# HIP FRACTURES IN LONG TERM CARE FACILITIES IN BRITISH COLUMBIA:

# INCIDENCE AND RISK FACTORS

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# ABSTRACT

Hip fractures (HFs) are common in long term care facilities (LTCFs). Reports on HF incidence for Canadian LTCFs are limited. To address the gap, this study analyzed retrospective databases from the Canadian Institute for Health Information (CIHI) from January 1, 2010, to December 31, 2014, for LTCFs in British Columbia (BC).  Information for the first event of HF was extracted from the Discharge Abstract Database (DAD) and for explanatory variables (e.g., health behaviors, body mass index, clinical conditions) from the Continue Care Reporting System (CCRS), based on RAI-MDS 2.0, which is hosted by the Canadian Institute of Health Information (CIHI).  Two research questions were addressed: 1) what is the incidence of hip fracture for residents aged 65 years and older living in LTCFs in BC, Canada, patterned by time (2010-2014), person-level (age and sex), and place (facility size, rural-urban locations, and health regions) factors? and 2) what person-level factors, health behaviors (smoking and alcohol consumption), place factors, and clinical factors (body mass index, diabetes mellitus, rheumatoid arthritis, osteoporosis, dementia, Parkinson's disease, and falls) are associated with hip fractures in adults aged 65 years and older living in LTCFs in BC, Canada?

The cohort included 33,739 residents (age ≥ 65 years) who resided in 305 LTCFs across BC. Results showed a downward trend in HF incidence rates (IRs) in all age groups (approximately 18% from 2010-2014), which was more pronounced in females than males. Results stratified by a combination of person, place, and time characteristics showed quite nuanced patterns of HF in this population. The results of the multivariable logistic regression indicated that compared to the youngest age group, there were higher odds of HF in those aged >= 90 years [OR= 1.34 (95% CI: 1.18,1.51)]. The study also found greater odds of HF for females [OR=1.61 (95% CI: 1.45,1.78)], those with a BMI classification of underweight [OR=1.81 (95% CI: 1.47, 2.23)], normal [OR= 1.82 (95% CI: (1.52, 2.18)], or overweight [OR= 1.36 (95% CI: (1.12, 1.65)] compared to obese, those with dementia [OR=1.46 (95% CI: 1.33, 1.62)] and  those who experienced a fall in the last month [OR=1.15 (95% CI: 1.02, 1.29)]. The results of this study provide important information on time trends in HFs among LTCF residents as well as risk factors. The results also offer preliminary information about the potential impact of rural-urban location and facility size on HF IRs, which can be the starting point for future studies on this topic beyond a single province.

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# DEDICATION

This work is dedicated to

my wife

Shazia

for her persistent support and encouragement.

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Temporal Trend: TT(s)

Long term care: LTC

Long term care facilities: LTCF(s)

Hip fracture: HF(s)

Incidence rate: IR(s)

Odds ratio: OR

Discharge Abstract Database: DAD

Canadian Institute of Health Information: CIHI

International Classification of Diseases, 10th Revision, Canada: ICD-10-CA

Continuing Care Reporting System: CCRS

Resident Assessment Instrument– Minimum Data Set 2.0:  RAI-MDS 2.0

Bone mineral density: BMD

Body mass index: BMI

Diabetes mellitus: DM

Rheumatoid arthritis: RA

Parkinson's disease: PD

# CHAPTER 1

This chapter describes relevant demographic trends in Canada, followed by the study rationale, purpose, and research questions.

## 1.0 Introduction

Consistent with temporal population patterns in other developed countries, Canada's population is aging.[1] In 2013, approximately 15% of Canada's population, comprising 5.4 million people, was aged 65 years and over. [2] By 2063, estimates forecast that the number of older adults will grow to 15 million, representing approximately one-quarter of the Canadian population. Canadians over 80 years of age are one of the fast-growing senior age groups, totaling 1.4 million in 2013, and expected to increase to 4 and 6 million by 2063. [3]

Aging is associated with more health problems, including an increased risk of fracture. An estimated 30,000 hip fractures (HFs) occur in Canada annually, with the majority occurring in those 75 years of age and over (75%) and in women (72%).[4] HF for older adults is associated with many adverse outcomes – for individuals, families, and the healthcare system.[5] Between one quarter and three quarters of older adults living independently before experiencing a HF report significantly lower levels of independence post fracture.[6] The psychosocial consequences of HFs include depression, a fear of falling, and social isolation.[7] Following a HF, an older adult's risk of death doubles and remains elevated for several years after the event.[8] For example, in Ontario, Canada, nearly one-quarter of women and one-third of men die within one year after a HF.[9] HFs also have serious economic costs. In Canada, the yearly healthcare-related costs of HF are estimated at 1.1 billion dollars.[10] Similarly, treatment costs for osteoporosis (a major HF aetiological factor) and resultant fractures combined reached 3.2 billion dollars annually.[10]

Older adults living in long term care facilities (LTCFs) are among the population most vulnerable to HFs in Canada.[11] Although estimates vary, an Ontario study [12] reported the incidence of HFs in LTCF residents in 2012 was approximately double that of same-aged adults living in the community. This estimate was even higher for residents in Saskatchewan.[13] Possible reasons for this difference are that compared to the community dwelling older adults, those in LTCFs are more likely to be older and female, both risk factors for HF.[11] Additionally, higher rates of cognitive impairment, osteoporosis, and falls in older adults living in LTCFs may contribute to a higher prevalence of HF and consequent functional decline and death.[14]

Research examining the determinants of HF among older adults has focused predominately on community dwellers. Risk factors for HF in community dwellers  include health

behaviours such as alcohol consumption [15] and smoking. [16] Additionally, concurrent clinical conditions such as body mass index (BMI), [17] diabetes mellitus (DM), [18] rheumatoid arthritis (RA),[19] osteoporosis,[20] dementia, [21] Parkinson's disease (PD),[22,23] and falls [24, 25] have been associated with an increased risk of HF. Environmental correlates of HF have also been examined for community dwellers. An individual's geographical location has an impact on the likelihood of fractures of all kinds, including HFs.[26] HFs are more common in urban than rural settings.[27,28]

## 1.1 Rationale and research questions

Epidemiological data is vital for implementation of preventive measures and to inform health care planning and management. The results of studies with community dwelling older adults suggest that the determinants of HF are multifactorial. With a few exceptions,[12,13] corresponding information for Canadians living in LTCFs is sparse. To address this gap, the aim of this study was to provide reliable information about the incidence and correlates of HF in LTCF dwellers in British Columbia (BC). BC was selected as the sampling frame since the older adult population in this province is increasing significantly. It currently ranks fifth among all Canadian provinces and territories. For instance, BC's proportion of older adults increased from 15.7% in 2011 to 18.3% in 2016.[2] Also, seven of the top ten largest older adult populated municipalities in Canada are in BC [29] with significant numbers of older adults living in LTCFs.[30]

Using several administrative databases managed by the Canadian Institute for Health Information (CIHI), two research questions guided this investigation:

1) What is the incidence of hip fracture for residents aged 65 years and older living in LTCFs in BC, Canada, patterned by time (2010-2014), person-level factors, and place?

2) What person-level factors (age and sex), health behaviors (smoking and alcohol consumption), place factors (facility size, rural-urban locations, and health regions), and clinical factors (BMI, DM, RA, osteoporosis, dementia, PD, and falls) are associated with hip fracture in adults aged 65 years and older living in LTCFs in BC, Canada?

