n=6), windspeed (n=7), and atmospheric pressure (n=1). The full results for each study including all statistical data can be seen in Table 15 and Table 19.

2.3.2.1 Temperature

A total of twenty-eight of the included articles on weather conditions included information on the impacts of temperature on physical activity levels (See Tables 4 and 5). Most of these studies were done in the USA (n=6), and the United Kingdom (UK) (n=6) (See Figure 3).

2.3.2.2. Temperature and general physical activity. From the quantitative studies done on the impacts of temperature and general physical activity, some studies showed that physical activity increased as temperature increased (Aspvik et al., 2018; Jones et al., 2017; Timmermans et al., 2016; Witham et al., 2014). It was also shown that only certain temperatures were associated with higher levels of physical activity. The study done by Ho et al showed that physical activity decreased when temperatures were high but peaked between temperatures of 16 °C to 19.3 °C (Ho et al., 2022). However, physical activity levels did not decrease significantly in association with warmer temperatures in cities with sub-tropical climates (Ho et al., 2022). In a study done by Aoyagi and Shepard (2010) daily step count peaked when the mean outdoor temperature was 17°C (Aoyagi & Shepard, 2010). Another study showed that temperatures between 6.7°C and 10.3°C were negatively associated with physical activity levels but only for those aged ≥75 (Cepeda et al., 2018). Overall, higher temperatures were associated with lower levels of physical activity (Clarke et al., 2015; Giehl et al., 2012) as well as colder temperatures (Giehl et al., 2012; Price et al., 2012; Wu et al., 2017). However, one study showed that daily temperature did not significantly impact physical activity (Hoppmann et al., 2017*).*

2.3.2.3. Temperature and Walking. Temperature also impacted walking levels. Warmer weather was associated with more walking (Delclos-Alio et al., 2019; Klenk et al., 2012; Klimek et al., 2022; Prins & Van Lenthe, 2015). The study done by Dunn et al., 2012 found that an increase in temperature was associated with women being more likely to walk 2.5 miles/week, however higher temperatures were associated with a decreased probability of men walking 2.5 miles/week (Dunn et al., 2012)

2.3.2.4. Temperature and Cycling. Warmer temperatures were associated with an increase in cycling (Prins & Van Lenthe, 2015*)*. However, one study showed physical activity was higher up to temperatures of 26-28°C and less when temperatures exceeded that threshold, this threshold was lower for older adults, compared to younger individuals (Heaney et al., 2019).

2.3.2.5 Qualitative data and themes. There was a total of ten qualitative studies that focused on how temperature impacts physical activity. Results from these studies showed that cold weather was a major barrier to individuals choosing to participate in general outdoor physical activity (Bjornsdottir et al., 2012; Normansell et al., 2014; Sanders et al., 2018; Schmidt et al., 2016; You et al., 2021). Very hot temperatures were also stated as a barrier to participating in physical activity (Bösch et al., 2022; Samra et al., 2019; Schmidt et al., 2016; You et al., 2021). Warmer temperatures facilitated walking but temperatures that were too hot were a barrier (Leung et al., 2021). Colder temperatures were also stated as a barrier towards walking (Gallagher et al., 2010; Marquez et al., 2016).

Table 4

Summary of Quantitative Studies on Temperature

Relationship	**Author(s) and year of publication**	**Results**
	Aoyagi & Shepard 2010	Habitual physical activity was positively associated with temperature. Temperature decreased physical activity above 17°C.
	Aspvik et al., 2018	Physical activity was positively influenced by temperature.
	Clarke et al., 2015	Extreme heat was associated with individuals choosing to avoid exercise.

Temperature and General Physical Activity	*Cepeda et al., 2018*	Temperatures between 6.7-10.3°C were negatively associated with physical activity levels for those aged (≥75).
	Giehl et al., 2012	Weather (the cold and the heat) limited the practice of physical activity.
	Ho et al., 2022	Physical activity decreased in association with high temperatures in cold/temperature cities. Physical activity did not decrease significantly in cities with sub-tropical climate.
	Hoppmann et al., 2017	Daily temperature did not show to significantly impact daily physical activity.
	Jones et al., 2017	Daily physical activity was positively associated with temperature.
	Klimek et al., 2022	Temperature was positively associated with daily walking duration and time spent out of home.
	Price et al., 2012	Number of adults counted using the trail system were highest during moderate temperatures, and lowest during colder temperatures.
	Timmermans et al., 2016	Temperature was positively associated with outdoor physical activity levels (minutes per day).
	Witham et al., 2014	Daily activity for all participants increased in association with higher minimum daily temperature.
	Wu et al., 2017	Colder temperatures decreased total physical activity.
	Delclos-Alio et al., 2019	Warmer weather facilitated walking; colder weather decreased walking.
	Dunn et al., 2012	Higher temperatures increased walking probability

Temperature and Walking		for women but decreased walking probability for men.
	Klenk et al., 2012	Average daily walking duration increased as daily maximum temperature increased.
	Prins & Van Lenthe., 2015	Walking time was positively associated with temperature.
Temperature and Cycling	*Heaney et al., 2019*	Temperature was positively associated with cycling. However, cycling decreased once temperatures reached 26-28°C.
	Prins & Van Lenthe., 2015	Cycling was positively associated with temperature.

Table 5

Summary of Qualitative Studies on Temperature

Relationship	**Author(s) and year of publication**	**Results**
Barriers to General Physical Activity	*Bjornsdottir et al., 2012*	Colder weather (and ice) was identified as a barrier to physical activity.
	Bösch et al., 2022	Barriers to physical activity included high temperatures.
	Normansell et al., 2014	Cold weather was stated as a barrier to walking.
	Samra et al., 2019	The primary barrier to physical activity included extreme weather (e.g. hot temperatures).
	Sanders et al., 2018	From the participants that stated weather influenced physical activity, cold weather was what would decrease exercise.
	Schmidt et al., 2016	Adverse weather conditions, primarily cold weather along with ice, and slush were

		mentioned as a barrier to physical activity.
	You et al., 2021	Bad weather including hot or cold temperatures were mentioned as a key barrier to physical activity.
Facilitators towards Walking	*Leung et al., 2021*	Warmer/sunny weather was stated as a facilitator to walking.
Barriers towards walking	*Gallagher et al., 2010*	Cold weather was stated as a barrier to walking.
	Leung et al., 2021	Temperatures that were considered too hot were considered a barrier towards walking.
	Marquez et al., 2016	Colder temperatures and very hot temperatures all negatively impacted walking.

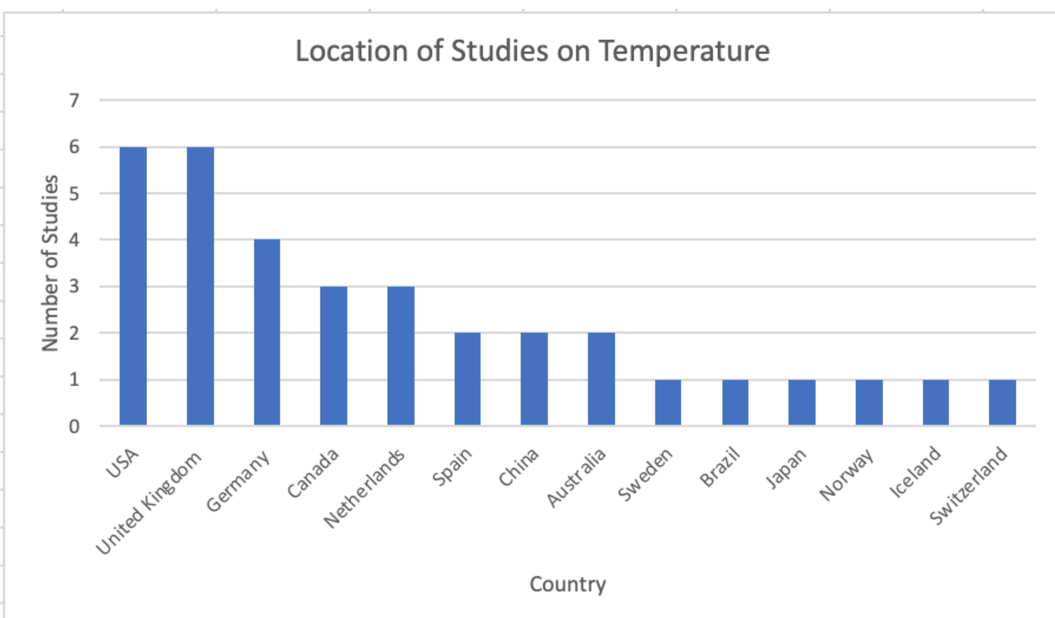

Figure 3. Chart showing the country of each study providing results on Temperature. Note: Some studies included participants from more than one location.

2.3.3 Precipitation

Out of the included studies done on weather, a total of 19 articles provided results on how precipitation might affect physical activity levels (See Tables 6 and 7). Most of these studies included participants from the United Kingdom (UK) (n=4) and Germany (n=4) followed by the USA (n=3), and Netherlands (n=3) (See Figure 4).

2.3.3.1. Precipitation and Physical Activity. Overall, the presence of rain was shown to decrease physical activity (Aoyagi & Shepard, 2010; Aspvik et al., 2018; Cepeda et al., 2018*;* Giehl et al., 2012; Clarke et al., 2015; Hoppmann et al., 2017; Wu et al., 2017). It is also important to note that the study done by Aspvik et al 2018 showed that precipitation influenced physical activity differently depending on the time of year and the individual's fitness level (Aspvik et al., 2018). Warmer months (April-October) in association with precipitation negatively impacted physical activity in unfit individuals, not those who had higher fitness levels from a study done in Norway (Aspvik et al 2018). However, during months commonly associated with colder temperate (November-March) precipitation increased physical activity levels but only in males that were considered moderately fit and fit (Aspvik et al 2018). There was only one study that did not show an association between precipitation and physical activity, and that was done by Timmermans et al in 2016. This study showed that precipitation did not show significance in impacting outdoor physical activity in healthy individuals.

2.3.3.2. Precipitation and Walking. Results showed that overall, precipitation is negatively associated with walking (Delclos-Alio et al., 2019; Klenk et al., 2012; Klimek et al., 2022; Prins & Van Lenthe, 2015).

2.3.3.3. Qualitative data and themes. From the seven qualitative studies, rain was stated as a weather variable that was a barrier to participating in general outdoor physical activity (Bösch et al., 2022; Leung et al., 2021; You et al., 2021). Rain was also considered a barrier to walking (Gallagher et al., 2010; Normansell et al., 2014; VanCauwenberg et al., 2012; Prins & Van Lenthe, 2015). Snow was also shown to be negatively associated with walking as it was commonly associated with an increased fear of falling (Marquez et al., 2016).

Table 6

Summary of Quantitative Studies on Precipitation

Relationship	**Author(s) and year of publication**	**Results**
Precipitation and General Physical Activity	*Aoyagi & Shepard 2010*	Precipitation decreased physical activity (step count).
	Aspvik et al., 2018	Physical activity levels decreased in association with heavy rain.
	Clarke et al., 2015	Rain/thunderstorms were associated with decreased physical activity.
	Cepeda et al., 2018	Precipitation was negatively associated with physical activity levels.
	Giehl et al., 2012	Rain was a weather condition that limited the practice of physical activity.
	Hoppmann et al., 2017	Precipitation decreased daily physical activity levels.
	Timmermans et al., 2016	Precipitation was not significantly associated with impacting physical activity.
	Wu et al., 2017	Precipitation was associated with decreasing total physical activity (counts per minute).
Precipitation and Walking	*Delclos-Alio et al., 2019*	Presence of rain decreased walking time.
	Klenk et al., 2012	Average daily walking duration decreased with, increased average daily precipitation.
	Klimek et al., 2022	Rain decreased daily walking duration for both men and women.

	Prins & Van Lenthe., 2015	Walking time was negatively associated with rain

Table 7

Summary of Qualitative Studies on Precipitation

Relationship	**Author(s) and year of publication**	**Results**
Impact of Rain on Physical Activity	*Bösch et al., 2022*	Weather barriers to physical activity included rainfall.
	Leung et al., 2021	Rainy weather is a barrier and increases fear of slipping.
	You et al., 2021	Rain was associated with bad weather, which was a key barrier to physical activity.
Impact of Rain on Walking	*Gallagher et al., 2010*	Presence of rain was stated to inhibit walking.
	Normansell et al., 2014	Rain was stated as a barrier to walking.
	VanCauwenberg et al., 2012	Rainy weather inhibited walking due to puddles on sidewalks as well as mud.
Impact of Snow on Walking	*Marquez et al., 2016*	Snow negatively impacted walking. Snow also increased fear of falling.

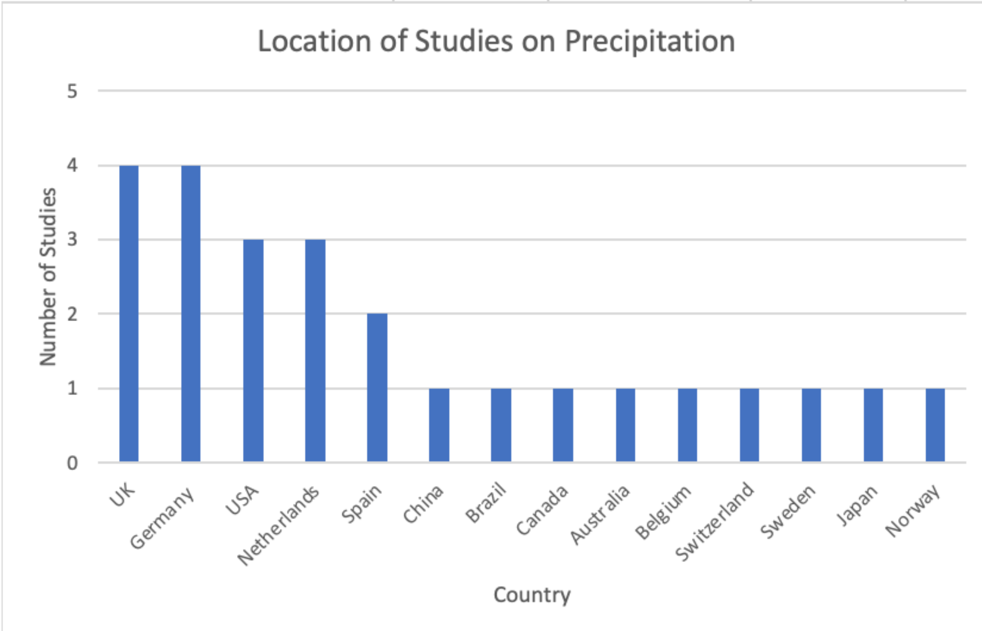

Figure 4. Chart showing the country of each study providing results on Precipitation. Note: Some studies included participants from more than one location.

2.3.4 Studies on Humidity

A total of six studies provided results on how humidity might impact physical activity levels (See Table 8). Study locations varied as two were done in Germany, one in Australia, one in Canada and another in the Netherlands. The study done by Timmermans et al used data from participants located in Germany, the Netherlands, Spain, Sweden and the United Kingdom (See Figure 5). Overall, the humidity was negatively associated with physical activity levels (Cepeda et al., 2018; Jones et al., 2017; Timmermans et al., 2016). The average daily walking duration was shown to decrease with increasing humidity levels (Klenk et al., 2012, Klimek et al., 2022). In a qualitative study done by Samra et al., 2019 extreme weather including high humidity was listed as a barrier to physical activity (Samra et al., 2019).

Table 8

Summary of Studies on Humidity

Relationship	Author(s) and year of publication	Results
Impact of Humidity on general physical activity	*Cepeda et al., 2018*	Humidity was negatively associated with physical activity levels.
	Jones et al., 2017	Physical activity decreased with increased humidity.
	Timmermans et al., 2016	Relative humidity was negatively associated with outdoor physical activity.
Impact of Humidity on walking	*Klenk et al., 2012*	Average daily walking duration decreased with, increased humidity.
	Klimek et al., 2022	Daily walking duration decreased with, increased humidity for both men and women.
Impact of Humidity on general physical activity (qualitative)	*Samra et al., 2019*	A barrier to physical activity was extreme weather which included high humidity levels.

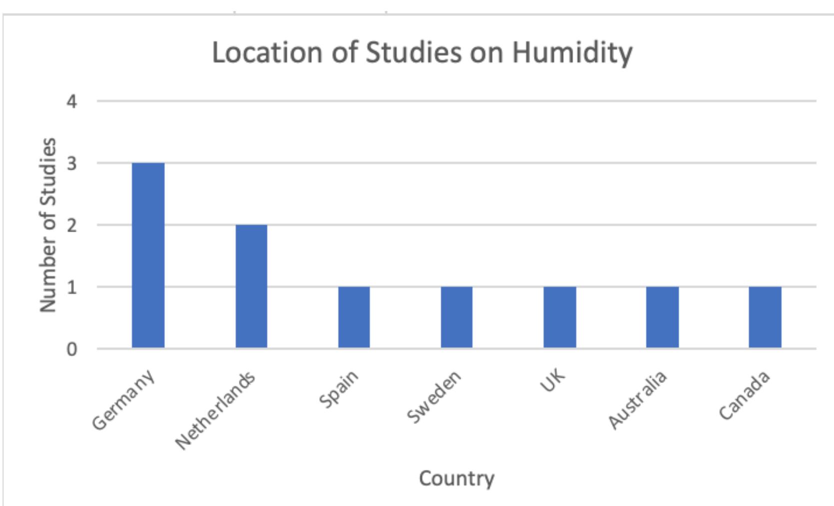

Figure 5. Chart showing the country of each study providing results on Humidity. Note: One study included more than one location.

2.3.5 Studies on Windspeed.

A total of seven studies provided results on how windspeed might impact physical activity levels (See Table 9). Study locations varied as the majority were done in the Netherlands and Germany. Other locations included Iceland, Canada, Spain, Sweden, and the UK (See Figure 6). Five of these studies were quantitative and two studies were qualitative studies.

2.3.5.1 Quantitative Data Windspeed was negatively associated with physical activity levels (Cepeda et al., 2018). The average daily walking duration was shown to decrease with increased windspeed (Klenk et al., 2013). Higher windspeed also decreased daily walking duration and time spent out of home for both men and women (Klimek et al., 2022). However, the study done by Timmermans did not show windspeed to be significantly associated with outdoor physical activity minutes per day (Timmermans et al., 2016). Another study showed that walking was positively associated with windspeed (Prins & Van Lenthe., 2015).

2.3.5.2 Qualitative Data and Themes. The wind was a factor mentioned as a barrier to physical activity in a qualitative study (Bjornsdottir et al., 2012). Another study done by Schmidt et al study in 2016 stated that adverse weather conditions along with ice, slush or strong wind were barriers to physical activity due to fear of falling (Schmidt et al., 2016).

Table 9

Summary of Studies on Windspeed

Relationship	**Author(s) and year of publication**	**Results**
Impact of Windspeed on Physical Activity (Quantitative Studies)	*Cepeda et al., 2018*	Windspeed was negatively associated with physical activity levels.
	Klenk et al., 2012	Average daily walking duration decreased with, increased average wind speed.

	Klimek et al., 2022	Daily walking duration decreased in association with increasing wind.
	Prins & Van Lenthe., 2015	Windspeed was positively associated with walking time.
	Timmermans et al., 2016	Windspeed did not show any significance in terms of affecting physical activity.
Impact of Windspeed on Physical Activity (Qualitative Studies)	*Bjornsdottir et al., 2012*	Wind was a barrier to physical activity.
	Schmidt et al., 2016	Higher winds were an example of an adverse weather condition that made outdoor physical activity less desirable.

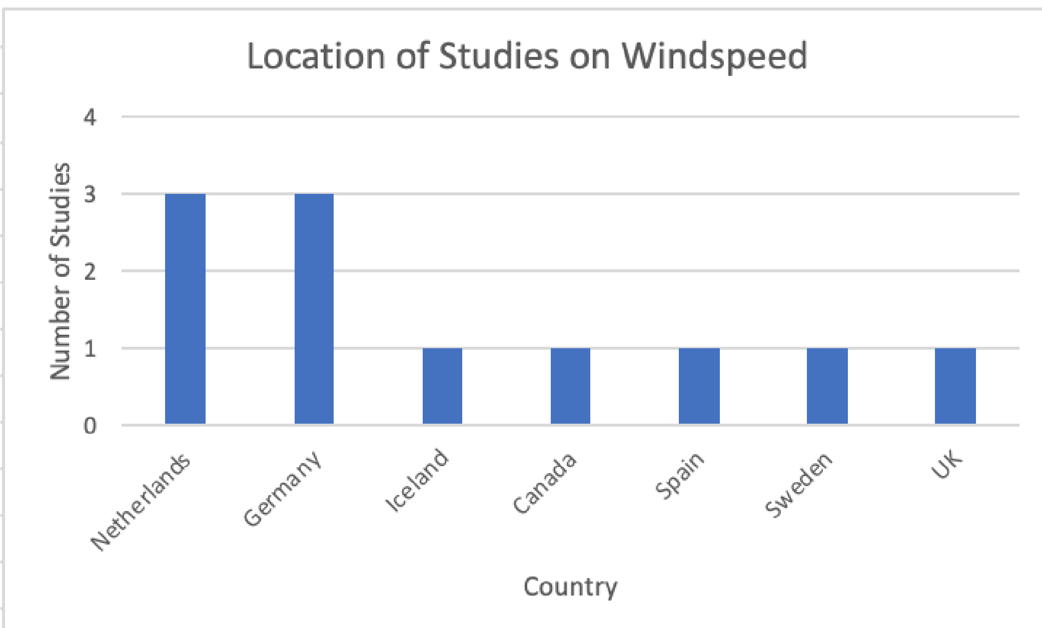

Figure 6. Chart showing the country of each study providing results on Windspeed. Note: One study included more than one location.

2.3.6 Atmospheric Pressure and Physical Activity.

Only one study determined how atmospheric pressure might affect physical activity and this study showed that physical activity levels were affected (Timmermans et al., 2016).

2.3.7 Studies on Daylight/Solar Radiation

All 10 studies done on how daylight affects physical activity were quantitative (See Table 10). The location of these studies varied; United Kingdom (n=3), Germany (n=2), Netherlands (n=2), Iceland (n=1), Canada (n=1), and USA (n=1) (See Figure 7). The full results including all statistical data can be seen in Table 16 and Table 19.

2.3.7.1 Daylight/Solar Radiation on Physical Activity. Hours of daylight was shown to be positively associated with physical activity (Arnardottir et al., 2017; Cepeda et al., 2018; McMurdo et al., 2012; Schepps et al., 2018, Witham et al., 2014. Wu et al., 2017). The study done by Schepps et al in 2018 showed that when day length was ≥14 hours, that total number physical activity levels (measured by steps per day) were at its highest (Schepps et al., 2018). Daylight/solar radiation were also positively associated with walking and total time spent outside of home (Klenk et al., 2012; Klimek et al., 2022). Another study showed for older adults (>65) increasing sunshine was associated with an increase in cycling (Prins & Van Lenthe., 2015). However, the study done by Hoppmann et al in 2017 showed that daylight hours did not show statistical significance in terms of affecting average daily activity counts/min or average daily step counts/min (Hoppmann et al., 2017).

Table 10

Summary of Studies on Daylight/Solar Radiation

Relationship	**Author(s) and year of publication**	**Results**
	Arnardottir et al., 2017	Longer daylight was associated with higher total physical activity.
	Cepeda et al., 2018	Daylight was positively associated with physical activity.
	Hoppmann et al., 2017	Daylight did not significantly impact daily physical activity.

Daylight and General Physical Activity	*McMurdo et al., 2012*	Daylight was positively associated with daily physical activity.
	Schepps et al., 2018	When day length was ≥14 hours, that total number of steps per day was at its highest
	Witham et al., 2014	Daily activity counts were positively associated with hours of daylight.
	Wu et al., 2017	Daylight was positively associated with total physical activity (counts per minute).
Daylight and Walking	*Klenk et al., 2012*	Average daily walking duration increased with daylight and solar radiation.
	Klimek et al., 2022	Sunshine duration increased daily walking duration and time spent out of home.
Daylight and Cycling	*Prins & Van Lenthe., 2015*	Increasing sunshine was associated with a slight increase in cycling.

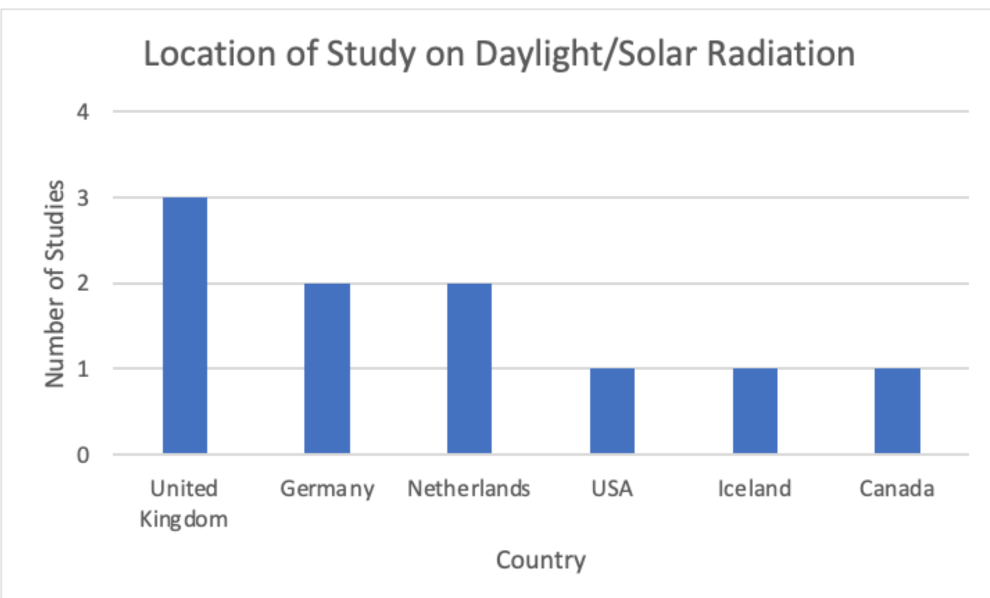

Figure 7. Chart showing the country of each study providing results on Daylight/Solar Radiation.

2.3.8 Studies on Seasonal Impact

A total of 14 studies discussed how seasonality might affect physical activity levels among older adults (See tables 11 and 12). The location of these studies varied; Japan (n=4), USA (n=3), United Kingdom (n=2), Canada (n=2) and one study each from, Iceland, Belgium, and the Netherlands (See Figure 8). The full results including all statistical data can be seen in Table 17 and Table 19.

2.3.8.1 Seasonal Impact on Physical Activity

Impacts of seasonal change were found to be very apparent across all studies. Studies showed that physical activity was lowest when comparing a snowfall season and a non-snowfall season (Amagasa et al., 2020; Ogawa et al., 2018). Results also showed overall that physical activity levels were lower in the winter months (Kimura et al., 2015; McCormack et al., 2010; Nakashima et al., 2019; Arnardottir et al., 2017). However, the season or specific months of higher physical activity levels differed between some studies. Some studies showed that physical activity levels were shown to be highest in the Spring (McCormack et al., 2010; Nakashima et al., 2019; Price et al., 2012), but some studies showed that physical activity levels were higher in the Summer (Kimura et al., 2015; Arnardottir et al., 2017). One study also showed that the odds of walking on a South Carolina Rail-Trail were highest in the summer compared to fall, winter and spring (Price et al., 2012). The study done by Barkley et al in 2017, showed that for those living in a non-residential community, physical activity levels in the summer compared to the winter did not differ significantly ($p>0.05$) (Barkley et al., 2017). In another study, levels of physical activity were highest in the summer compared to winter for those 60-74 but in the old-elderly participants (≥75) there was no significant association (Cepeda et al., 2018). The odds of older individuals (≥65) choosing to exercise indoors were higher during the summer when faced with adverse weather conditions (Wagner 2019).

2.3.8.2 Qualitative Data Four of the fourteen studies that included information on seasonality were qualitative studies. The themes brought forward in interviews were similar among participants. In one study, from the participants that stated season correlated with their physical activity levels, the reason was because they would be less likely to participate in physical activity if the weather was cold and wet (Sanders et al., 2018). In the study by Normansell et al in 2014 it was determined that during the winter one might be less active (Normansell et al., 2014). It was also mentioned that in the spring, summer, and autumn it's nicer to go for a walk as opposed to the winter (Van Cauwenberg et al., 2012). Participants mentioned that one might be less active in the winter due to the fear of falling due to ice and slush (Schmidt et al., 2016).

Table 11

Summary of Quantitative Studies on Season

Relationship	**Author(s) and year of publication**	**Results**
Seasonal Impact on General Physical Activity between a Snowfall and non-snowfall season	*Amagasa et al., 2020*	Activity levels of older individuals were higher during the non-snowfall season compared to snowfall season.
	Ogawa et al.,2018	Average step count was lower during the snowfall season (February) and higher during the non-snowfall season (September).
	Barkley et al., 2017	Results showed that physical activity did not differ

Seasonal Impact on General Physical		significantly between baseline (June and July) and follow up (December and January) within the sample living in a non-residential area.
	Cepeda et al., 2018	Levels of physical activity were highest in the summer compared to winter for those 60-74. In the old-elderly participants (≥75) there was no significant association between physical activity and season.
	Kimura et al., 2015	Results show that physical activity (steps per day) were higher in the summer (mid-July to mid-August), and lower in the winter (mid-January to beginning of February).
	McCormack et al., 2010	For those aged 60+ recreational walking prevalence was highest in the spring (March and April). Prevalence was lowest in the winter (January and February).
	Nakashima et al., 2019	The number of steps taken per day were lowest in the winter and highest in the spring.
	Wagner et al., 2019	Odds of adults aged ≥65 years showed greater odds of choosing to participate in outdoor exercise during the summer than the winter.
	Arnardottir et al., 2017	Total physical activity was higher in the summer; compared to the winter.
Seasonal Impact on Walking	*Price et al., 2012*	Number of older adults walking on the trail was highest during the summer.