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# CHAPTER 2

## 2.0 Literature review

Chapter 2 begins with a demographic overview of aging in Canada and British Columbia, followed by a definition of hip fracture, the consequences of hip fracture, and trends in hip fracture incidence over time, including for those residing in both community and long-term care facilities. Research on the patterning of hip fracture by characteristics related to person and place is reviewed, as are studies examining hip fracture in relation to health behaviors and clinical conditions.

## 2.1 Demographic shifts

### 2.1.1 Demographic shifts in Canada

The Canadian population has increased substantially (56%) in the last four decades, and surpassed 35 million in 2016.[2] According to Canada's 2011 Census, the proportion of older adults is 14.8%.[31] The 2016 Census reports that the aging population has increased significantly to 16.9%.[2] The Census has reported the most substantial increase in the proportion of older adults since 1871.

Consequently, in 2016 for the first time in Canadian history the number of older adults exceeded the group below 15 years of age (5.9 million versus 5.8 million).[2] Between 1982 and 2012, the age group 65 years and above showed the most significant increase. For instance, older adults aged 65 years increased by more than 100% while the 85 and over group increased by 250%.[32]

The proportion of the most aged older adults (85 and older) is expected to proliferate rapidly in the next few decades. In 2010, about 53% of older adults were between ages 65 and 74, 33% were between ages 75 and 84, and 13% were 85 and older. This latter group accounted for 2% of the total population of Canada in 2011.[2] In 2031, it is predicted older adults aged > 85 years will account for a similar proportion of all seniors and 3% of the total population of Canada. [33] By 2046, these proportions will have nearly tripled: the eldest older adults (age 85 and older) will account for 9.7% of the total population. While overall >65 years older adults will most likely reach around 40% of the total Canadian population. [3]

### 2.1.2 Demographic shifts in British Columbia

In BC, the number of older adults is expected to rise from approximately 853,000 in 2016 to an estimated 1.47 million over the next 20 years.[34] The highest growth, 19.4% from 2011 to 2016, was noted among those 85 years and older  and has been exponential by a factor of 4 compared with the overall Canadian population growth rate . The subpopulation of older adults over 100 years of age grew even more rapidly from 2011 to 2016 by 41.3%. [29] The proportion of older persons jumped from 15.7% in 2011 [31] to 18.3% in 2016 [2] with a significant number living in BC LTCFs. [30]

### 2.1.3 Demographic shift worldwide

A rising trend in the older adult population is also seen worldwide. The United Nations (UN) predicts that by the year 2045, the number of individuals aged 60 years and older will exceed the number of individuals under 15 years of age.[35] Regions experiencing the most significant increase in this age group include Europe and North America. By the year 2060, older adults will account for approximately 151 million people in Europe [36] and comprise 22% of the American population.[37]

## 2.2 Overview of hip fracture

### 2.2.1 Definition of hip fracture

A HF is a break in the upper quarter of the femur (thigh) bone. [38] There are three types:

**Intra-capsular (transcervical) fracture**

These fractures occur at the level of the neck and the head of the femur and are generally within the capsule. The capsule is the soft-tissue envelope that contains the lubricating and nourishing fluid of the hip joint itself.

**Inter-trochanteric fracture**

This fracture occurs between the upper bony prominence called the greater trochanter and a lower bony prominence called the lesser trochanter.

**Sub-trochanteric fracture**

This fracture occurs below the lesser trochanter in a region that is between the lesser trochanter and an area approximately 2 1/2 inches below it.

The extent of the break depends on the forces that are involved. The type of surgery used to treat a HF is primarily based on the bones and soft tissues affected, or on the level of the fracture. The hip is a ball-and-socket joint. It allows the upper leg to bend and rotate at the pelvis.[39]

### 2.2.2 Trends in hip fracture

HF is an important cause of morbidity and has become a significant health problem worldwide. It has been estimated that the overall HF burden will increase to 6.3 million in

2050.[39] On the one hand, longevity is improving globally, though on the other hand, it co-exists with clinical conditions that increase the risk of HF, including diabetes, [40] neurological disorders such as dementia, [41] and fall. [25] It is expected, therefore, that the increase in older adult population will raise the number of HFs.[42,43] Therefore, it is pivotal to begin with trends for HFs.

### 2.2.2.1 Canadian trends

In Canada, there is a reported downward trend for HF IRs. A study published in 2009 based on pan-Canadian CIHI Discharge Abstract Database (CIHI-DAD) metadata over 20 years (1985-2005) described a persistent downward pattern of age-adjusted HF IRs in both sexes.[42] In the same analysis, HF rates decreased incrementally by 1.2% per year for the period 1985–1996. After that, this rate further sloped down 2.4% until the end of the study period (2005). Provincial studies from BC yielded the same downward trend in HF IRs, particularly after 1995, although they were preceded by stable rates in the 1980s (an overall 8% decrease was seen in incidence rates for both female and male).[44] Overall, TTs in an Ontario-based study, [12] with more than ten years of observation, demonstrated that the absolute number of fractures increased over time in the community due to an increasing population of older adults. However, IRs showed a decreasing pattern for both community and LTCF-dwelling older adults with a more noticeable decline among LTCFs from 2004 to 2012.[12]

Furthermore, CIHI revealed a 13% reduction in the HF IRs in 2005–2006, as compared with 2001–2002, after adjustments were made for population growth and age.[45]   At present, the recent trend illustrates a steady decline in HF IRs in Canada [4,42] However, the estimated annual national numbers for HFs are predicted to climb to 41,701 in 2035 (6,048 in BC). [46]

### 2.2.2.2 North American and European trends

HF IRs vary throughout North America. Initially, during the second half of the 20th century, an increasing trend was reported for both sexes with advancing age. A recent study in the US of those aged 65 years and older, registered between 1986–2005, identified 786,717 HFs. An increasing IR of approximately 9% was identified for the first ten years (1986-1995), followed by a decline of 24.5% in the last ten years (1996–2005) of the study.[47] However, of the growing older adult population in the US, the gross number of HFs is projected to increase to more than 500,000 per year by 2040.[48] Indeed, European countries reported similar findings of an overall

increase in HFs due to a growing population of older adults.[49] However, in general, the literature on HF IRs worldwide showed a declining trend.

### 2.2.2.3 LTCF trends

HF incidence within LTCFs are 4 to 8 times higher than among similar age groups of community-dwelling older adults.[50] The estimated annual IR of HFs in LTCFs is approximately 4% and the risk is 2-11 times higher than for community dwellers.[51] Even higher IRs were reported from a US study.[52] A recent Ontario-based study reported that the risk of HFs is at least 1.8 times greater in LTCFs than in the community for people matched by age and sex. The rate in women is 1.5 times higher, whereas in men it is 4.3 times higher.[11] Another study reported that the incidence of first time HFs for LTCF residents in 2012 was 31% of the total HFs that occurred among older adults of London, Ontario.[12] This number was even higher in Saskatchewan at 41% of total (community and LTCF combined) provincial HFs.[13] However, there is only one report on TT is available from Ontario with an average annual percent change of -3.49% (- 3.97 , -3.01) between 2002–2012.[12] In summary, in LTCFs the HF incidence is proportionally higher compared to community dwellers in Canada and elsewhere.