Table 12

Summary of Qualitative Studies on Season

Relationship	**Author(s) and year of publication**	**Results**
Seasonal Impact on General Physical	*Normansell et al., 2014*	Another participant stated that during the winter they are less active due to the cold weather or rain. It was also mentioned that in the spring, summer and autumn it's nicer to go for a walk as opposed to the winter.
	Sanders et al., 2018	Season was correlated with physical activity participation among older adults.
	Schmidt et al., 2016	Fear of falling was the most common perceived environmental barrier to participating in outdoor physical activity. This fear is the most common during the winter due to ice and slush.
Seasonal Impact on Walking	*Van Cauwenberg et al., 2012*	Summer, spring and fall weather influences walking. winter weather was stated as a barrier to walking.

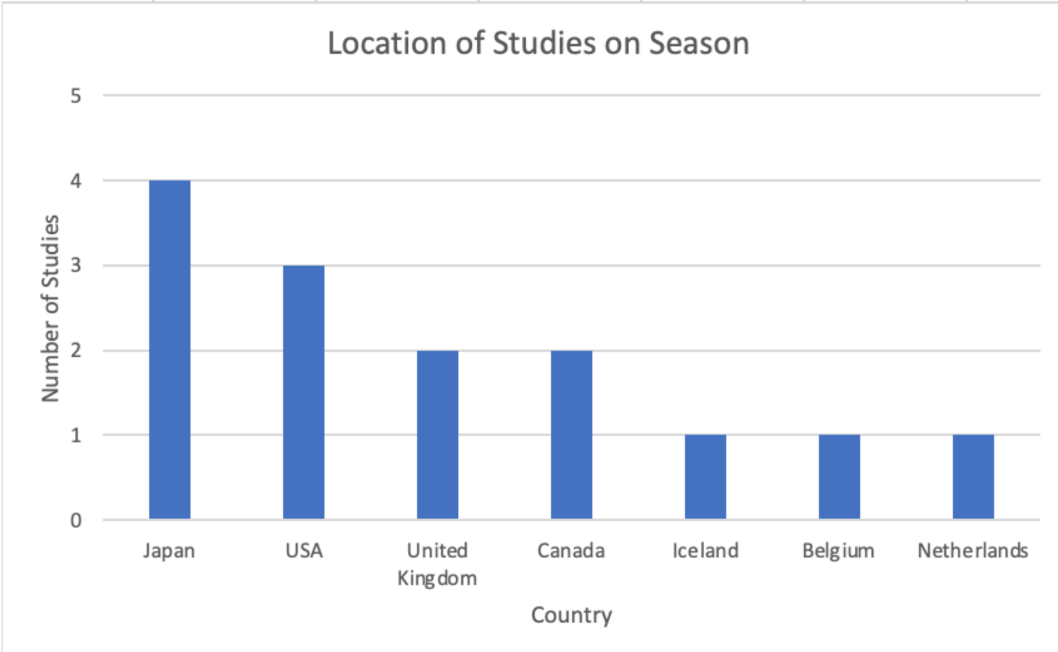

Figure 8. Chart showing the country of each study providing results on Season.

2.3.9 Studies on Air Quality

A total of three (quantitative) articles included in this review studied how air quality might affect physical activity on older adults living (See Table 13). The full results including all statistical data can be seen in Table 18 and Table 19. A study done in the USA showed that older adults tend to be less active and that an increase in levels of $PM_{2.5}$, PM_{10} and O_3 was shown to be associated with decreased physical activity (Roberts et al., 2014). Another study looked specifically at the effects of $PM_{2.5}$ concentration on total hours of walking in older adults living in Beijing, China. Results showed that total hours were reduced when the $PM_{2.5}$ concentration increased (Yu et al., 2017). The third study that addressed air quality was studies adults aged 61+ living in old residential communities located in Nanjing, China (Yu et al in 2021). Results showed that activities of daily living as well as nature-exposure activities were negatively association with poor air quality (Yu et al in 2021). Overall, results from these three studies show that poor air quality will lower the chances of older individuals choosing to go outside and participate in physical activity.

Table 13

Summary of Studies on Air Quality

Relationship	**Author(s) and year of publication**	**Results**
Impact of Air Quality on Physical Activity	*Roberts et al., 2014*	The relationship between age and air pollution showed that older adults were less likely to be active
	Yu et al., 2017	Increased air pollution ($PM_{2.5}$ concentration) lowered walking levels.
	Yu et al., 2021	There was a negative relationship between nature-exposure activities and poor air quality.

2.4. Discussion

Overall, a variety of environmental factors showed to have significant impacts on physical activity levels of older adults. More greenspace, warmer temperatures and more hours of daylight increased physical activity levels. Temperatures considered too hot or too cold, precipitation, high humidity and windspeed were associated with lower physical activity levels. Atmospheric pressure did not show to impact physical activity levels; however, this information is only from one study.

Greenspace has been shown to have a positive relationship with physical activity among adults aged 60 and older, although this relationship is mediated by weather, aesthetics, and proximity to greenspace. Greenspace aesthetics and proximity are known to be positively associated with socioeconomic status, i.e., those of higher socioeconomic status live in greener neighbourhoods with greater aesthetically pleasing and in closer proximity to greenspaces (Besser & Mitsova, 2021; De Vries et al., 2020). Whereas those of lower socioeconomic status live in less green neighbourhoods with less aesthetically pleasing and live in further proximity to greenspaces (De Vries et al., 2020). Beyond physical activity facilitation, greenspace has been shown to be associated with positive physical and mental health benefits, such as increased mental wellness and decreased stress and cardiometabolic conditions (Kardan et al., 2015; Lanza-León et al., 2021). As such, greenspace may be used as a facilitator to decrease the socioeconomic health gap and promote physical activity and increase overall physical and mental health among adults aged 60 and older.

Weather variables addressed in this systematic review included temperature, precipitation, humidity and windspeed and air pressure. The weather variables that showed to impact levels of physical activity most prominently were temperature and precipitation. Overall, warmer temperatures were associated with more physical activity. However, lower temperatures as well as higher temperatures were associated with lower levels of physical activity (Giehl et al., 2012). Precipitation was negatively associated with physical activity levels. Some studies stated that a major reason why precipitation (rain/snow) is associated with low levels of physical activity is due to cloud cover (You et al., 2021) as well as the fear of slipping and/or falling (Gallagher et al., 2010, Leung et al., 2021). Other weather variables negatively associated with physical activity included humidity and windspeed. Atmospheric pressure did not show to have any impact on physical activity. However, some studies showed that atmospheric pressure might be linked to an increase in headaches or migraines specifically on days when barometric pressure decreased or increased (Maini & Schuster, 2019). Barometric pressure is known to fluctuate in association with humidity, temperature changes, and storms (Maini & Schuster, 2019). Therefore, more studies on this topic would be beneficial to determine if the barometric pressure is directly correlated with physical activity levels.

People from the United States tend to be 2 to 3 times more likely to exercise outdoors than indoors which is why weather conditions can have a major impact on physical activity levels (Wagner et al., 2019). Even though findings tended to be consistent it is important to recognize that these studies took place in various locations. Geographic location is important to consider as weather conditions can vary day to day as well as depending on geographic location. Individuals that live in locations with higher seasonal variations in temperatures and precipitation might show more variation in physical activity levels throughout the year compared to someone who lives in areas with more consistent temperatures, like sub-tropical or tropical regions. Other demographic factors that could influence one's decision to participate in physical activity include, age, gender, race, ethnicity, socioeconomic strata, and community settings (Seefeldt et al., 2002). Areas with higher crime rates, unavailable childcare, fear of personal safety, lack of access to facilities, and fear for personal safety are all examples of factors that could also influence physical activity (Seefeldt et al., 2002).

This information can be very helpful when predicting implications of climate change in the future. A very common effect of climate change is more frequent and persistent adverse weather conditions (Mirza, 2003). It is also known that certain areas worldwide might be more prone to highly adverse weather conditions, including heat waves, droughts, and extreme storms (Mirza, 2003). Future studies should consider modifying exercise in adverse or more extreme weather events (Mirza, 2003). It is also essential that policies should be put in place at the level of individual jurisdictions based on the climate projections for the local area, over and above the generic climate action at the level of a nation and the world in general.

Seasonal variation in relation to physical activity is very important when working with an older population as seasons tend to impact physical activity over a longer period. Studies found that activity levels tend to be higher in the spring and summer. Lower levels of physical activity are found in the winter. Even though weather conditions can fluctuate day to day and throughout seasons, certain weather conditions (e.g., temperature) can provide a broader understanding of how physical activity might be affected over a longer period (e.g., months). Physical activity levels might be lower in the winter due to shorter day length as daylength was found to be positively associated with levels of physical activity. Another reason could be because older adults tend to have lower thermoregulation as aging has been shown to be associated with decreased heat tolerance and thermoregulation (Kenney & Hodgson, 1987; Heaney et al., 2019). As a result, older adults might be affected by changes in temperature more so than younger age groups (Heaney et al., 2019). Winter weather as also associated with the increased fear of slipping/falling as conditions associated with winter weather often include snow as well as the presence of ice or slush (Gallagher et al., 2010). These concerns are valid as older adults have excessive risk of fall-related fractures (Traynor & MacDermid, 2008), often fragility fractures that occur due to slips/falls in the face of compromised bone strength. Fall risk is a major factor in determining physical activity with aging influenced by prior fall history, perceived risk, and actual risk, all of which are related to weather conditions.

Air quality was another factor that was shown to have a negative impact on physical activity. Therefore, older adults that live in highly polluted areas are more likely to forgo exercising outside or participating in outdoor activities due to poor air quality. Even though there is a limited number of studies that show how air quality affects physical activity of older individuals, previous literature shows that a reason many individuals might choose to forgo outdoor activities while air quality is poor due to the adverse effects that this can have on your physical health (Hu et al., 2017, Zhu et al., 2021). If air quality is poor, some individuals might exercise indoors because they believe this would limit their exposure (Hu et al., 2017). One of the significant reasons why individuals might choose to forgo or postpone participating in outdoor activities while air quality is poor could be due to pre-existing health conditions (O'Neill et al., 2012). This is because if someone has asthma, cancer, or a known cardiovascular or respiratory issue, higher amounts of exposure to particulate matter may worsen symptoms or exacerbate the illness (O'Neil et al., 2012).

Air quality is also known to be impacted by weather (Ramsey et al., 2014). Warmer and drier temperatures are found to be associated with a decrease in air quality, specifically associated with an increase in ozone concentration (Ramsey et al., 2014). Air quality is only expected to get worse and is a major contributor to global climate change (Ramsey et al., 2014). Therefore, cities and governments must work toward implementing strategies to lower air pollution (Landrigan, 2017). An example of this might include using more renewable energy sources. It would also be beneficial for urban planners to work towards developing initiatives that would influence walking and biking in highly populated cities (Landrigan, 2017). Implementing more long-term strategies to lower emissions will not only be beneficial to the overall environment but have a positive impact on the health of the population. Given the importance of environmental factors in physical activities behaviours, physical health clinicians and exercise professionals should be tailoring exercise prescriptions to accommodate the local and seasonal environmental factors, and empowering patients to have options that optimize physical activity when environmental barriers are present.

2.4.1 Future research

Weather, greenspace, daylight, seasonal change, and air quality are all examples of environmental factors that influence physical activity. However, some of the findings could be influenced by where these studies were done. Most of the studies done on greenspace were done in China, from the studies done on weather, majority were done in the USA and United Kingdom, and most of the studies done on seasonality were done in Japan. Overall, a majority of all the studies included in this systematic review were done in, the USA (n=11), United Kingdom (n=11) and China (n=10). Therefore, it would be beneficial to see more studies done in other parts of the world to determine how/if certain factors might impact individuals differently based on their location. It would also be beneficial to conduct more studies in the future that looks specifically at how humidity levels, windspeed, atmospheric pressure and air quality might affect the physical activity levels of older adults as limited research has been done on how these weather conditions affect older adults specifically. This information could provide a better understanding on how exercise levels may be affected now or in the future based on future climate projections. Overall, it is important to know which environmental factors and climate change factors are of particular concern to older adults in all locations around the world. This information is important when making policies about greenspace, making physical activity plans, adapting physical activity recommendations/infrastructure to consider the impact of climate change since older adults may experience unique weather/climate challenges due to higher fall risk, fragility, or comorbid health concerns.

2.4.2 Limitations

Although we were able to synthesize a substantial body of literature, there were some limitations that should be considered. Even though we kept our search terms broad while conducting our literature search, there is still the possibility that some information could have been missed since environmental exposures are diverse and there are no standards for defining exposures. Another limitation is that we limited our synthesis to studies that were published in the English language. A third limitation is that there are regional differences in what might be defined as the optimal temperature/environment for exercise as weather can be interpreted as relative rather absolute; further different components of weather may interact e.g., wet, and warm weather may not be much of a barriers as wet and cold weather. This complicated synthesizing data from environmental studies within and across studies.

2.5. Conclusions

This systematic review demonstrated that environmental factors have an impact on physical activity levels in adults. Based on the studies reviewed it was determined that more greenspace, warm/moderate weather, and longer hours of daylight have a positive association with physical activity levels of older adults. However, very hot temperatures, cold temperatures, high humidity, high windspeed and poor air quality are negatively associated with the physical activity levels of older adults. The seasonal change also affected physical activity, as winter was consistently shown to lower physical activity levels and spring showed higher physical activity levels, summer weather also influenced physical activity levels however not when temperatures were considered too hot. Overall, during moderate-warmer temperatures is when peak physical activity levels were observed.

It is crucial to understand which environmental factors are of particular concern to older individuals. However, it is also important to be mindful of the geographic location, socioeconomic status of these individuals and other demographic variables that might influence physical activity levels as well. This type of information is beneficial to policymakers, urban planners as well as health professionals worldwide. It is important that older adults learn how to modify their activities when faced with climate or weather barriers as well as other environmental factors now and into the future.

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Data Extraction Tables:

Greenspace

Author	**Type of study**	**Study Population**	**Country of Study Participants**	**Type of Physical Activity**	**Overall Outcome or results**
Adlaka et al., 2021	Qualitative (Interviews)	N=60 Individuals aged ≥60.	India	All physical activity	From interviews conducted, one of the benefits of urban greenspace included physical activity promotion. Greenspace was also identified as a nice place to go for walks as it provided fresh, clean air and shade.
Besser & Mitsova 2021	Quantitative (Cross-Sectional Study)	n=72,753 Individuals aged ≥65 years from the 2017 National Household Travel Survey	USA	All physical activity	A higher percentage of forest in a neighbourhood was associated with a higher level of walking (min/day): Adjusted estimate=0.028 (95% CI: 0.006, 0.050), p-value=0.01. No association was found between percentage of neighbourhood open space and walking minutes/day: Adjusted estimate: -0.008 (95% CI: -0.048,0.033), p-value=0.71.
Dadvand et al., 2016	Quantitative (Cross-Sectional Study)	N=3461 (≥65; n=851)	Spain	All physical activity	Subjective proximity to greenspace was significantly associated with a greater chance of achieving moderate-high physical activity for those aged ≥65: Adjusted odds ratio= 1.69, (95% CI: 0.91, 3.17), p<0.10.
Dalton et al., 2016	Quantitative (Cohort Study)	N=15,672 Mean age of 62	United Kingdom	All physical activity	This study used linear regression to determine the association between the exposure to neighbourhood greenspace and the change in recreational/outdoor physical activity by measuring metabolic

					equivalent cost (MET) hours/week. To determine the association between greenness exposure and difference in physical activity (from baseline to follow up) multi-variable regression models were used. Results from model 2 which adjusted for baseline physical activity, age, sex, BMI, social class and marital status showed that there was an increase in physical activity by 4.21 (MET) hours/week between quartile 1 (least green quartile) and quartile 4 (most green quartile) (95% CI: 1.60, 6.81), p=0.002 in terms of overall physical activity. For change in recreational physical activity there was an increase in 4.03 MET hours/week (95% CI: 2.36, 5.71), p<0.001. For outdoor physical activity levels showed a change in 1.28 hours/week (95% CI: 0.38, 2.19), p=0.0006.
Finlay et al., 2015	Qualitative (Interviews)	N=161 All individuals aged 65-86	Canada	All physical activity	Findings from interviews show that greenspace is a motivating factor towards leaving the house as well as engaging in exercise and overall physical activity, factors also associated with greenspace that influenced physical activity included trees, flowers, shade and pristine natural features.
Gong et al.,2014	Quantitative (Cross-Sectional Study)	N= 1,010 All men aged 66+	United Kingdom	All physical activity	Regular physical activity was found to be positively associated with a higher percentage of neighbourhood greenspace in both model 1 OR=1.25 (95% CI: 1.09, 1.44), p=0.002 as well as model 2 OR=1.21 (95% CI: 1.05, 1.41), p=0.008. Model 1 adjusted for area type and area deprivation, model 2 adjusted for individual factors.
Huang et al., 2018	Quantitative (Cross-Sectional Study)	N=2214 individuals aged 65+	China	All physical activity	Four models were used in this study to help examine how ecological and individual factors are associated with regular physical activity. Model 1

					showed the influence of urbanization on regular physical activity. Achieving regular physical activity was associated with increasing urbanization OR=2.59 (95% CI: 1.69, 3.96). Model 2 showed the association of urbanization level, built environment and regular physical activity. Results showed that increased urbanization was associated with an increased amount of physical activity, OR=2.80 (95% CI: 1.72, 4.57), and parks, greenery and squares were also associated with regular physical activity OR=1.41 (95% CI: 1.02, 1.95). Model 3 showed the association of ecological-level factors on regular PA. Only increased urbanization was associated with increased physical activity amount, OR=2.14 (95% CI: 1.22, 3.73). Model 4 showed association of all individual and ecological variables. Again, the only ecological variable showing an association was increased urbanization, OR=1.90 (95% CI: 1.05, 3.42).
Keskinen 2018	Quantitative (Cross-Sectional Study)	N=848 community-dwelling older people aged 75-90.	Finland	All physical activity	This study was done to determine the association between the objective and perceived environment and physical activity. Two models were used however only model 2 adjusted for age, sex, number of chronic conditions, years of education, time at current address, type of residential area. Results show (for those without walking difficulties) that the objectively assessed features of the natural environment in the 500m neighbourhood perceived as a facilitator to outdoor mobility included presence of water, OR=2.57 (95% CI: 1.66-3.98) ($p<0.05$), higher number of land types, OR=3.34 (95% CI:

					1.99-5.60) (p<0.05), higher diversity of land use OR=3.35 (95% CI: 2.01-5.60) (p<0.05), and habitat diversity within a large natural area OR=1.82 (95% CI: 1.11-2.96) (p<0.05). The objectively assessed features of the natural environmental in the 1000m neighbourhood perceived as a facilitator to outdoor mobility include high number of land types, OR=3.13 (95% CI: 1.76-5.55) (p<0.05), and higher diversity of land use OR=2.53 (95% CI: 1.53-4.20) (p<0.05).
Klompmaker et al., 2018	Quantitative (Cross-Sectional Study)	N=354,827 (Total) n=151,726 (aged ≥65)	Netherlands	All physical activity	1)*Normalized Difference Vegetation Index (NDVI) (Elderly group):* A positive association was found between surrounding greenness and being physically active outdoors for at least 150min/week. Statistical significance was shown for the two highest NDVI quintiles: NDVI Quintile (≤0.61): [OR=1.06 (95% CI: 1.00, 1.11)].NDVI Quintile (>0.61): [OR=1.11(95% CI: 1.05, 1.17)]. *2)Surrounding Greenness based on Dutch land-use database (TOP10NL):* For the elderly group no association or statistical significance was found for being physically active outdoors for at least 150min/week.
Kou et al., 2021	Qualitative (Interviews)	N=20 Individuals aged ≥60	United Kingdom	All physical activity	Themes considered important when determining what influences older individuals use of parks, and percentage of participants mentioning theme. 1)Variation of natural elements (almost all >75%) 2)Park accessibility (almost all >75%) 3) Park amenities (51-75%) 4) Sports facilities (51-75%) 5) Maintenance, and aesthetics (51-75%) 6)walking and cycling facilities in parks (25-50%)

					7)Park safety (25-50%) 8)Slopes (25-50%)
Lin et al., 2020	Quantitative (Cohort Study)	N=3944 Participants aged 65-98	China	All physical activity	This study was done to determine how built environment characteristics influenced physical activity. Three models were included in analysis however only Model 3 adjusted for all covariates. The built environment was organized by 3 different classes. Class 1 was considered a "commercial area," Class 2 was "residential" and Class 3 was considered to have more greenspace and sky view. Overall, Class 3 was shown to have a much slower decline in walking as physical activity in comparison with class 2: $\beta = 1.19$ (95% CI: 0.42, 1.95).
Lu 2018	Quantitative (Cross-Sectional Study)	**Analysis 1 (2011):** *n*=24,773 (Total) n=3624;14.7% (Individuals aged ≥65) **Analysis 2 (1994):** *n*=1994 (Total) n=392;20% (Individuals aged ≥65).	China	Walking	In this study multilevel regressions were done. For analysis 1, logistic regression was done in order to determine the association between street greenness and the likelihood of walking. For analysis 2, linear regression was used to determine the relationship between street greenness and walking time. Analysis 1 showed that for those ≥65, they had higher odds of walking compared to those 5-17, in both the 400m buffer OR=1.763 (95% CI: 1.590, 1.950), $p<0.001$, and the 800m buffer OR=1.760 (95% CI: 1.593, 1.950), $p<0.001$. Analysis 2 did not show significance in the relationship between greenness, and built environment and individual factors, and walking time (in minutes) for the 400m buffer OR=0.043 (95% CI: −0.101, 0.189), p=0.548 and 800m buffer OR=0.057 (95% CI: (−0.086, 0.201), p=0.430.
Lu et. al., 2018	Quantitative (Cross-Sectional Study)	N=90,445 (Total participants)	China	Walking	There were two layers to this study. Layer 1 analyzed if urban greenspace is associated

		n=10,643 (Individuals aged ≥65)			with the decision to walk. Layer 2 (sensitivity analysis) looked at if urban greenspace is associated with walking time. Results from analysis 1 showed that age is positively associated with odds of walking as those aged ≤65 had higher odds of walking in comparison to those aged 2-17 (reference), OR=0.57 (95% CI: 0.51, 0.62), p<0.001. In the second layer age was shown to be positively associated with walking time β=0.03 (95% CI: 0.01, 0.05), p=0.021.
Machón et al., 2020	Quantitative (Cross-Sectional Study)	N=634 Individuals aged >65	Spain	All physical activity	Physical activity levels were assessed by asking participants if they engaged in any physical activity over the last two weeks. Results showed that there was statistical significance between older age and lower physical activity over the two weeks (OR=0.94, 95% CI= 0.91–0.97); p=0.0003. Proximity to park-green spaces (within walking distance) was related to increased physical activity over the last two weeks, OR= 1.64, 95% CI: 1.03–2.61; p=0.039.
Miralles-Guasch et al., 2019	Quantitative (Longitudinal Study)	N=63 All participants aged 65+	Spain	All physical activity	Those aged 65-75 were overall more active (3.9 median min) compared to those over 75 years old (2.0 median min), p=0.003. Individuals that lived 301-600m from greenspace were the most active (median time active=7.5 min) p=0.020. Mixed-effects linear regression was done that looked at the effect of individual characteristics on total time in urban greenspace, sedentary time in urban greenspace and active time in urban greenspace. Increasing age was associated with increasing sedentary time in urban greenspace B=0.012, standard error=0.006, p=0.049. Age was

					negatively associated with active time in urban greenspace, B=−0.017, standard error=0.006, p=0.007
Vich et al., 2021	Quantitative (Cohort Study)	N=181 (Adults aged 65+)	Spain	All physical activity	Model 1 showed the association between daily physical activity time and explanatory factors related to individuals' daily behaviour. Results showed that greenspace visiting was positively associated with daily physical activity time (B= 27.654); p=0.000. A negative relationship was found for rain in relation with daily physical activity levels (B= -16.338); p=0.002. A negative relationship was found between temperature and daily physical activity levels (B= -15.277); p=0.033 and a negative relationship was also found for age in association with daily physical activity time (B= -3.114); p=0.001.
Wang et al., 2021	Quantitative (Cross-Sectional)	N=4784 respondents aged ≥60	China	Cycling	Results showed that when the percentage of green land use that is the most effective in providing a cycling friendly environment peaked at 12%. When the percentage of green space land use is beyond 25%, older adults were shown to cycle less.
Yuen et al., 2019	Quantitative (Cross-Sectional Study)	N=554 (Total participants) n=156 (Participants aged ≥65)	China	All physical activity	Overall metabolic equivalent of task (MET)-Minutes per week were positively associated with percentage of greenspace (Pearson r = 0.092; p < 0.05). Results for the usage of within nearby district facilities by active participants of different age groups, showed that individuals aged 45-64 had the highest metabolic equivalent of task (MET)-Minutes per week (mean±SD = 5118±1631), followed by those aged ≥65 (mean±SD=4728±1245). Those aged ≤65 used the major open space (parks and promenade) the most daily.

Zandieh et al., 2019	Quantitative (Cohort Study)	N=173 ≥65 years of age	United Kingdom	Walking	This study looked at different characteristics of greenspace and how each might influence outdoor walking levels, these included the closest, the most attractive and largest neighbourhood greenspace. Results showed that only size (ha) of neighbourhood greenspace was found to have a significant relationship on outdoor walking, as size was positively related to outdoor walking levels for all three characteristics of neighbourhood green spaces. 1) Closest: (B= 0.09, SE=0.04) ($p<0.05$). 2) Most attractive: (B= 0.11, SE=0.05) ($p<0.05$). 3) Largest: (B= 0.17, SE=0.07) ($p\geq0.01$).
Zhai et al., 2020	Quantitative (Longitudinal Study)	N=234 All participants aged 60+	China	All physical activity	Results from the multiple regression analyses showed that step count was negatively associated with age ($\beta = -0.164$, $p = 0.011$). Step count in relation to natural areas are positively associated ($\beta = 0.158$, $p = 0.015$), and step count was positively associated in relation to the presence of outdoor fitness equipment in the urban park ($\beta = 0.149$, $p = 0.021$).
Zhai et al., 2021	Quantitative (Cross-Sectional Study)	N=286 Individuals aged 60+	China	All physical activity	Results show that greenspace facilitated physical activity as seniors visit parks frequently and 62.43% of physical activity intensity during park visits was spent engaging in moderate-vigorous physical activity. Park characteristics that further promoted both light intensity the most included park pathways wider than 3.5m, OR=2.444 (95% CI: 2.239, 2.668) and park pathways narrower than 3.5m, OR=1.817 (95% CI: 1.648, 2.003. These characteristics also influenced moderate-vigorous intensity physical activity levels the most, pathways wider than 3.5m, OR=2.398 (95% CI: 2.179)

					and pathways narrower than 3.5m, OR=1.915 (95% CI: 1.724, 2.128.
Zhou et al., 2020	Quantitative (Cross-Sectional Study)	N=972 Individuals aged 60+	China	All physical activity	A structural equation model (SEM) was used in this study to analyze which pathways link neighbourhood greenness and physical activity. Results show that the mediating pathways via physical activity that showed significance was between streetscape greenery and physical exercise (standardized estimate=0.81) (positive relationship).

Table 14. Results showing impacts of greenspace on physical activity (95 % CI= 95% Confidence Interval, OR= Odds Ratio), B= unstandardized coefficient, SE= standard error, SD=standard deviation.