### 2.2.2.4 Factors involved in lowering trends

The phenomenon of the lowering HF trend in Canada and elsewhere is somewhat peculiar, as presumably the geriatric population is at a higher risk of incurring a HF due to a high prevalence of associated frailty. Despite this fact, the incidence of HFs continues to decrease. Some well explained contributory factors have been considered. For example, there have been improvements in the health management of older adults along with enhanced avoidable risk prevention techniques.[53] Correspondingly, some established preventive protocols have been identified as useful factors for avoiding HFs. These include rigorous safety checks, better staff education, modifying the physical environment, [54] and applying hip protectors. [55] Concomitantly, from the mid-1990s onwards favorable trial outcomes demonstrated the efficacy of bisphosphonates in low-impact fractures. Prescription rates for these medications have increased tremendously with positive results. [56] Similar findings were reported for calcium and vitamin D supplementation programs. [57]

Growing awareness of the importance of healthy lifestyles has also brought positive changes to reinforce this trend. [58] In Canada, for example, smoking has declined over time. Smoking rates have decreased from 25% in 1999 to 13% in 2015, and have led to improvements for older Canadians at an average body weight.[59] Reduction in alcohol consumption and improvement in physical activity levels are among a few other positive contributing factors.[60] Such improvements have led to an excellent health perception by 90% of Canadians. [59]

Another highly relevant factor linked with changing epidemiology is the improvement in fall prevention strategies. Currently, there is a declining pattern of falls [61] that suggests the possibility of the positive impact of fall prevention strategies. [62] It is also possible that a quick decline of HFs may be due to improved screening and treatment of osteoporosis. [56] Since osteoporosis increases bone porosity, it dramatically increases the chances of a HF if a person falls. [63] Therefore, improved preventive strategies [64] along with improvements in average bone mineral density (BMD) [65] may have offset changing HF indices.

## 2.3 Consequences of hip fracture

### 2.3.1 Health related

HFs elicit many adverse outcomes including pain, disability, immobilization, functional decline, delirium, and even premature death. Reports describing patterns of mortality after HF events have found increased mortality rates of at least 12–20% in the first year post-HF. [66,67] CIHI recently reported that the mortality risk post-HF increases by 128% for those aged 85 to 94, and by over 300% for those aged 95 and above. [45] A recent report from the Unites States on LTCF residents showed a 36.2% mortality increase by 180 days post HF in partially-dependent residents, and a 53.5% increase for totally-dependent residents. [68] Thus, despite the overall declining trend the persistent mortality rates associated with HFs remains of great concern worldwide [47,69] and within Canada.[70]

Post HF additional compromises to an individual's quality of life remain a crucial issue for the individual, family and care providers. Many older patients develop disabilities of mobility after HF surgery. After receiving surgery for their HFs, 25% of patients (who were independent

prior to surgery) required a LTCF, with 60% of patients becoming dependent in more than one activity of daily living.[71] Compromised quality of life impacts individuals, society, and the health care system. People who experience a HF frequently need longer hospitalization often followed by prolonged rehabilitation. In a recent review, it has been estimated that one-year post HF, approximately, 2% of survivors fail to return to their pre-fracture mobility, 35% are incapable of walking independently, and 20% are unable to shop independently.[5] Psychosocial consequences of a HF including possible depression, fear of falling and disability, institutionalization, and social isolation are particularly crucial for a frail aged population. [72] Residents in LTCFs tend to experience poorer post-HF outcomes compared to community dwellers.  A study conducted in Canada aiming to assess post-HF functional outcomes among seniors reported 39% patient who died after their discharge from hospital post HF were from LTCFs and 20.5% from the community. [70]

### 2.3.2 Financial

The financial burden of HFs is of paramount concern for the healthcare system. Approximately 45% of the provincial and territorial governments' healthcare expenditures are devoted to older adults [73] despite this group accounting for only 15% of the population. [2] The above factor is important in the context of HFs. It has been estimated that the 90-day average episode costs for HFs vary from $32,618 to $42,796 across Canada's healthcare system. [9] Ontario contributes up to $282 million annually for HF treatment costs alone.[74] In LTCFs, individual HF treatment costs are estimated at $44,156 dollars for each event. Estimated annual costs for osteoporosis and fractures combined among LTCF residents amount to $3.9 billion. [75]

Multifactorial costs are associated with hospitalization and subsequent rehabilitation for patients with HFs. A Canadian study in 2011 evaluated the longitudinal costs of HFs from a Canadian perspective reported that the mean total 1-year direct costs for treatment was $27,527 in 1997.[76] This number is much lower than the mean direct cost of $52,232that was reported 12 years later. [9] Another United States study reported that despite being only 14% of the total number of fractures, HFs comprise 72% of total fracture treatment expenditures. [77] Based on a one-year study, it has been estimated that in the United States HFs resulted in the loss of more

than 550,000 person-years of life with lifetime healthcare costs approaching $25 billion, which could potentially lead to the premature loss of 1.1 million years of life with associated healthcare costs of $47 billion. [78]

## 2.4 Risk factors for hip fracture

In Canadian LTCFs several factors have been reported to indicate a higher propensity for HFs. [14] Similarly, in other parts of the world, studies have been published on elderly community dwellers in general, but not specifically for LTCF residents; these studies showed some association between HFs and multiple individual and clinical factors such as health behaviors like alcohol use [15] and smoking. [16] Clinical factors (i.e., BMI, [17] DM, [18] RA, [19] osteoporosis, [20] dementia, [21] PD, [22,23] and falls [24,25]) have also been implicated. In addition, several environmental factors are associated with HFs for community dwellers. For instance, the urban and rural impact of HFs for community dwellers worldwide has been reported. There has been an increase of fractures (of all kind) in urban settings compared to rural areas. [27,28] These factors are not well explored in LTCFs. Recently, a pioneer study from Saskatchewan described urban-rural differences and IRs for the size of the facility. [13] The following section will include a literature review of the factors mentioned above.

### 2.4.1 Age and sex

The risk of HFs increases sharply with age. HF is a condition common among older adults, with a natural impact on routes of recovery, management, planning of care, and existing resources, and research. [80] Studies have reported an exorbitant increase in HF rates with an increase in mean age, rising from 22.5 and 23.9 per 100,000 people for men and women respectively at age 50 years, to 630.2 and 1289.3 per 100,000 people by the age of 80 years.[81] A Canadian study, based on five years of nationwide HF data, reveals a strong link with older age, as only 3.9% of HFs were found among individuals aged 50 years or under, versus 21% in the 50-74 age group, and 75% of HFs occurring among those 75 years and older. [4] In 2008, a review over a four-decade period (1959–1998) described demographic changes, with the mean age of HF incidences increasing steadily from 73 years of age in the 1960s, to 79 years of age in the

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1990s. [82] An estimated 30,000 HFs happen in Canada each year with the majority occurring in those 75 years of age and older (75%). [42]

It is expected that by 2031, approximately 45% of HFs will occur among those 85 years or older. [83] This prediction may have already eventuated in some jurisdictions. In Quebec, for example, it has recently been reported that older adults over the age of 85 have a 45% chance of having a HF. [80] A similar trend was reported in other Canadian studies. [83]

In general, older adults in Canadian LTCFs are more likely to be frail, which presumably explains some increased risk relative to their community-dwelling counterparts. [11] The estimated prevalence of HFs in LTCFs is approximately 20% and is highest among residents approaching 90 years of age. [52] The studies reported fracture rates in LTCFs between 4 to 8 times higher than similar age groups of community-dwelling older adults. [51,52]

There are a few reports with different estimates available on HFs in LTCFs. For instance, an Ontario study reported the incidence of first time HFs in 2012 for LTCF residents was 31% of the total HFs occurring in the combined community and LTCF populations. [12] An even higher number of HFs were reported from Saskatchewan at around 41% of the combined community and LTCF populations. [13] Therefore, advanced age and frailty related issues may predispose residents for HFs. The differences in reported numbers between studies may be due to different methodologies and differences in study population.