Weather Conditions

Author	**Type of Study**	**Study Population**	**Location of Study Participants**	**Environmental Factor(s)**	**Type of Physical Activity**	**Overall Outcome or results**
Aoyagi & Shepard 2010	Quantitative (Cross-Sectional Study)	N=5000 Male and female participants ≥65 years of age	Japan	-Temperature -Precipitation	All physical activity	This study looked at factors affecting habitual physical activity of older individuals. Results from the Nakanoko study done in Japan showed that step count decreased from approx. 6600 steps per day to approx. 4000 steps per with an increase in precipitation. Daily step count peaked at 17°C (mean outdoor temperature).
Aspvik et al., 2018	Quantitative (Cohort Study)	N= 1219 Adults (70–77 years old)	Norway	-Temperature -Precipitation	All physical activity	This study determined that physical activity levels were higher in warmer months (April-October) (555.6 counts per min) compared to colder months (November-March) (597.3. counts per min)

						(p<0.01). Results from fixed-effects regression model showed that weather (precipitation, temperature, and wind) explained a variance of 1.2% (R^2 within) in overall physical activity. Variance in physical activity was much lower in Colder months (November-March) (R^2 within = 0.4% compared to warmer months (April-October) (R^2 within=2.8%). Temperature was positively associated with physical activity in counts per minute (CPM) in both cold moths CPM=10.6 (0.9), p<0.01 and warm months CPM=33.3 (2.1), p<0.01 . Precipitation only influenced physical activity in colder months CPM=38.2 (12.7), p<0.01. In association with wind (m/s) physical activity levels decreased during the colder months CPM= -8.4 (5.2), p<0.01 but CPM still increased during the warmer months CPM=15.0(2.2), p<0.01.
Bjornsdottir et al., 2012	Qualitative (Interviews)	N=10 Women living in retirement communitie	Iceland	-Temperature -Wind	All physical activity	From the interviews conducted it could be determined that

		s aged 72-97.				facilitators to physical activity in retirement communities when it comes to the physical environment included non-slippery sidewalks, good outdoor areas, proximity to shops, familiar surroundings, and indoor exercise facility. Barriers to activity in terms of the physical environment included cold weather, wind and icy walkways, hills and stairs, poor outdoor areas, shops far away, unfamiliar surroundings and no indoor exercise facility.
Bösch et al., 2022	Qualitative (Interviews)	N=34 Adults aged 65+	United Kingdom n=8; Germany n=9; Switzerland; n=17)	-Temperature -Precipitation	All physical activity	This study identified barriers to implementation intentions for physical activity. Weather conditions were stated as an important factor when planning physical activity. Summer heat and rainfall were barriers to physical activity.
Clarke et al., 2015	Quantitative (Cohort Study)	N=502 (n=182 individuals aged ≥65)	USA	-Temperature -Precipitation	All physical activity	This study focused on the impact that weather has on the daily lives of adults. Heat altered older adult's daily activities (28.19%) more so than for younger individuals (19.97%). Precipitation was

						shown to alter younger individuals (58.47%) daily activities more so than older adults (48.15%). Icy conditions were shown to increase the odds of older adults to choose not to participate in outdoor physical activity; OR=1.41 (95% CI: 0.40, 5.03).
Delclos-Alio et al., 2019	Quantitative (Cohort Study)	N=227 Seniors (≥65 yrs. old).	Spain	-Temperature -Precipitation	Walking	Results show that lower temperatures (<10°C) negatively impact daily walking minutes in areas of low walkability; (b = −0.15, *p*-value = 0.01). Precipitation was negatively associated with daily walking minutes for those in areas of high walkability (b = −0.12, p < 0.01).
Dunn et al., 2012	Quantitative (Cohort Study)	N=793 Retired Americans between the ages of 65-90	USA	-Temperature	Walking	Fixed-effects results from regression showed that lower temperatures increase was significantly associated with women being more likely to walk 2.5 miles/week; (Coeff=1.056; 95% CI: 0.933-1.122), p<0.1. Random effects model showed for men that higher temperatures were associated with decreased probability of walking 2.5

						miles/week for men (Coeff=0.963; 95% CI: 0.936-0.992), p<0.05. Precipitation was not shown to significantly affect walking for ither men or women.
Gallagher et al., 2010	Qualitative (Photo-voice methodology)	N=21 Individuals aged 61-85 years old.	USA	-Temperature -Precipitation	Walking	A theme identified as a factor determining walking in older, urban, African American adults included weather. Only 4 participants (19%) of sample mentioned weather to ither encourage or discourage walking. Three participants (14%) mentioned fresh air encouraged walking, 3 participants (14%) mentioned cold, or rainy weather discouraged walking and 2 participants (9.5%) mentioned that the fear of falling on ice discouraged walking.
Heaney et al., 2019	Quantitative (Longitudinal Study)	N=43,395,834 participants in total n=646,934 Individuals aged 65+ Citi Bike® bikeshare data was used.	USA	-Temperature	Cycling	This study focused on how daily temperature might affect bike usage from 2013-2017. Results show that in association with age, ridership of older individuals started to decline at lower temperatures compared to younger

						individuals: threshold maximum temperature for those aged 18-24 was 28.1°C (95% CI: 27.3, 28.9), whereas the threshold maximum temperature for those aged 65+ was 25.8°C (95% CI: 25.2, 26.3).
Ho et al., 2022	Quantitative (Timeseries Study)	Participants were from 5 Chinese Cities. **Beijing**: N=11.1 million (65+; 1.2% of study population) **Shanghai**: N=9.6 million (65+; 1.7% of study population) **Chongqing**: N=2.8 million (65+; 1.3% of study population) **Shenzhen**: N=4.9 million (65+; 0.5% of study population) **Hong Kong:** N=0.4 million (65+; 0.7% of study population)	China	-Temperature	All physical activity (particularly step count)	Results showed that older individuals aged 65+ tended to have lower daily step counts in all cities compared to those aged 18-64 (particularly noticeable in Hong Kong). Step count decreased in association with warmer weather but was significantly noticeable just before October, especially in Hong Kong, Shenzhen, and Chongqing for both age categories (18-64 and 65+). Step count in relation to colder temperatures, was only noticeable in Shenzhen where elderly step count decreased by an additional 130 steps (approx.).
Jones et al., 2017	Quantitative (Cohort Study)	N=50 Community -dwelling older adults aged 71-89.	Canada	-Temperature -Humidity	All physical activity	Physical activity counts (avg hourly cts/min) increased as temperature increased; r= 0.20 ($p<0.01$), $r^2 = 0.05$. Physical activity counts (avg

						hourly cts/min) decreased when humidity % increased; r= -0.15 ($p<0.01$), r^2=0.02, as snow on the ground (cm) increased; r= -0.38 ($p<0.01$), r^2 = 0.2.
Marquez et al., 2016	Qualitative (Exploratory focus group study)	N=20 Average age of participants above 60	USA	-Temperature -Precipitation (snow)	Walking	In this study weather was found to be a neighborhood/environmental factor that affected walking behaviour in older Latino adults. Participants stated that colder temperatures, very hot temperatures, ice and snow all negatively impacted walking.
Samra et al., 2019	Qualitative (Interviews)	N=46 Participants were male (n=12) and female (n=34) aged 65+.	Australia	-Temperature -Humidity	All physical activity	Barriers to physical activity stated by participants included physical health problems (most discussed barrier), followed by extreme weather (e.g., humidity or hot temperatures). Less common barriers included lack of motivation, steep hills and concern for safety.
Timmermans et al., 2016	Quantitative (Cohort Study)	N=2,439 (Total study sample aged 65-85)	Germany, Netherlands, Spain, Sweden and the United Kingdom	-Temperature -Precipitation -Atmospheric pressure -Relative humidity -Wind speed	Physical activity (walking outside, cycling, gardening, household work, one or two sports)	Results showed that for participants without osteoarthritis (OA) temperature was positively associated with total outdoor physical activity (B=1.98;

						p<0.001). Relative humidity was negatively associated with outdoor walking (B=-0.46; p=0.01).

Table 15. Results from studies showing impacts of climate/weather on physical activity (95 % CI= 95% Confidence Interval, OR= Odds Ratio)

<u>Daylight</u>

McMurdo et al., 2012	Quantitative (Cross-Sectional)	N=547 All are participants aged 65+	United Kingdom	-Day light	All physical activity	Average hours of sunlight was significantly associated with an increase in daily physical activity counts. Beta=317.6 SE=132.7 t= -2.52 p<0.0001
Schepps et al., 2018	Quantitative (Cohort Study)	N=16,741 Mean age age=72.0 (All participants are women)	USA	-Day length	All physical activity	When day length was ≥14 hours steps per day was at its highest (5691.3; 95% CI: 5623.0, 5759.7), as well as moderate to vigorous physical activity minutes (37.3; 95% CI: 36.5, 38.1) and light intensity physical activity minutes per day (360.2; 95% CI: 357.9, 362.5). Sedentary minutes per day was at its lowest when day length was ≥14 hours (495.7; 95% CI: 493.1, 498.3).

Table 16. Results from studies showing impacts of daylight on physical activity (95 % CI= 95% Confidence Interval)

Season

Author	Type of Study	Study Population	Location of Study Participants	Type of Physical Activity	Overall Outcome or results
Amagasa et al., 2020	Quantitative (Longitudinal Study)	N=355 Japanese adults aged 65-84 living in a rural area.	Japan	All physical activity	Activity levels of older individuals were measured by them wearing an accelerometer on their wrist. Light-intensity physical activity decreased between the non-snowfall season, (377.1 min/day) and snowfall season, (308.3 min/day). Moderate to vigorous physical activity levels also decreased between the non-snowfall season, (39.8 min/day) and snowfall season, (30.7 min/day). Overall physical activity levels were lower in snowfall season compared to the non-snowfall season.
Barkley et al., 2017	Quantitative (Quasi-Experimental Study)	N=16; Adults aged ≥65	USA	All physical activity	Results showed that physical activity did not differ significantly ($p>0.05$) between baseline and follow up within the sample living in a non-residential area. At baseline (June and July) minutes spent in light physical activity were approximately 252.8 min per day, and in the winter (December and January) it was 242 min per day. In terms of moderate-vigorous physical activity minutes spent in light physical activity at baseline were approximately 15.7 min per day and in the winter it was 19.8 min per day.
Kimura et al., 2015	Quantitative (Longitudinal Study)	N=39 healthy community-dwelling adults aged 65-80.	Japan	All physical activity	Results show that steps per day were higher in the summer (8084±3237) compared to the winter (6098±2625) ($p<0.0001$). Summer was considered mid-July to mid-August, and winter was considered mid-January to beginning of February.
McCormack et al., 2010	Quantitative (Longitudinal Study)	N=4354 (Total). n=912 (Participants aged 60+)	Canada	All physical activity	For those aged 60+ recreational walking prevalence was highest in the spring (79.8%) (March

					and April) (OR=1.65, 95% CI: 1.06, 2.56) and showed statistical significance (p<0.05). Prevalence was lowest in the winter (January and February) (70.8%) (OR=1). For those aged 60+ prevalence of transport-related walking, moderate-intensity physical activity and vigorous-intensity physical activity did not show significance.
Nakashima et al., 2019	Quantitative (Cross-Sectional Study)	N=22 Age, 75.1 ± 7.3 years	Japan	All physical activity	The number of steps taken per day were lowest in the winter (4,917.6 ± 3,172.8) and highest in the spring (6,242.0 ± 3,228.6). This showed a significant difference (p<0.01). Time spent per day participating in low-intensity physical activity was highest in the spring (50.4 ± 20.1 min) (p<0.01), however summer showed very similar results (50.3 ± 22.8 min) (p<0.01). Lowest levels occurred in the winter (38.4 ± 20.2 min). When measuring the time (min per day) participating in moderate-high-intensity physical activity no significance was found.
Ogawa et al.,2018	Quantitative (Longitudinal Study)	N=35 Participants aged 69.3 ± 5.3 year	Japan	All physical activity	Participants wore a device called the Lifecorder during a snowfall season (February) and a non-snowfall season (September). This study aimed to determine how climatic conditions affect daily activity levels. In terms of weather conditions, results show form Spearman's rank correlation coefficient (rs) that average temperature was significantly positively associated with average step count (rs=0.37) (p<0.001) during the non-snowfall season. Average precipitation was significantly negatively associated with average step count (rs=-0.47) (p<0.001) during the non-snowfall season. Average

					snowfall was significantly positively associated with average step count (snowfall season) (rs=0.46) (p<0.05).
Wagner et al., 2019	Quantitative (Cross-Sectional Study)	N=502 Male: Female 231: 271 n=180 (Individuals aged ≥65)	USA	All physical activity	Results showed that adults aged ≥65 years showed greater odds (OR = 3.00, 95% CI: 1.24,7.29; p = 0.02) of choosing to participate in indoor exercise as opposed to outdoor exercise during adverse weather condition during the summer.

Table 17. Results from studies showing seasonal impacts on physical activity (CI= Confidence Interval, OR= Odds Ratio)

Air Pollution

Author	**Type of Study**	**Study Population**	**Location of Study Participants**	**Type of Physical Activity**	**Overall Outcome or results**
Roberts et al., 2014	Quantitative (Cross-Sectional Study)	N = 329,628 Male and female subjects from 2249 U.S. counties. Aged 18+. -Included adults aged ≥65	USA	All physical activity	The relationship between air pollution and age showed that the odds of physical inactivity increased with age: OR=2.0 (95% CI: 1.80, 2.21).
Yu et al., 2017	Quantitative (Longitudinal Study)	Outcome-specific N*s* = 848-890 -Average age of participants was 67 years old	China	All physical activity	Results showed that PM2.5 concentration was negatively associated with total hours of walking in the last week for both total hours of walking (coefficient= - 4.69; 95% CI: -8.08, -1.30), leisure-time PASE score (coefficient= -71.16; 95% CI: -113.41, -28.91), and total PASE score (OR.= -110.67; 95% CI: -162.08, -59.25).

Table 18. Results showing impacts of air pollution on physical activity (95 % CI= 95% Confidence Interval)

Studies Including Multiple Environmental Factors

Author	**Type of Study**	**Study Population**	**Location of Study Participants**	**Environmental Factors**	**Type of Physical Activity**	**Overall Outcome or results**
Arnardottir et al., 2017	Quantitative (Longitudinal Study)	N=138 Participants	Iceland	-Season -Day-length	All physical activity	Total physical activity (×1000 counts ×

		are aged 73-91				day^{-1}) was higher in the summer; mean=111 (SD=68) compared to the winter mean=93 (SD=55). Higher temperature was associated with higher total physical activity: β=0.17 (95% CI: 0.11;0.22), p<0.05. Longer daylight was associated with higher total physical activity β=0.14 (95% CI: 0.09;0.19), p<0.05
Cepeda et al., 2018	Quantitative (Cross-Sectional Study)	N=1116 Young-elderly (65–74 years, n = 449); Old-elderly ≥75, n=323)	Netherlands	-Season -Temperature -Precipitation -Humidity -Sunlight -Windspeed	. All physical activity	When looking at seasonal pattern of activity among age groups, young-elderly adults (65-74), levels of light physical activity (min/day) as well as moderate-vigorous physical activity (min/day) were highest in the summer (12.8min per day) compared to winter (8.6 min/day). In the old-elderly participants (≥75) there was no significant association between physical activity and season. Results also showed that for young elderly individuals (65-74) precipitation was negatively associated with levels of light physical activity; coefficient -1.7 (95% CI: -3.2. -0.2) as well as relative humidity; coefficient= -2.5 (95% CI: -4.1, -0.8). In terms of moderate to vigorous physical activity, sunlight was positively associated with physical activity; coefficient= 1.3 (95% CI: 0.0, 0.25). Precipitation and relative humidity were also negatively associated with moderate to vigorous physical activity. For old-elderly participants (≥75), temperatures of 6.7-10.3°C decreased

						levels of light physical activity levels; coefficient = -4.5 (95% CI: -8.0, -1.0). Windspeed was also negatively associated with light physical activity levels; coefficient = -3.3 (95% CI: -5.3, -1.4). Sunlight was positively associated with levels of light physical activity levels; coefficient=4.2 (95% CI: 2.2, 6.3) whereas precipitation; coefficient =−3.4 (95% CI: −5.1, −1.6) and relative humidity coefficient= −2.4 (95% CI: −4.5, −0.2) had a negative association. For levels of moderate to vigorous physical activity, temperatures of 6.7-10.3°C windspeed and precipitation showed a negative association and sunlight showed a positive association.
Giehl et al., 2012	Quantitative (Longitudinal Study)	N=1656 Individuals aged 60+	Brazil	-Greenspace -Temperature -Precipitation	All physical activity	Weather (cold, rain, heat) was shown to limit the practice of physical activity in both the crude analysis, Prevalence ratio (PR)=1.23 (95% CI: 1.01, 1.51) (p=0.04), and adjusted analysis, Prevalence ratio (PR)=1.26 (95% CI: 1.05, 1.52) (p=0.02). Existence of greenspace did not show to limit the practice of physical activity in the crude analysis PR=1.03 (05% CI: 0.85;1.26) (p=0.74).
Leung et al., 2021	Qualitative (Interviews)	N=38 Individuals aged 60+	China	-Natural environment (greenspace, cleanliness etc.) -Precipitation -Temperature	Walking	Weather was found to be both a facilitator and barrier to walking. Rainy weather is a barrier and increases fear of slipping, warmer/sunny weather is a facilitator to walking but not on days that are too hot.

						Individuals also mentioned that the natural environment (e.g., fresh air, flowers, plants, and greenery), cleanliness and aesthetics made walking more enjoyable.
Normansell et al., 2014	Qualitative (Interviews)	N=43 n=23 (individuals aged 60-75)	United Kingdom	-Temperature -Season -Precipitation	Walking	The environment was identified as a theme that could increase walking. A sub-theme of the environment included weather/season/climate. A participant stated that they enjoyed fresh air and exercise. Another participant stated that during the winter they are less active due to the cold weather or rain. It was also mentioned that in the spring, summer and autumn it's nicer to go for a walk as opposed to the winter.
Price et al., 2012	Quantitative (Cross-Sectional Study)	N=1053 Individuals aged 60+	USA	-Season -Temperature	Physical activity on trails	Out of the total number of older adults observed using a South Carolina Rail-Trail, the number of older adults using the trail was highest was highest in the spring (40.1%) and lowest in the summer (10.8%). At moderate temperature is when most older adults were using the trail (56.2%) as well as when weather was partly sunny (76.8%) and time period was in the morning (29.3%).
Prins & Van Lenthe., 2015	Quantitative (Cohort Study)	N=43 Individuals aged older than 65 made up 62.5% of sample.	Netherlands	-Temperature -Precipitation -Windspeed -Sunlight	-Walking -Cycling	Results showed that walking time was positively associated with temperature; Unstandardized β =0.10 (95% CI: 0.01; 0.20) ; Standardized β= 0.06 (95% CI: 0.00; 0.12) and wind speed; Unstandardized β = 0.14 (95% CI: 0.01; 0.27) ; Standardized β= 0.05 (95% CI: 0.00; 0.09). However walking time was

						negatively associated with rain; Unstandardized β= −2.09 (−3.21;−0.97) ; Standardized β= −0.08 (−0.12;−0.04). Cycling was shown to be positively associated with temperature; unstandardized β= 0.07 (0.02; 0.11) ; Standardized β= 0.09 (0.03; 0.15). Cycling was shown to increase with increasing sunshine for those ≥65; (b = 0.01; P = 0.956).
Sanders et al., 2018	Qualitative (Formative Study)	N=34 Individuals aged 65-90	United Kingdom	-Season -Temperature	All physical activity	Season/weather was shown to be correlated with physical activity participation among older adults. Overall, there were 8 individual mentions (multiple mentions not included) from the older individuals that stated weather could negatively impact physical activity (n=4) stated that cold and wet conditions were barriers. The other participants (n=4) stated weather doesn't affect exercise. Time/day was the factor that had the most individual mentions per person (n=28). Overall, 13 showed that time of day didn't really impact physical activity in any way, whereas 15 mentioned that time of day did impact physical activity.
Schmidt et al., 2016	Qualitative (Description Study)	N=10 participants aged 69-94	Canada	-Temperature -Season -Wind	All physical activity	Fear of falling was the most common perceived environmental barrier to participating in physical activity. This fear is the most common during the winter. Adverse weather conditions including cold weather, along with ice, slush or strong wind was also mentioned as barriers.

Van Cauwenberg et al., 2012	Qualitative (Interviews)	N=57 (Total study sample aged ≥65)	Belgium	-Natural environment including greenspace -Precipitation -Season	Walking	Eight categories of surrounding environment were showed to affect walking for transportation. These included 1) Access to facilities 2) Walking facilities 3) Traffic safety 4) Familiarity, 5) Safety from crime 6) Social contacts, 7) Aesthetics and 8) Weather. -In terms of aesthetics, natural elements including parks, fields, woods, rivers, and ponds were associated as a facilitator to walking. These factors were more appreciated in the summer, spring and fall as opposed to the winter. Weather and greenery were stated to facilitate walking during the spring and summer. Winter weather was stated a barrier to walking due to early darkness and fear of falling due to ice or snow.
You et al., 2021	Qualitative (Interviews)	N=258 Individuals aged 61+	Australia	-Temperature -Precipitation -Cloudiness -Natural environment	All physical activity	Results showed that bad weather was listed as a key barrier to physical activity (e.g., hot or cold temperatures, rain, cloudy). Other environment related barriers included lack of an exercise facility nearby and poor natural environment.

Yu et al., 2021	Quantitative (Longitudinal Study)	N=258 Individuals aged 61+ living in old residential communities.	China	-Air quality -Greenspace	All physical activity	*Greenery and poor air quality impacts:* Results showed that leisure activities are positively associated with greenery (B=0.248), activities of daily living were negatively associated with greenery (B= -0.298) and nature-exposure activities were negatively associated with poor air quality (B=-0.216) but positively associated greenery (B=0.168).
Hoppmann et al., 2017	Quantitative (Cohort Study)	N=126 community-dwelling older adults from Metro Vancouver aged 65+.	Canada	-Temperature -Precipitation -Day light	All physical activity	Daily precipitation negatively impacted average daily activity counts/min, (-3.12), $p<0.01$ as well as average daily step count (−0.11, $p < .01$). Daylight hours and daily temperature did not show statistical significance ($p>0.05$) in terms of affecting physical activity.
Klenk et al., 2012	Quantitative (Cohort Study)	N=1324 individuals aged ≥65	Germany	-Temperature - Radiation -Daylight -Precipitation -Wind speed -Humidity	Walking	Strong associations were found between weather conditions and physical activity in older people. Average daily walking duration increased with an increase in radiation (16.1 min for men and 19.2min for women). Temperature was also positively associated with walking duration as an increase in temperature by approximately 10°C increased walking duration by approximately 7min for both men and women. Daylight also increased walking duration as days with 16 hours of sunlight compared to days with 9hours of sunlight increased walking duration by 12.6min for men and 13.3 min for women but showed no significant effect once adjusting for other

						weather variables. Precipitation, wind speed and humidity were negatively associated with walking duration for men and women.
Klimek et al., 2022	Quantitative (Cohort Study)	N=1,329 Aged ≥ 65 Individuals are from the ActiFE (Activity and Function in Older People in Ulm) study	Germany	-Temperature -Solar radiation -Daylight -Humidity -Windspeed -Precipitation	Walking	Predictions of walking duration was observed for both men and women. Temperature was positively associated with daily walking duration as walking duration increased by 6.1min (95% CI: 5.2; 7.0) for women and 6.1min (95% CI: 5.2; 6.9) for men. For solar radiation, walking duration increased the most between radiation levels of >2770-<5190kWh/m^2 to >5190 kWh/m for both men and women. For men the walking duration increased by 8.3 min (95% CI: 7.3; 9.2) and for women walking duration increased by 8.4 min (95% CI: 7.6; 9.3). Sunshine was also positively associated with walking duration as the highest increase as more sunshine duration by 7.6 min (95% CI: 6.7; 8.5) for women and 6.2min (95% CI: 5.2; 7.1) for men. Humidity was negatively associated with walking duration for both men and women. From the third highest humidity value (> 87- ≤ 94%) to the highest (> 94%) humidity value men's walking duration

						decreased by 5.1 min (95% CI: − 5.9; − 4.2), for women walking duration decreased by 3.4 min (95% CI −4.3, − 2.4). Windspeed was also negatively associated with physical activity, higher windspeed decreased walking duration by 5.2 min (95% CI: −6.1; − 4.3) for women and 4.1 min (95% CI: − 5.0; − 3.3) for men. Increased precipitation (rain >1.6mm/h) decreased walking duration by 4.6 min (95% CI: − 5.1; − 4.1) for women and 3.7 min (95% CI: − 4.2; − 3.2) for men.
Witham et al., 2014	Quantitative (Cohort Study)	N=547 Male and female adult participants aged 65 and older.	United Kingdom	-Temperature -Daylight	All physical activity	Daily activity counts increased were positively associated with minimum daily temperature; (1319; 95% CI: 626, 2012), $p<0.0$. Daily activity counts were also positively associated with day-length; (1931; 95% CI: 264, 3598), $p<0.05$.
Wu et al., 2017	Quantitative (Cross-Sectional Study)	N=4051 n=1,267 Individuals aged 65+	United Kingdom	-Temperature -Precipitation -Day length	All physical activity	Higher precipitation levels were associated with lower physical activity (decrease in daily counts per minute); -26.0 (95% CI: -29.9, -22.0), $p<0.001$ and maximum temperatures; -29.1 (95% CI: -35.3, -22.9), $p<0.001$. Shorter day length also decreased counts per minute; -25.9 (95% CI: -34.4, -17.4), $p<0.001$.

Table 19. Results from studies showing impacts of multiple environmental factors on physical activity (95 % CI= 95% Confidence Interval, OR= Odds Ratio, SD=Standard Deviation)

Quality Appraisal Tables

Quantitative Non-Randomized Studies

Study	Question						
	S1	S2	3.1	3.2	3.3	3.4	3.5
Amagasa et al., 2020	yes	yes	yes	yes	yes	yes	yes
Aoyagi & Shepard 2010	yes	yes	yes	yes	yes	yes	yes
Arnardottir et al., 2017	yes	yes	yes	yes	yes	yes	yes
Aspvik et al., 2018	yes	yes	yes	yes	yes	yes	yes
Barkley et al., 2017	yes	yes	yes	yes	yes	yes	yes
Besser & Mitsova 2021	yes	yes	yes	yes	yes	yes	yes
Cepeda et al., 2018	yes	yes	yes	yes	yes	yes	yes
Clarke et al., 2015	yes	yes	yes	yes	yes	yes	yes
Dadvand et al., 2016	yes	yes	yes	yes	yes	yes	yes
Dalton et al., 2016	yes	yes	yes	yes	yes	yes	yes
Delclos-Alio et al., 2019	yes	yes	yes	yes	yes	yes	yes
Dunn et al., 2012	yes	yes	yes	yes	yes	yes	yes
Giehl et al., 2012	yes	yes	yes	yes	yes	yes	yes
Gong et al.,2014	yes	yes	yes	yes	yes	yes	yes
Heaney et al., 2019	yes	yes	yes	yes	yes	yes	yes
Ho et al., 2022	yes	yes	yes	yes	yes	yes	yes
Hoppmann et al., 2017	yes	yes	yes	yes	yes	yes	yes
Huang et al., 2018	yes	yes	yes	yes	yes	yes	yes
Jones et al., 2017	yes	yes	yes	yes	yes	yes	yes
Keskinen 2018	yes	yes	yes	yes	yes	yes	yes
Kimura et al., 2015	yes	yes	yes	yes	yes	yes	yes
Klenk et al., 2012	yes	yes	yes	yes	yes	yes	yes
Klimek et al., 2022	yes	yes	yes	yes	yes	yes	yes
Klompmaker et al., 2018	yes	yes	yes	yes	yes	yes	yes
Lin et al., 2020	yes	yes	yes	yes	yes	yes	yes
Lu 2018	yes	yes	yes	yes	yes	yes	yes
Lu et. al., 2018	yes	yes	yes	yes	yes	yes	yes

Machón et al., 2020	yes	yes	yes	yes	yes	no	yes
McCormack et al., 2010	yes	yes	yes	yes	yes	yes	yes
McMurdo et al., 2012	yes	yes	yes	yes	yes	yes	yes
Miralles-Guasch et al., 2019	yes	yes	yes	yes	no	yes	yes
Nakashima et al., 2019	yes	yes	yes	yes	yes	can't tell	yes
Ogawa et al.,2018	yes	yes	yes	yes	yes	yes	yes
Price et al., 2012	yes	yes	yes	yes	yes	yes	yes
Prins & Van Lenthe., 2015	yes	yes	yes	yes	yes	yes	yes
Roberts et al., 2014	yes	yes	yes	yes	yes	yes	yes
Schepps et al., 2018	yes	yes	yes	yes	yes	yes	yes
Timmermans et al., 2016	yes	yes	yes	yes	yes	yes	yes
Vich et al., 2021	yes	yes	yes	yes	yes	yes	yes
Wagner et al., 2019	yes	yes	yes	yes	yes	yes	yes
Wang et al., 2021	yes	yes	yes	yes	yes	can't tell	yes
Witham et al., 2014	yes	yes	yes	yes	yes	yes	yes
Wu et al., 2017	yes	yes	yes	yes	yes	yes	yes
Yu et al., 2017	yes	yes	yes	yes	yes	yes	yes
Yu et al., 2021	yes	yes	yes	yes	yes	yes	yes
Yuen et al., 2019	yes	yes	yes	yes	yes	no	yes
Zandieh et al., 2019	yes	yes	yes	yes	yes	yes	yes
Zhai et al., 2020	yes	yes	yes	yes	yes	yes	yes
Zhai et al., 2021	yes	yes	yes	yes	yes	yes	yes
Zhou et al., 2020	yes	yes	yes	yes	yes	yes	yes

Table 20. Quality appraisal of quantitative studies (All non-randomized studies)

Study	**Question**						
	S1	**S2**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
Adlaka et al., 2021	yes	yes	yes	yes	yes	yes	yes
Bjornsdottir et al., 2012	yes	yes	yes	yes	yes	yes	yes
Bösch et al., 2022	yes	yes	yes	yes	yes	yes	yes
Finlay et al., 2015	yes	yes	yes	yes	yes	yes	yes

Gallagher et al., 2010	yes	yes	yes	yes	yes	yes	yes
Kou et al., 2021	yes	yes	yes	yes	yes	yes	yes
Leung et al., 2021	yes	yes	yes	yes	yes	yes	yes
Marquez et al., 2016	yes	yes	yes	yes	yes	yes	yes
Normansell et al., 2014	yes	yes	yes	yes	yes	yes	yes
Samra et al., 2019	yes	yes	yes	yes	yes	yes	yes
Sanders et al., 2018	yes	yes	yes	yes	yes	yes	yes
Schmidt et al., 2016	yes	yes	yes	yes	yes	yes	yes
Van Cauwenberg et al., 2012	yes	yes	yes	yes	yes	yes	yes
You et al., 2021	yes	yes	yes	yes	yes	yes	yes

Table 21: Quality Appraisal of qualitative studies

Chapter 3

Effects of Environmental Factors on The Physical Activity Levels of Participants Who Sustained a Wrist Fracture Within the Canadian Longitudinal Study of Aging (CLSA)

Caitlin Wright[1,2], Joshua Vincent[1,4], Joy MacDermid[1,2,3], Jason Gilliland[1,5,6,7]

[1] School of Health and Rehabilitation Sciences, University of Western Ontario, London, Ontario, Canada

[2] Roth | McFarlane Hand and Upper Limb Centre, St. Joseph's Hospital, London, Ontario, Canada

[3] School of Physical Therapy, University of Western Ontario, London, Ontario, Canada

[4] School of Rehabilitation Science, McMaster University, Hamilton, Ontario, Canada

[5] Department of Geography and Environment, University of Western Ontario, London, Ontario, Canada

[6] Department of Paediatrics, University of Western Ontario, London, Ontario, Canada

[7] Department of Epidemiology and Biostatistics, University of Western Ontario, London, Ontario, Canada

3.0 Abstract

Background: Many older adults in Canada are not meeting daily physical activity requirements. Weather and climate are associated with physical activity in population studies. Older adults who have incurred a distal radius fracture, an early fragility fracture, are likely to consider climate as a determinant of their physical activity decisions.