Sex differences exist for HF incidents as women are relatively more vulnerable to HFs. Slightly less than three quarters (72.3%) of all HF admissions in acute hospitals occurred for women (men 27.7%) during 1985–2005. [83] Overall, the percentage of women who suffer HFs shows an increasing trend in Canada. Osteoporosis Canada estimates that at least one in three women and one in every five men will suffer an osteoporotic fracture in their lifetime. [10] In another Canadian study, women with HFs were significantly older than men by a mean difference of 4.6 years and a higher percentage of women with HFs were diagnosed with osteoporosis, dementia, and rheumatologic diseases. [80]

Furthermore, bone health is more often compromised among women. Marked bone loss with age is relatively more common in women compared to men. Complex physiological mechanisms, such as hormonal deprivation of estrogen in the postmenopausal state and

demographic variation (e.g. socioeconomic status) may exert an influence on HF risks. [84] It is evident that both older males and females generally manifest lower levels of calcium and vitamin D. [85] However, these conditions are more prevalent among females, often due to postmenopausal effects and hormonal influences. [86] Women tend to live longer than men and hence present a proportionally higher HF prevalence. Most researchers report a female: male HF incidence ratio of 2:1 over the age of 65. [87]

A unique link between HF and bony structural architecture has also been reported. [88] Bone size tends to increase during aging, whereas cortical thickness decreases due to the fact that endo-cortical resorption outweighs periosteal apposition. Consequently, the bending strength of the tubular bones decreases significantly resulting in bone fragility. [89] Men tend to have comparatively bigger bones and stronger mechanical properties, even after adjustments for age, body weight, and body height compared to females. [90] It has been reported that the bones of older adult patients who have sustained HFs have been shown to possess relatively lower cortical thickness, lower sectional modulus of elasticity, and higher buckling ratio characteristics that in turn increase vulnerability to HFs. [91,92] These are the bony characteristics of older females who sustained fracture. For instance, women who sustained HFs were reported to have thinner femoral neck cortices, longer hip axes, greater neck-shaft angles, narrower femoral shafts, and higher acetabular widths compared with the non-fracture control group. [88] These characteristics possibly account for the differential epidemiology between sexes.

As mentioned above, HFs are mainly related to the older adult population and LTCFs, which are primarily comprised of seniors over the age of 65, the majority of whom are female. One recent study of LTCF females found an association between a high prevalence of inflammatory blood markers and poor mobility, which also contributes in HFs. [93] Several studies reported relatively higher preponderance of HFs among females in LTCFs. Canadian studies from Ontario [11,12] and Saskatchewan [13] comparing HF IRs between LTCFs and those in community care revealed that higher percentages of HFs occurred among LTCF residents and were most prevalent among females aged 65 or older.

### 2.4.2 Health behaviors

#### 2.4.2.1 Alcohol

Alcohol is a modifiable risk factor that has been found to be associated with osteoporotic HFs. [94] A higher consumption of alcohol may result in a higher probability of fractures because of complex biochemical phenomena involving multiple endocrinal abnormalities. [95] These effects may include impaired free testosterone in men, altered estradiol levels in women,[15] and high cortisol levels in both sexes, which are well-known risks for HFs. [95] In addition, alcoholism results in poor nutritional status and pancreatic insufficiency, particularly of the exocrine type, resulting in malabsorption and low vitamin D levels that again render a patient more prone to HFs. [96] Moreover, alcohol reduces muscle control and induces confusion and memory loss with chronic use; such anomalies may make an individual more prone to falls, thereby indirectly contributing to changes in HF epidemiology. [97]

Alcohol is additionally considered one of the highest risk factors globally for its effects and disease burden on the healthcare system. [94] In Canada, 4258 deaths occurred (1.9% of all deaths) related to alcohol abuse in 2002. [98] In 2012, $14.6 billion was spent on alcohol linked health problems. [99]

Although these descriptions are for the overall population, older adults are no exception. It has been reported that 48% percent of older adults in Canada consume alcohol regularly. [100] Similar findings have revealed similar patterns among older adults elsewhere: approximately 48% of adults aged 65–74 years and 38% of adults 75 years of age and older in the United States consume alcohol regularly. [101] It has also been reported that 11% of Canadians aged 65 years or more exceed the recommended consumption limits. [102]

A pan-Canadian survey indicated that 2.8% of Canadian seniors had at least one additional health problem related to their drinking in the year preceding the survey. It has also been reported that alcohol dependency was present with 6 –11% of all seniors' hospital admission. [103] However, LTC-linked reports on this subject are scarce; one report provided a meager picture that alcohol was a related factor in about 24% of residents affected with dementia. [104] Hence, since alcohol plays a role in bone metabolism and may influence HF incidents, it is an important risk factor to consider.

**2.4.2.2 Smoking**

Smoking is a potentially harmful yet modifiable risk associated with morbidities of various types and negatively affects life expectancy. In Canada, significant numbers of people smoke tobacco; for instance, 22% of Ontario inhabitants smoke. [104] Complex mechanisms are involved in smoking-related pathological changes. Nicotine inhalation in chronic smokers results in an anti-proliferative effect in an individual's bones. [105] It may induce altered calcium and adrenocortical hormonal activity resulting in bone resorption, [106] increased cortisol levels, [107] and altered osteoclastic activity. [108] Smoking also interferes with vitamin D and calcium absorption, in turn altering bone architecture, particularly in postmenopausal women. [109] It has also been found that among older adult smokers BMI was significantly lower relative to non-smokers for both men and women. [110]

Several reports have shown similar hazard patterns of smoking amongst the adult population. One meta-analysis found an increased lifetime HF risk of 31% among women and 40% among men smokers. [16] Similarly, increased risk ratios (RR) have been reported in other meta-analyses: among female smokers RR=1.36 and among male smokers RR=1.59, based on adjustments for BMI. [111] A similar pattern was revealed in another recent meta-analysis based on 14 prospective cohorts (RR=1.47) when comparing current smokers to those who had never smoked. [112] It has been reported that smoking cessation reduces the risk of HFs in men after five years, while the deleterious effects of smoking seem to be more long-lasting in female ex-smokers. [113] Along the same lines, a recent meta-analysis based on ten prospective studies suggested that the positive impact of smoking cessation is realized after ten years from an individual's cessation date but not earlier. [114]

It is sometimes presumed that residents of LTCFs are not able to smoke because they are frail older adults. If one considers the significant proportion of Canadian smokers among the adult population, and the historic pattern of smoking several decades ago when baby boomers were adolescents and smoking was considered trendy, along with the prolonged response time of smoking cessation on HFs (explained above), it is imperative to assess the potential impact of smoking habits among residents in LTCFs.