Objectives: This study was done to determine the effects of environmental factors on the physical activity levels of individuals as reported in the Physical Activity Scale for the Elderly questionnaire (PASE) by individuals who have sustained a previous wrist fracture within the Canadian Longitudinal Study of Ageing (CLSA) comprehensive cohort.

Methods: In total, 919 participants aged 45+ who reported having sustained a wrist fracture and completed the PASE questionnaire were extracted from the CSLA cohort (approximately 50,000 people). The environmental variables used in this regression analysis were annual total precipitation as rain (mm), annual total precipitation as snow (mm), ALE (active living environment) Index, barometric pressure (7-day average prior to first interview) (kPa), relative humidity (7-day average prior to first interview), temperature (7-day average prior to first interview) (Celsius), sulfur dioxide (7-day average prior to first interview) (ppb), ozone (8-hour max), ozone (7-day average prior to first interview) (ppb), $PM_{2.5}$ (7-day average prior to first interview) and NO_2 (7-day average prior to first interview) (ppb). Temperature was recoded into four variables as cold (-22°C to 0°C), cool (1°C to 10°C), warm (11°C-20°C), and hot (21°C-28°C). To determine which factors affected PASE levels a stepwise multiple regression was completed using IBM SPSS Statistics 28.0.1.

Results: The environmental factors that impacted PASE levels were sulfur dioxide ($\beta = 4.779$, $p = 0.010$) and ALE Index; ($\beta = 2.482$, $p = 0.017$). This shows that PASE levels increased in association with higher SO_2 levels and ALE Index.

Conclusion: This study showed that physical activity levels were positively associated with higher SO_2 levels and living in a community that has a higher ALE Index. This information can be beneficial to health care workers as well as urban design as highly walkable areas are known to increase physical activity levels of older adults.

3.1. Introduction

Physical activity is crucial to physical and mental health (Stanton et al., 2014). However, around one-third of the world's population does not meet the minimum weekly guidelines for physical activity (Stanton et al., 2014). It is recommended that individuals should aim for 150 min per week of moderate aerobic activity or 75 min of vigorous aerobic activity (Stanton et al., 2014). Resistance training is also encouraged at least twice weekly to maximize health benefits (Stanton et al., 2014). By meeting the weekly physical activity requirements, individuals will have a lower risk of developing certain cancers, type 2 diabetes, and other chronic illnesses (Stanton et al., 2014). Physical activity also positively impacts mental health and can lower anxiety and depressive symptoms (Stanton et al., 2014). Unfortunately, many older adults, do not meet daily physical activity requirements. According to the Canadian Partnership Against Cancer, the percentage of adults that meet Canadian physical activity guidelines decreases with age. For example, for those aged 45-54, approximately 57% meet daily physical activity requirements; for those aged 55-65, 55% met the requirements; by 65-74, this decreased to 46% and by the age of 74+ only 24% met requirements (Canadian Partnership Against Cancer, 2022).

It is important to study the aging population as the world's population is rapidly aging (He et al., 2015). Older adults are also considered at a higher risk of poor health (Aday, 1994). Wrist fractures are very common, and distal radius fractures (DRF), a type of wrist fracture, are known to be one of the most common types of bone fractures (Liporace et al., 2009). Even though distal radius fractures can occur in all age groups, there is a sharp increase in incidence in women at age 50, which occurs to a lesser extent in men (MacDermid et al., 2021). Distal radius fractures are known to be the second most common fractures in the elderly and the most fractured bone in women over 50 years old (Levin et al., 2017). Wrist fractures can vary in severity, and a low bone mineral density (BMD) can be a reason why distal radius fractures might be more severe or have a higher chance of occurring (Liporace et al., 2009). Most DRFs are called fragility fractures because they occur from a fall from level ground, which indicates bone quality as a contributing factor (Philip et al., 2019).

Older adults are more susceptible to a DRF as BMD decreases with age and takes longer to heal from a fracture (Gehrmann et al., 2008). Due to older adults being more prone, they must be aware of and practice ways to maintain an overall healthy bone density (Carter & Hinton, 2014). Many studies have shown that physical activity and exercise can improve bone quality and decrease one's chances of sustaining a future fracture. (Fonseca et al., 2014; Carter & Hinton, 2014). As bone resorption decreases in men and women around the age of 50, this is what can lead to decreased bone mass (Carter & Hinton, 2014). Therefore, it is important to decrease the rate at which this occurs by focusing on nutrition and strength training, which can also help you prevent developing osteoporosis (Carter & Hinton, 2014).

Unfortunately, various environmental factors might lead to individuals choosing not to participate in physical activity (Garriga et al., 2021). Some examples include seasonal change due to the temperature difference that accompanies certain seasons (Garriga et al., 2021). Physical activity levels tend to be higher in the summer or spring than in other seasons, particularly winter (Garriga et al., 2021). Other factors to consider are weather conditions, including temperature, precipitation (rain or snow), relative humidity and barometric pressure.

Air quality is another environmental factor that might influence one's desire to participate in physical activity (Hu et al., 2017). Previous literature shows that individuals are less likely to participate in outdoor physical activity if air quality is poor (Hu et al., 2017). Poor air quality could decrease the likelihood of an individual participating in outdoor physical activity due to the negative health effects of exposure to poor air quality (Hu et al., 2017; Marmett et al., 2020). It is important to note that air pollution is also a huge threat to health globally and is of particular concern in highly urbanized areas, as approximately 92% of the world's population currently lives in cities with poor air quality (Marmett et al., 2020). It is important to better understand how air quality might impact an individual's physical activity levels.

The built environment where a person lives might also determine their level of physical activity (Mytton et al., 2012). When determining levels of one's physical activity, urban design, land use and the built environment all play a major role (Devarajan et al., 2020). To promote physical activity or even walking and biking as transportation, cities should aim to have safe and well-connected public transit, wide pavements, bike lanes, playgrounds, walking paths, and parks/greenspaces (Devarajan et al., 2020). Many studies have shown that open spaces and wide pathways promote a feeling of safety and well-being, which can encourage walking (Devarajan et al., 2020). Access to parks and open greenspaces, are known to increase physical activity levels (Devarajan et al., 2020).

There is currently limited evidence on the effects of environmental factors on the physical activity levels of individuals who sustained a wrist fracture. Therefore, this study aims to determine the potential effects of environmental factors on the physical activity levels of individuals who have previously sustained a wrist fracture within the Canadian Longitudinal Study of Ageing (CLSA) comprehensive cohort.

3.2. Methods

3.2.1 Study Population

This study's population included both male and female participants who reported to have sustained a wrist fracture within the Canadian Longitudinal Study on Aging (CLSA) comprehensive cohort. We then compared this data to how often they participated in physical activity. We also compared the level of physical activity to the environmental data to determine any correlation between environmental factors and the level of physical activity. The data from participants used in this regression are from baseline.

The CLSA database collected information from approximately 50, 000 individuals across Canada aged 45-85 when they joined the study (Raina et al., 2009; Raina et al., 2019). The individuals participating in this study are being followed for at least 20 years to obtain information on different factors of aging (Raina et al., 2009; Raina et al., 2019). In total, 919 participants within this cohort reported having sustained a wrist fracture and provided information on physical activity levels. A total of 648 participants were female, and 271 were male. The age of individuals in this study ranged from 45-85 at the time of data collection. (See Table 22). All baseline data was collected through telephone interviews, in-home face-to-face interviews, or data collection site visit questionnaires (Canadian Longitudinal Study on Aging).

Data collection for baseline information started in September 2011 and ended in December 2015 (Canadian Longitudinal Study on Aging).

3.2.2 Physical Activity Measurement

The CLSA measured physical activity levels using the Physical Activity Scale for the Elderly (PASE). The PASE can be completed by self-administration or administered through interviews and takes approximately 5-15 minutes to complete (New England Research Institutes Inc, 1991). In the PASE, there are 12 different types of activities included (New England Research Institutes Inc, 1991). The weight is multiplied by the frequency value for each activity, and the sum of each of these values determines the participant's PASE score (New England Research Institutes Inc, 1991). A higher PASE score indicates a higher level of physical activity (New England Research Institutes Inc, 1991).

3.2.3 Environmental Variables

Environmental data used in this analysis was obtained from linked CANUE (The Canadian Urban Environmental Health Research Consortium). Variables that were used included annual total precipitation as rain (mm), annual total precipitation as snow (mm), ALE (active living environment) Index, barometric pressure (7-day average prior to first interview) (kPa), relative humidity (7-day average prior to first interview), temperature (7-day average prior to first interview) (Celsius), sulfur dioxide (7-day average prior to the first interview) (ppb), ozone (8-hour max), ozone (7-day average prior to first interview) (ppb), $PM_{2.5}$ (7-day average prior to first interview) and NO_2 (7-day average prior to first interview) (ppb). The temperature was recoded into four variables cold (-22°C to 0°C), cool (1°C to 10°C), warm (11°C-20°C), and hot

(21°C-28°C). The Active Living Environment represents the active living friendliness of communities (Colley et al., 2019). It demonstrates how communities were built and their relationship with the physical activity levels of individuals within that area (Colley et al., 2019). It was measured by the sum of the z-scores of intersection density, dwelling density, points of interest and transit measures.

3.2.4 Statistical Analysis

Quality checking of the data was performed by CW and JV, and an examination of descriptive statistics was conducted. After missing data patterns were analyzed, multiple imputation was used to handle missing environmental data. A stepwise multiple regression was completed to determine if the environmental variables listed above predicted the physical activity levels of CSLA participants with a history of a wrist fracture. All statistical analysis was completed using IBM SPSS Statistics 28.0.1.

3.3 Results

In total, 459 participants were interviewed in the cold season, and 460 participants were interviewed in the warm season. Out of these participants, 648 were female, and 271 were male. The age of these participants ranged from 45-86 (See Table 22).

	Frequency	**Percent (%)**
Language		
English	792	86.2

French	127	13.8
Season		
Cold (November-April)	459	49.9
Warm (May-October)	460	50.1
Sex		
Male	271	29.5
Female	648	70.5
Age group (years)		
1 (45-54)	96	10.4
2 (55-64)	272	29.6
3 (65-74)	281	30.6
4 (75+)	270	29.4

Table 22. Descriptive statistics for participants (n=919)

The weather variables that corresponded the most with PASE levels were sulfur dioxide levels ($\beta = 4.779$, $p = 0.010$) and ALE Index; ($\beta = 2.482$, $p = 0.017$). Overall, the regression was statistically significant $R^2 = 0.012$, $F(2, 916) = 5.775$, $p = 0.003$ (See Tables 23 and 24). This low R^2 value indicates a low correlation between PASE levels, and the environmental variables used in this analysis, as the regression only explains 1.2% of the variance. The Durbin-Watson value indicated no first-order autocorrelation (See Table 23).

Overall, higher sulfur dioxide showed the highest correlation with PASE levels, followed by a higher ALE index (See Table 25). Weather variables, including rain, snow, barometric pressure, relative humidity, temperature, ozone (8-hour max), ozone (7-day average), PM2.5, and NO2 (nitrogen dioxide), did not show any correlation with PASE levels of older adults who have previously suffered from a wrist fracture within the Canadian Longitudinal Study on aging dataset.

R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Durbin-Watson**
0.112	0.012	0.010	70.06297	2.142

Table 23: Model Summary of regression analysis

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Regression	56694.250	2	28347.125	5.775	0.003
Residual	4496478.565	916	4908.819		
Total	4553172.816	918			

Table 24: ANOVA table

<table>
<tr><th rowspan="2">Variable</th><th colspan="2">Unstandardized Coefficients</th><th>Standardized Coefficient</th><th rowspan="2">t</th><th rowspan="2">Sig.</th><th colspan="2" rowspan="2">95% Confidence Interval</th></tr>
<tr><th>β</th><th>Std. Error</th><th>Beta</th></tr>
<tr><td>Constant</td><td>149.470</td><td>2.959</td><td></td><td>50.510</td><td><0.001</td><td>143.662</td><td>155.277</td></tr>
<tr><td>So2_7days_com</td><td>4.779</td><td>1.850</td><td>0.085</td><td>2.584</td><td>0.010</td><td>1.149</td><td>8.409</td></tr>
<tr><td>ALE16_06_COM</td><td>2.482</td><td>1.038</td><td>0.079</td><td>2.390</td><td>0.017</td><td>0.444</td><td>4.520</td></tr>
</table>

Table 25: Coefficients table

3.4 Discussion

This study showed that sulfur dioxide had the highest influence on PASE levels out of the environmental variables studied. Although it is unlikely that sulfur dioxide levels directly influence the physical activity levels of older adults, it is important to note that SO_2 can be an indicator of air quality as it is a well know air pollutant (Kinney, 2008). Cars, buses, planes, boats, power plants, and oil refineries are all examples of primary sources of air pollution (Almetwally et al., 2020). Even though air quality is affected by various anthropogenetic activities, it can also be affected by weather and other meteorologic factors (Kinney, 2008). Weather variables that can affect air quality include temperature, humidity, windspeed, wind direction and atmospheric mixing height (Kinney, 2008). Higher temperatures, as well as increased humidity, are known to be correlated with an increase in emissions (Kinney, 2008). Also, lower windspeed decreases the dispersal of air, which can result in poor air quality (Kinney, 2008). Even though in this regression analysis, temperature also did not show to be significant in predicting PASE levels, previous studies focus on how temperature can influence physical activity levels. Previous studies show that individuals tend to exercise outside more during warmer than colder months (Aspvik et al., 2018). As a result, physical activity levels might be higher during periods of poor air quality due to the warmer weather.