### 2.4.3 Clinical factors

#### 2.4.3.1 Body mass index (BMI)

Body mass index (BMI) is calculated by dividing an individual's weight in kilograms by his or her height in meters squared. The international standard categories for BMI are shown in Table 2.1. The World Health Organization (WHO) considers a BMI in the range of 18.5-24.9 to be healthy for most adults. [115]

**Table 2.1:** Classification of BMI

| Classification | BMI Category | Risk of developing health problems |
|---|---|---|
| Underweight (low BMI) | <18.5 | Increased |
| Acceptable weight range (also consider normal BMI) | 18.5 - 24.9 | Least |
| Overweight (high BMI) | 25.0 - 29.9 | Increased |
| Obese | | |
| Class I | 30.0 - 34.9 | High |
| Class II | 35.0 - 39.9 | Very high |
| Class III | ≥ 40.0 | Extremely high |

Older age is associated with changes in the internal milieu of the body, including an individual's biochemical composition, muscle mass, and changes in hormonal responses. [116] A lower BMI is often a consequence of ageing, with HFs being an associated risk for those with low BMI. Risk of fractures when adjusted for age has been reported to be inversely proportional to a BMI below 25 in both sexes, with a relatively steeper association among men.[117]

Low BMI is common in LTCFs possibly due to residents' multiple comorbidities and frailty. [118] A meta-analysis, based on 20 studies comprising approximately 20,000 institutionalized residents, reported that a considerable proportion of residents suffered from nutritional problems and low BMI, particularly those with end-stage dementia and long-standing chronic

diseases. It also noted a more widely spread prevalence of low BMI among LTCF residents, albeit with significant variation in exact BMI definitions. [119] A lower BMI and correspondingly lower bone mineral density and their consequential link with HFs raises the importance of further exploration of BMI and its association with HFs in LTC settings.

### 2.4.3.2 Diabetes mellitus

Diabetes mellitus (DM) is a variable disorder of carbohydrate metabolism caused by a combination of hereditary and environmental factors and usually characterized by inadequate secretion or utilization of insulin. There are two types of DM (type I insulin dependent, and type II insulin independent) and both are related to complex endocrinological problems associated with metabolic disturbances in the body. [120] The association of DM (both type I and II) and HFs is correlated. [18,40] Diabetes associated symptoms may include visual disturbances, peripheral neuropathies, frequent hypoglycemic episodes, and otherwise impaired glucose levels. [121] These are all common complications of DM that could indirectly increase the vulnerability to HFs by influencing other potential risk factors, such as falls, for incurring a HF. Both type I and II DM have been linked with factors that negatively influence bone strength and quality and may predispose an individual to HF. [122] In one recent meta-analysis [18] the association between DM and HF risks were similar between men and women. This study was based on data comprising 6,995,272 participants with DM, and 82,293 involving HFs; the resulting analysis shows a risk ratio of 2.07 (95% CI 1.83-2.33) using a random effect model. [18]

The incidence of HFs are reported as high among older adults with DM, particularly older adult women. [123] Additionally, DM is a chronic condition that incurs the risk of prolonged institutionalization for older adults. [124] A higher prevalence of DM in LTCFs has been reported, for instance, in the USA 32.8% of residents are diagnosed to have DM [125] and approximately 27% in Canada[126] Since ample evidence is available showing DM is a risk factor for HF among community dwellers, its association may also be influential in the frail population of LTCFs in the Canadian setting.

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### 2.4.3.3 Rheumatoid Arthritis

Rheumatoid arthritis (RA) is an autoimmune condition associated with inflammatory responses within the joint spaces, leading to joint destruction and deformity, and functional disability. This systemic condition, under the influence of inflammatory markers, frequently develops into a multi-system disorder. RA in advanced age is invariably associated with increased mortality, more frequent hospitalizations, impaired quality of life, and/or multi-system involvement with compromised organ function, for instance, pulmonary, renal, and cardiovascular dysfunction. [127] It is often associated with osteoporosis, a factor behind HF occurrences, either directly due to untoward disease effect or indirectly due to its treatment effects e.g. steroid therapy, which is a mainstay of treatment for RA. Osteoporosis and its sequelae have been a matter of interest for many researchers for decades; numerous studies have shown an association between RA and osteoporosis. [128]

Osteoporotic fractures, particularly HFs, are a serious entity associated with increased mortality and functional disability with those who have RA. A UK-based study based on 30,262 patients with a follow up of 7.2 years revealed an incidence rate of 5.7% for HFs among RA patients. Furthermore, the relative risk was 2.0 (95% CI 1.8-2.3) compared to normal controls. Patients who were using steroid therapy had a relative risk of 3.4; 95% CI 3.0-4.0. [129] A large European study on HF presentations in acute care hospitals revealed 5.6% of HF incidents occur among RA patients, with a relative risk calculated at 3.26 (95% CI 2.26-4.70). [19] A similar trend was reported in another large prospective cohort study involving 47,034 RA patients followed over 1.6 years (median), in which the proportion of patients with RA and HFs was 1.9% and the relative risk for HF was 1.62 (95% CI 1.43-1.84). [130] RA is relatively common among the older adult population but despite this, subset information on RA related to LTCFs in Canada is scarce. Considering its prevalence and pathological nature, this area needs further exploration with a focus on LTCFs and HFs.

### 2.4.3.4 Osteoporosis

Osteoporosis is a metabolic condition resulting in impaired bone mineral density (BMD) making bones brittle and weak. The diagnosis is made by measuring BMD using dual-energy x-

ray absorptiometry (DEXA) or bone densitometry. It is an important public health issue since a significant proportion of seniors are afflicted with fracture risks, which increase threefold with each standard deviation decrease in BMD as measured at the hip. [131] When encountering inadvertent falls, individuals with brittle bones due to osteoporosis are more prone to HFs. [20]

It is estimated that 10–15% of falls result in injury, [132] among them, HF cases are imperative to consider since 90% of HFs are linked with low-stress trauma due to falls. [24] Impact on the neck of the osteoporotic femur can increase HF risks several fold. [20] Concomitant clinical risk factors in seniors include low vitamin D and calcium, which can also independently contribute and augment the risk for osteoporosis and fractures. [133]

Approximately more than two thirds of HFs among elderly females are classified as fragility fractures (due to osteoporosis) despite a similar proportion of these patients never having been investigated and treated for osteoporosis. [134] Males are no exception to this dilemma, as a significant proportion of the male population is also underdiagnosed and under treated for osteoporosis. [135] The Osteoporosis Canada annual report 2009 revealed that the desired level of assessment for BMD, crucial for diagnosis, has not been achieved nationally. For instance, in Alberta, only 33.5% of those over 65 had access to osteoporosis assessment, whereas in BC only 22.2% could access this assessment. [136]

The IRs of osteoporosis-related fractures are up to 15.3 per 1000 person-years. [137] Indeed, up to 95% of women and 27% to 51% of men in LTCFs are thought to have low BMD. [138] In this complex medical milieu, with the higher prevalence of falls, the risk of HFs has continued to increase. [139] Furthermore, many of these LTCF residents have never received a formal assessment for this condition, resulting in higher numbers of untreated older adults. [140] This prevailing situation warrants the evaluation of osteoporosis and its association with HFs in LTC residents.

### 2.4.3.5 Dementia

Dementia is a clinical impairment of memory and its consequential syndromic complex state caused by neurodegeneration. It exists in several forms including Alzheimer's disease (AD), vascular dementia, Lewy bodies dementia, frontotemporal dementia, drug-induced dementia,

mixed dementia, and Parkinson's dementia. It is associated with several symptoms hallmarked by impaired memory and characterized by progression in general cognition, with the eventual loss of capability for independent living. [141] In 2010, 35.6 million people globally were living with dementia, and it is estimated that this figure will double in 2030. [142]

According to the Neurological Health Charities of Canada report, in 2011, 310,000 individuals were living with AD in Canada, and their estimated number will total 639,700 in 2031. [143] This formerly rare disease has become one of the top 8 diseases of priority globally [144] with about 5.3 million individuals with AD in the USA in 2015, among which 5.1 million were 65 years or older. [145] In 2010, 35.6 million people globally were living with AD and it is estimated that the figure will double in 2030. [142]

The incidence of HFs is relatively higher among older adults with dementia. [146] One recent meta-analysis, based on six cohort studies, reported a twofold increase of HFs among people with AD (risk ratio of 2.18). [144] Several factors have been implicated in HF occurrences among those with AD and other forms of dementia with concomitant nutritional deficiencies. [146] For individuals with dementia, falls are most likely due to intrinsic factors related to impaired cognition. The possibility of an intrinsic cause of falls among older adults may be explained by a link between cognition and disturbed gait that may lead to falls resulting in HFs.[147] Seniors with dementia can expect to consume relatively higher levels of pharmacotherapy, such as antipsychotics, anticholinergic, and other medications that may increase the possibility of postural hypotension or syncopal attacks further resulting in impaired balance and falls. [148]

HF morbidity associated with dementia and Alzheimer's is also higher among LTCF residents in Canada. In a report conducted with institutionalized older adults in Canada, the risk ratio for HFs for those with Alzheimer's disease was reported as 2.18 (95% CI 1.26-3.79).[41] Further, recent evidence from Ontario suggests that within 280 days of admission to a LTCF, there is a higher risk of HFs among residents with neurological conditions, including dementia and Alzheimer's disease.[149] Statistics Canada reported the prevalence of dementia and Alzheimer's disease among LTC residents in 2011-2012 was 39.8% for men aged 65–79 years, rising to 53.1% for men over 80 years of age; and 43% for women aged 65–79 years, rising to

56.8% for women over 80.[150] Therefore, consideration of these types of morbidity indices is important for the evaluation of HFs in LTCFs.

### 2.4.3.6 Parkinson's Disease

PD is a complex neurodegenerative disorder of bodily movement, which is second in frequency to Alzheimer's disease among the aged population. It is a neuro-psychiatric syndrome manifested by overlapping features of muscular rigidity, slowing of movement, dementia, and ranges from depressed mood to overwhelming psychosis and insomnia with devastating autonomic dysfunctions in later stages. [151]

PD is associated with individual and societal effects, including decreased quality of life [152] and increased mortality,[151] increased health expenditures,[153] increased co-morbidities,[152] and increased pharmaceutical usage.[154] These features are more prominent among residents living in LTCFs.[155] A Canadian study reported an average age of Parkinson's afflicted LTC residents of 82.6 years, with a prevalence of 6.2% among all LTCF residents in Canada.[156]

HFs in patients with PD is most probably due to muscle rigidity and reduced mobility frequently associated with falls.[157] This is further complicated by a high prevalence of low BMD and osteoporosis among this vulnerable population[158] affecting around 91% and 61% of women and men with PD respectively.[159] Similarly, the use of multiple pharmaceuticals, particularly neuroleptics, also raises a preponderance to HFs.[160]

Several recent studies have reported a higher risk of HFs in PD. For instance, in a stratified sample comprised of 20% of US hospital admissions over approximately two decades, a total of 3.63% HFs among PD patients was noted, with the prevalence of PD up to 4.48 times higher as compared to other types of morbidity after adjusting for age and sex.[161] In Taiwan, it has been reported that HFs occur in 10.4% of PD-afflicted patients, versus 4.1% among people without PD.[23]

Many older adults with PD eventually live in LTCFs due to overwhelming disabilities. For instance, 10% of residents diagnosed with PD usually have multiple co-morbidities.[152] Recent evidence from BC has suggested the occurrence of falls among PD residents in LTCFs is RR 1.3 (95% CI 1.03—1.65) higher than among those without PD.[162] Although reports on HFs secondary

to PD in Canadian LTCFs are not available, the impact of PD may be considered an important risk factor for HFs in this frail population.

### 2.4.3.7 Falls

Falls are the leading cause of injury hospitalizations for seniors across the country, contributing to 9% of all emergency department visits by older adults. It is estimated that one in three people aged 65 and over experiences a fall each year.[139] In Canada, approximately 1.4 million seniors fell at least once in 2005, it is estimated that in 2036, this figure will increase to 3.3 million.[163] Falls can lead to serious injuries, reduced mobility, LTCF admission,[24] and are the leading cause of both fatal and non-fatal unintentional injuries among seniors.[164] It is reported that 0–15% of fall-oriented injuries resulted in serious injuries, including fractures and head injuries, and about 0.2 to 1.5 percent of falls resulted in a HF[132] of which 90% of such cases were linked to low-stress trauma.[24]

In 2008-2009, the age-standardized rate of hospitalization due to falls was 15.5 per 1000 for older adults.[165] Compared to all reasons for hospitalization among Canadian seniors, fall-related hospitalizations account for 7.3%, with Newfoundland having the lowest percentage (5.3%) and BC having the highest (8.2%). The percentage of fractures (all types) among hospitalization due to falls in 2008-2009 was approximately 95% in Canada and the same in BC.[166]

Underlying issues that can lead to a fall include muscle weakness, vision problems, and side effects from medications. In some cases, cognitive impairment, including dementia and delirium, can increase the risk of a fall. [24] The frequency of falls is a key predictor of future incidents; for example, persons who had a fall within the previous month were five times more likely to experience another fall. Other risk factors for falls include increasing age and patients requiring supervision or physical guidance to walk.[45]

Among seniors, incidents of falls are even higher, with 1.7 falls per bed per year being reported.[167] These incidents can be explained by individuals experiencing greater frailty, less independence, and more frequent chronic conditions.[168] In one study conducted on LTCF residents in BC, it was reported that the risk of HF was increased several-fold by falls. The same

study reported that separate multiple fall events are more likely among older age groups. For instance, 227 falls were reported involving 130 individuals (mean age 78 years).[25] Moreover, the fall related hospitalization rate is 3.6 times higher for LTCF residents as compared with community seniors.[169] The description of falls mentioned above necessitates risk assessments for HFs in LTCFs.