One reason could be that they might be hesitant to participate in regular physical activity due to fear of slipping and/or falling (Jones et al., 2017). Season and time of year are also known to increase one's fear of slipping and/or falling (Jones et al., 2017). This is typically due to temperature changes and the presence of snow or ice during the winter months (Jones et al., 2017; Marquez et al., 2016). Previous studies have also shown that some older individuals, especially those who are less mobile, might also be hesitant to participate in physical activity because they are afraid of falling (Marquez et al., 2016). It is also important to note that most of the participants are women (n=648) as opposed to men (n=271). As a result, this could have influenced PASE levels as previous studies have observed differences in physical activity levels between males and females. A study done in 2005 states that older women tend to be less active than men (Lee, 2005). While this is consistent with the sex differences in DRF, it could reduce our confidence in the generalizability of the results to men. However, this was a minor concern since we were adequately powered for men and women. A study done in 2005 states that older women tend to be less active than men (Lee, 2005).

Air quality is very important and of particular concern to remember while participating in physical activity, as exposure to air pollution can be harmful (Almetwally et al., 2020). If individuals are outside for longer periods when air quality is poor, this could lead to acute and chronic health effects (Kampa & Castanas, 2008). Health effects include respiratory infections, heart disease, lung cancer, bronchitis, and asthma (Kampa & Castanas, 2008). A study by An et al. in 2018 states that it is recommended to stay indoors when air quality is poor instead of exercising outside (An et al., 2018). Those who wish to participate in physical activity in highly polluted and urbanized cities are encouraged to do so earlier in the morning when air quality tends to be better before rush hour (Carlisle & Sharp, 2001). This is especially important when it comes to those 60 years of age and older (Spickett et al., 2011). It is estimated that 1.4% of total mortality was due to outdoor air pollution, and 81% of those who die from outdoor air pollution are aged 60 and older (Spickett et al., 2011).

The Active Living Environment was also significant in influencing physical activity levels. The active living environment tends to increase physical activity levels as these highly walkable neighbourhoods are easy to navigate, have well-connected pathways, and have many destinations (Colley et al., 2019). Other factors of the ALE index can include bike lanes and using public transportation.

Living in areas with a high ALE index can increase physical and mental health. One study by Mah et al. in 2020 showed that individuals walked more in favourable ALEs and that walking was associated with lower incidences of premature cardiometabolic death (Mah et al., 2020). If an area has higher walkability and, as a result, influences physical activity, this is beneficial for older adults as increased physical activity is known to keep older individuals mobile. Physical activity also provides many mental health benefits, provides an overall better sense of well-being and self-esteem, and improves cognitive function and quality of life (Biddle, 2016).

Not only can increased active living environments benefit physical and mental health, but they can also lead to decreased pollution and a cleaner environment (Rodrigues et al., 2020). This is because if more people participate in active transport, less emissions will be released into the atmosphere (Rodrigues et al., 2020). This will improve the city's air quality and decrease emissions (Rodrigues et al., 2020). As a result, this will positively impact the health of the environment and can be used in cities as a climate change mitigation strategy.

3.4.1 Limitations

Even though a large database was used, and multiple environmental variables were included in this regression analysis, this study still had limitations. The first limitation includes that since participants had previously suffered from a wrist fracture, we did not control for the time since the fracture or other health comorbid health conditions that may have affected physical activity.

Another limitation of this study is that some environmental data was missing and had to be imputed. Even though this environmental data covered areas all over Canada, weather can also vary based on geographic location within the country. This could especially have impacted determining how temperature influences PASE levels. It is also important to note that since the environmental variables provided by CANUE were originally categorized into the warm season (May-October) and cold season (November-April), the temperature was recoded into four categories, cold, cool, warm, and hot. This could be a limitation because, based on the season or geographic location, one might perceive certain temperatures differently, and a temperature considered ideal at one time may not be ideal in a different location or season. Further climate factors interact in some cases, i.e., cold and rainy may be less favourable than rainy alone for physical activity, and these interactions were not evaluated. The climate factors were measured at a gross community level, not necessarily reflecting the climate of the local community of the person at different time points.

3.5 Conclusion

This study showed that SO_2 and ALE Index impacted the PASE levels of older adults. Poorer air quality, as indicated by sulfur dioxide levels and an activity-friendly-designed community environment, as indicated by a higher ALE index, were associated with better physical activity, as indicated by the PASE levels in a large sample of older adults who have previously sustained a wrist fracture, within the CLSA dataset. Other environmental factors included in this analysis that did not correlate with PASE levels were precipitation as rain, precipitation as snow, barometric pressure, relative humidity, temperature, ozone, $PM_{2.5}$, and NO_2.

Overall, it is crucial to understand which environmental factors most influence older adults' physical activity. Healthcare professionals should also consider other factors that might influence the physical activity levels of those who have previously sustained a wrist fracture. One example includes fear of slipping and/or falling, and another is poor balance or mobility. Alternative or modified exercises should be provided to prevent older adults from becoming physically inactive. Exercises should include aerobic and strength-building exercises to improve mobility and prevent older adults from becoming frail. When considering what might influence physical activity, someone's geographic location should also be considered, as certain weather conditions might influence one's physical activity levels. This information is also important in urban design, as highly walkable areas increase physical activity.

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Chapter 4

4.0 Discussion

Overall, a major threat to the health and well-being of society today is the lack of physical activity, especially in older age groups. Older age populations are known to be at higher risk of health issues, including low bone mineral density, which can lead to fractures, the most common being wrist fractures (Liporace et al., 2009). The impact of environmental factors on the physical activity levels of older adults, including those who have previously suffered from a wrist fracture, was examined in this thesis. Previous studies have been done on how environmental factors affect physical activity; however, limited studies have focused on the aging population. Since climate change is also a very prevalent issue today, this information can also be beneficial in predicting future trends in physical activity levels in older adults based on future climate projections. To address these topics, the first study provided insight into the current state of the evidence on the effects of environmental factors on physical activity levels for those 60 and older. The second study investigated the relationship between environmental factors and physical activity levels in those who previously sustained a wrist fracture in the Canadian Longitudinal Study on Aging (CLSA). This chapter will discuss the overall findings of each study and the impact of research, limitations, and directions for future research from this thesis.

4.1 General Summary

Since many older individuals are not meeting physical activity requirements to reach health benefits, a systematic review was done to investigate the current state of the evidence on the effects that environmental factors have on physical activity levels of those 60 years of age and older. Environmental factors that were addressed in this systematic review included greenspace, weather, daylight/solar radiation, season, and air quality. The specific weather conditions included temperature, precipitation, humidity, wind speed, and atmospheric pressure. Results showed that increased greenspace, moderate-warm weather, and longer hours of daylight all had a positive association with physical activity levels. It was found that the factors which decreased physical activity levels included hot temperatures, colder temperatures, high humidity, high windspeed and poor air quality. Physical activity levels in one study were shown to peak between temperatures of 16 °C to 19.3 °C (Ho et al., 2022). In terms of seasonality, physical activity levels were consistently lower in the winter and highest in the spring or summer, depending on the temperature.

The second study was a regression analysis that was done to determine the effects of environmental factors on the PASE individuals who have sustained previous wrist fractures within the Canadian Longitudinal Study of Ageing (CLSA) comprehensive cohort. Wrist fractures are very common, and distal radius fractures, a type of wrist fracture, are known to be one of the most common types of bone fractures (Liporace et al., 2009). This population was chosen within the CLSA as elderly populations are more susceptible to fractures due to their bones becoming increasingly frail as they age. The environmental variables used in this regression analysis were annual total precipitation as rain (mm), annual total precipitation as snow (mm), ALE (active living environment) Index, barometric pressure (kPa), relative humidity, temperature (Celsius), sulfur dioxide (ppb), ozone, $PM_{2.5}$ (ppb) and NO_2 (ppb). Temperature was recoded into four variables cold (-22°C to 0°C), cool (1°C to 10°C), warm

(11°C-20°C), and hot (21°C-28°C). Results showed that the environmental variables that impacted PASE levels were sulfur dioxide (SO_2) and the ALE Index.

This information benefits policymakers, urban planners, landscape architects, healthcare workers and the general population.

4.2 Limitations

A limitation of the first study is that some information could have been missed during the literature search portion of the systematic review. This is because even though the search terms were broad, there is no one way to define environmental exposures. Another reason is that the studies used were only published in English.

A second limitation that can be applied to both studies is that environmental factors affecting physical activity can vary significantly. This is because individuals can have different views about what might impact their decision to participate in physical activity. Weather can vary day-to-day as well by the hour. One example of this includes temperature because it can be very difficult to define what someone might consider too warm or cold to participate in outdoor physical activity. Also, different weather variables might impact individuals differently. For example, warm and wet weather might not affect physical activity as much as cold and wet weather. As a result, it can be difficult to synthesize data and draw conclusions based on specific weather variables.

Another limitation is that environmental factors can vary significantly based on geographic location. The first study looked at environmental factors from areas all around the world. As a result, it is hard to apply conclusions as to what environmental factors might influence the physical activity of all older adults. Instead, focusing on which environmental factors affect older adults in a specific region would be more beneficial. There were even limitations due to geographic location in the second study, which looked at Canada. This is because older individuals living on the East and West Coast experience more moderate temperature changes and increased precipitation throughout the year than those living in Ontario.

Many other factors that aren't directly related to environmental factors can prevent individuals from participating in physical activity. One factor preventing someone from participating in physical activity as they get older is decreased balance or mobility. Older individuals might be more nervous about participating in outdoor physical activity due to the fear of falling; this can also be true if snow or ice are present. This is an example of a limitation, especially in the second study. Individuals who have previously sustained a wrist fracture might be more cautious and nervous about participating in outdoor physical activity out of fear of falling and hurting themselves again.

4.3 Impact of Research

Despite differences in findings between each of the studies, these studies both show that environmental factors can affect the physical activity levels in older adults. As a result, it is crucial to implement strategies to encourage physical activity levels in older age groups. Some examples include healthcare workers encouraging older individuals to participate in physical activity and/or providing modifications for exercise when environmental factors might become a barrier to participating in outdoor exercise. This will improve physical activity levels and allow older individuals to feel more independent in their everyday life. Other important findings from this study show that increased greenspace and one's active living environment (ALE index) affect physical activity levels. This is something that urban planners, as well as landscape architects, should keep in mind when designing cities and landscapes. Areas with more greenspaces, streetscape greenery, and easier park access encourage physical activity. This is not only beneficial to one's physical health, but it also has positive benefits to mental health as physical activity and greener and more aesthetic landscapes have been shown to decrease depression and anxiety and promote a sense of well-being.

4.4 Future Directions

Future research will be beneficial as it will build on our current understanding of environmental factors affecting one's physical activity levels. Future research should consider being done on smaller scales (e.g., town, city, or province) rather than by country. This will allow for a better and more specific understanding of the environmental factors affecting older individuals within a specific area. It would also be beneficial if more studies were done that addressed how humidity levels, windspeed, atmospheric pressure and air quality might affect the physical activity levels of older adults. This is because limited research has been done on how these weather conditions affect older adults specifically. Another focus of future research should be on how the impacts of climate change might affect the physical activity levels of adults in the future. Locations all around the world are experiencing different environmental issues related to climate change; therefore, it would be beneficial to see how this might affect physical activity levels in the future. This would allow policymakers to implement climate strategies to mitigate these risks.

4.5 Conclusion

This thesis added to the current literature on how environmental factors affect physical activity in older adults. Both studies in this dissertation provided insight into how environmental factors can affect physical activity levels as one ages. Despite different findings between these studies, it is still crucial to implement strategies to encourage physical activity levels in older age groups. Findings from this study can guide future policy and environmental modifications to improve one's physical activity levels. It is important that future research continues, addresses different geographic locations, and focuses on climate change projections into the future to determine how physical activity levels might be impacted now and in the future.

Appendices

Appendix A: CLSA Access Agreement

clsa élcv Canadian Longitudinal Study on Aging
Étude longitudinale canadienne sur le vieillissement

Office use only / usage interne seulment

Application ID / N de la demande	1909032
Version / Version	B1
Date of Download / Date de téléchargement	2022-06-27

Changes to Co-Applicants and Support Personnel

Changements de codemandeur et de personnel de soutien

All Co-Applicants and Support Personnel being added to the project, who will require direct access to the CLSA data, must sign below and agree to comply with the conditions outlined in Articles 2.1 and 2.3 of the CLSA Access Agreement. Note: Anyone requiring access to data must use the email address of their affiliated institution. Data will only be released to institutional email addresses. /
Tous les codemandeurs et le personnel de soutien ajoutés au projet qui auront besoin d'un accès direct aux données de l'ÉLCV doivent signer ci-dessous et accepter de se conformer aux conditions énoncées aux articles 2.1 et 2.3 de l'Entente d'accès de l'ÉLCV. Remarque : Toute personne ayant besoin d'un accès aux données doit utiliser l'adresse électronique de l'établissement auquel elle est affiliée. Les données ne seront envoyées qu'aux adresses de courriel institutionnelles.

Co-Applicant and Support Personnel Information /
Informations sur le codemandeur et de personnel de soutien

Name / ***Nom***	**Affiliation /** ***Organisme d'appartenance***	**Email (see note above) /** ***Courriel (voir la remarque ci-dessus)***	**Signature /** ***Signature***
Caitlin Wright	Western University	[redacted]	[redacted]

Curriculum Vitae

Name:	Caitlin Wright
Post-secondary Education and Degrees:	University of Guelph Guelph, Ontario, Canada 2016-202, BSc. ENV.
	The University of Western Ontario London, Ontario, Canada 2021-Current. MSc.
Related Work Experience	Teaching Assistant The University of Western Ontario 2021-2023

Publications: Co-Author

Dixon, H. J., Elmarsafy, M., Hannan, N., Gao, V., Wright, C., Khan, L., & Gray, D. K. (2022). The effects of roadways on lakes and ponds: a systematic review and assessment of knowledge gaps. Environmental Reviews, (ja)