## 2.5 Hip fractures and the environment

### 2.5.1 Hip fracture in the general population

Fracture rates are known to vary between different geographical locations worldwide.[170] Estimates of HF incidents in Canada have indicated variations in age-adjusted rates both within and between provinces.[137] Variability due to age and sex has already been established and may be associated with differences between and within geographical regions.[4] For instance, the Canadian Multicenter Osteoporosis study in 2001[171] reported variations in BMD and other risk factors in different regions of Canada along with different HF incidence across provinces and cities. Fig 2.1 shows variation in different Canadian cities.[171]
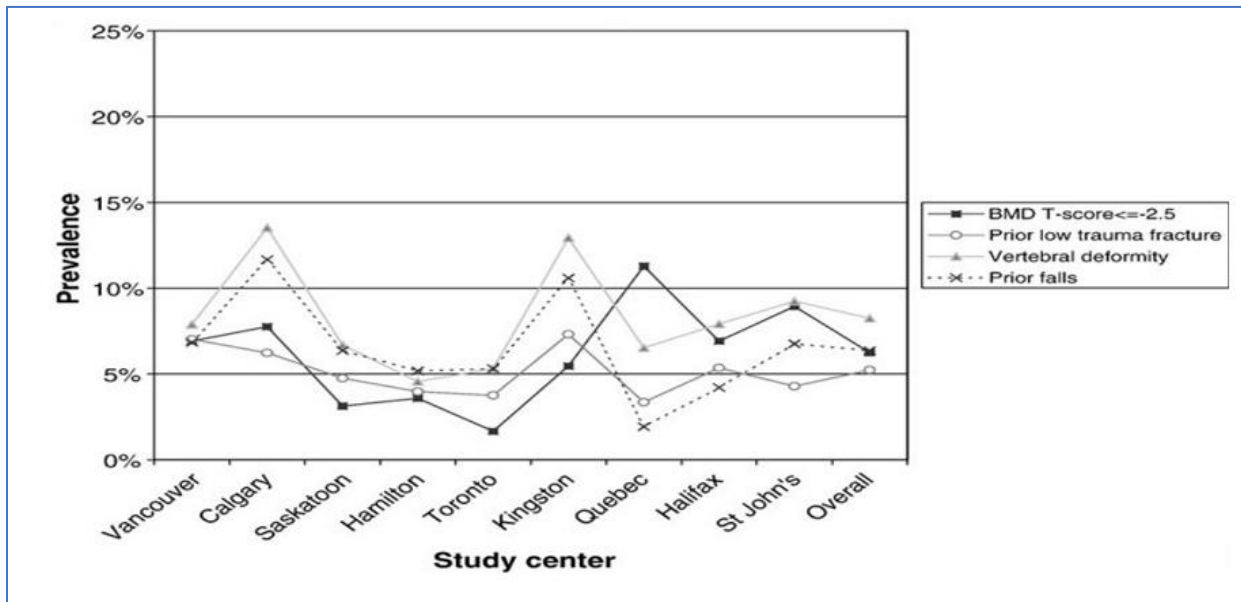


**Figure 2.1:** Variability in BMD score and other risk factors in different regions of Canada

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Similarly, falls are cited for having a strong association with geographic variations and low-trauma fractures. The European Prospective Osteoporosis Study (EPOS) has suggested that variable patterns of HFs are more likely attributable to the type of fall, rather than BMD alone.[172] Possible sources of geographic variation include genetic variations leading to variations in upper body sway, fall height, and vitamin D status; variations of nutrition and lifestyle variables; and finally, variations in snow and ice conditions. Fall frequency appears to be a contributing factor to geographic fracture variations.[137] The following section reviews LTCFs from the place perspective.

### 2.5.2 Hip fracture and facility size

LTCFs are categorized based on the number of beds: small (<30), medium (31-99) and large (> 99). Until recently, the literature did not provide reports on HF incidence variability by facility size. Thorpe et al.[13] revealed that large facilities in urban locations showed lower age-standardized IRs compared to rural areas. However, several facility-related characteristics have been described in the literature without the context of HFs and may be relevant to this morbidity. For instance, since small-sized and remotely located facilities may not have highly expert nurses and physicians (including specialists) circulating in the facilities around the clock, it can be assumed that smaller facilities may have different clinical outcomes as compared to larger state-of-the-art facilities.[173]

When considering LTCFs as systems, their mechanics can be seen to revolve around two fundamental dynamics: structural indicators and processes. These two crucial factors interplay individually and collectively in the health outcomes. Structural indicators consist of many components, including a facility's location, size as measured by bed capacity, and the presence of supporting laboratories. Additionally, human resources, including physicians, clinical associates, nursing staff, and other supporting staff, play a significant role in residents' health outcomes. However, information on the impact of these factors on health outcome is limited in the literature current. [174] Similarly, reports are scarce on procedural indicators about residents' diagnoses, comorbidities, and multifactorial complex management procedures, preventive strategies, and pharmacotherapy that significantly impacts health outcomes. [175]

Large facilities are more likely to have better and readily available support vis-à-vis specialist consultation and review.  These facilities are usually equipped with more modern technology and are better staffed. In terms of hospital attachment, facilities that are amalgamated with a regional health authority, or exist as multiple sites, may have access to a broader range of services and, therefore, yield better outcomes.[176] Similarly, differences in supporting staff numbers, qualification levels, working hours, privileges, and remuneration may exist between the large LTCFs located in metropolitan cities and small-isolated rural facilities. It has been reported that such differences may result in limitations to clinical assessments and diagnostic evaluations, resulting in compromised clinical outcomes.[177]

Recent Canadian research[178] focused on failures in combating potentially avoidable conditions within LTCFs. The report revealed that factors such as services and diagnostic capacities may ameliorate potentially avoidable hospitalizations. For example, up to 37% of hospitalizations among LTCF residents can be ascribed to such deficiencies. HFs accounted for 28% of preventable hospital admissions.[178] Therefore, such facility related factors could be important in HF morbidity. The epidemiology of HFs from the facility size perspective has not yet been assessed. However, given that facility size may affect the characteristics of care provided to LTCF residents, further evaluation of HFs by facility size is warranted.

### 2.5.3 Hip fracture by health region

One Canadian report showed variable IRs in different health regions within a province. In Saskatchewan, IRs for HFs were slightly varied between health regions from 41.96 to 75.24 fractures/per 1000 person years.[13] The rest of the provinces, including BC, do not have any reports published yet. In BC, LTCFs are established in all five health regions (i.e., Interior Health, Fraser Health, Vancouver Coastal Health, Vancouver Island Health, and Northern Health). Considering the variation of HFs in terms of the location of the BC health regions is also needed.

### 2.5.4 Hip fracture by rural/urban location

In the context of geographical variation in HF epidemiology, various published reports have described rural and urban differences. Predominantly, urban settings have shown higher

IRs of HFs than rural settings. [26,27] Aside from HFs, differences in healthcare treatment outcomes (e.g., better in urban settings due to secondary-tertiary hospital availability) between rural and urban settings have been discussed, which would presumably hold importance for HFs. [173,179]

Generally, urban settings have higher reported IRs for HFs than rural settings,[28,180] however, several studies showed contradictory patterns. For example, one study reported a higher HF incidence in the urban areas, compared to rural areas in Sweden, [181] but another study from the same Scandinavian country reported no difference. [182] A nine-year prospective cohort study in Poland revealed a significantly and relatively lower urban HF rate. [183] Whereas, in Iran, the reported incidences of HFs in urban areas were higher than that of rural areas. [184] Hong Kong showed similar results, with HFs being more common in urban areas, whereas in Shanghai, HFs are not as common.[185] In contrast, urban Taiwan has been estimated to possess Asia's third highest HF rate among all urban areas studied. [186] These variations in urban versus rural areas may be ascribed to different methodologies, recruitment criteria, and/or differences in characteristics of the study populations i.e. differences in BMD in urban-rural area. [187]

Regarding rural-urban locations and LTCFs there is only one study from Saskatchewan that reported HF IRs at the provincial level. [13] This study revealed that standardized HF rates for males and females were lowest in urban settings, but age and sex-stratified HF rates were similar across urban and rural settings, with the exception of females aged 90 or over, where rates were higher in urban areas and lower in rural areas.

In conclusion, given the wide array of evidence detailing the link between older adults and HFs, this study has decided to focus on LTCFs in BC, where a significant number of older adults are residing in LTCFs. Hence, the evaluation of HF IRs and their association with risk factors will add beneficial information for the Canadian LTCFs.

# CHAPTER 3

## 3.0 Methodology

In this chapter, the data sources and study population are described, followed by details regarding the variables measured and the statistical analyses conducted, the latter organized according to research question.

## 3.1 Data sources and study population

The data for this study was obtained through two data sources compiled by the Canadian Institute for Health Information (CIHI):

1. The CIHI-Discharged Abstract Database (CIHI-DAD); and

2. The Continuing Care Reporting System (CCRS) that keeps information provided by LTCFs of BC recorded by the standard protocol of Resident Assessment Instrument–Minimum Data Set 2.0 (RAI-MDS 2.0).

The CIHI-Discharged Abstract Database (CIHI-DAD) is a Canadian national database that stores information on all international classifications of diseases in Canada (ICD-10-CA), with coded entities from acute care institutions in Canada, including discharges. This data has been validated for HF morbidity.[188] The CCRS contains demographic and clinical information for residents as well as LTCF related information, including the number of beds in each facility and facility location.[189] Resident information stored in the CCRS is collected using the Resident Assessment Instrument–Minimum Data Set 2.0 (RAI-MDS 2.0).[190] The first assessment using the RAI-MDS 2.0 is conducted when an individual is first admitted into a LTCF and is then assessed every three months. Residents' information for co-morbidities in the RAI-MDS 2.0 is available only in the form of "Yes" or "No"; no information is available on disease stage or severity. In BC, the CCRS database typically contains LTCF data and, unlike other provinces in Canada, does not contain the number of LTCF beds situated within acute care facilities or within hospitals.[191] Considerable evidence attests to the reliability and validity of RAI-MDS 2.0 in Canada.[192] These datasets were linked using an encrypted residents' ID number and various inclusion/exclusion criteria were applied to create a study population (Figure 3.1).
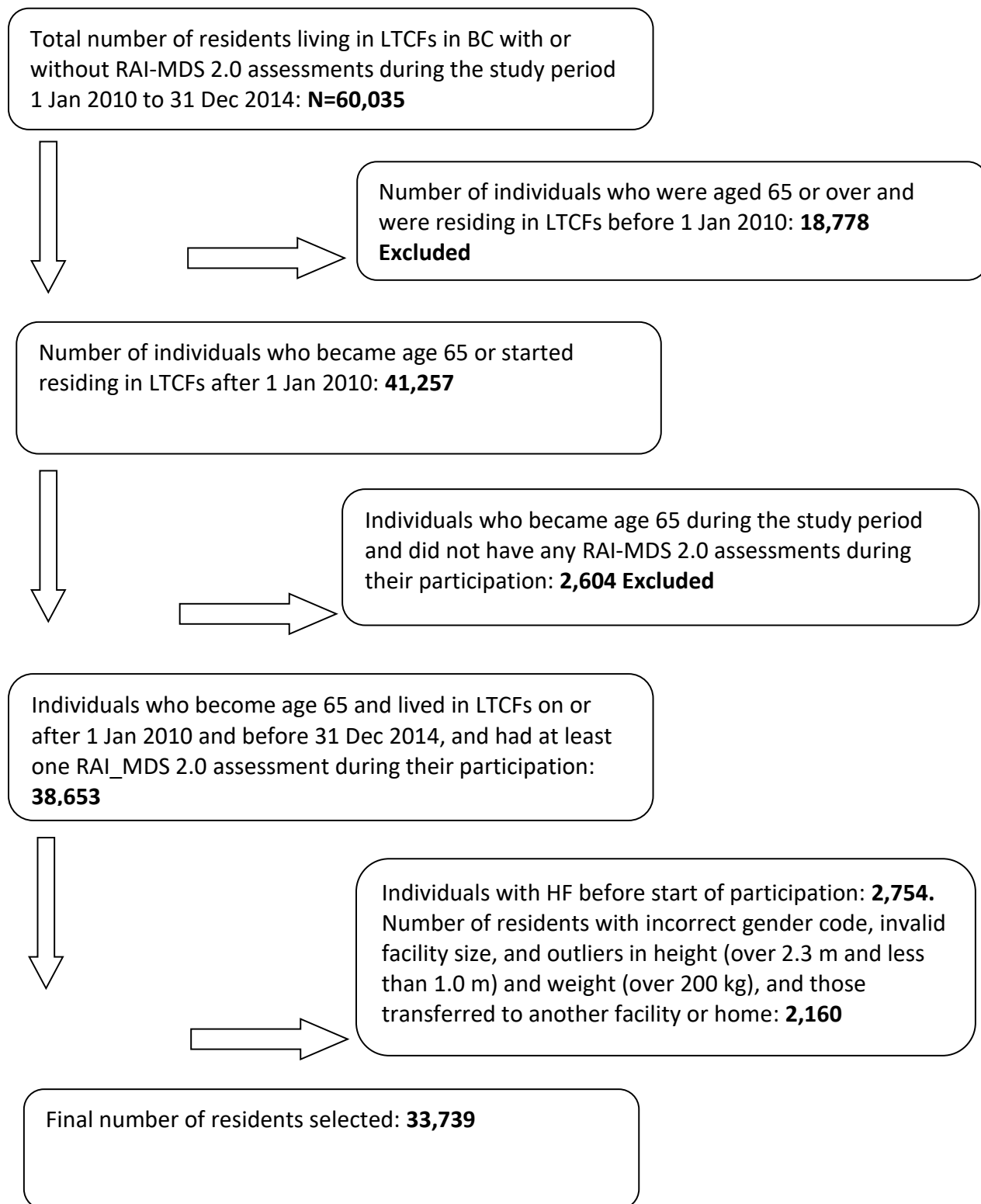
**Figure 3.1:** Flowchart of steps for cohort selection of residents of LTCFs in BC

The inclusion criteria for this study included being a resident in a BC LTCF between January 01, 2010 to December 31, 2014, with the age of admission being 65 years or older during the study period, sex recorded as male/female, and at least one RAI-MDS 2.0 follow-up assessment available. To obtain residents' demographic and clinical information, the most recent RAI-MDS 2.0 assessment was used.

The exclusion criteria included residents with unclear age/sex specifications, with dual entry or unavailable assessment data, younger than 65 years of age throughout the study period, with no initial or follow-up RAI-MDS 2.0 assessment, or with a history of HFs before the study start date, and/or other HFs (if any) followed by one during the study period. The residents transferred to another facility or to home were also excluded. The final cohort for this study included 33,739 older adults who entered one of 305 LTCFs located in the province of BC, Canada from January 01, 2010 to December 31, 2014. The data provides an admission date and a discharge date (i.e., discharge equals death). Residents transferred to other LTCFs or to their homes were excluded from the analyses.

Given that this study used publicly available CIHI data, it was deemed as exempt from the requirement of Research Ethics Board review and approval according to article 2.2 of the Tri-Council Policy Statement (TCPS).

## 3.2 Study Variables

### 3.2.1 Dependent variable

Hip fracture events were identified from CIHI-DAD data, categorized according to the International Classification of Diseases, 10th Revision, Canada (ICD-10) code S72.0, S721 or S72.2[193] between January 1, 2010 and December 31, 2014; the first event of HF was defined as the first dated record of HF occurring post LTC entry for an individual within the study period. Only first HF events were considered and combined with appropriate denominators to estimate hip fracture incident rates (research question 1) and used as a dichotomous dependent variable (yes, no) in logistic regression analyses (research question 2).

## 3.2.2 Independent variables

Independent variables were used to provide strata-specific estimates of the incidence of HFs (research question 1) and/or as predictors of incident HFs in multiple logistic regression analysis (research question 2). Person variables included age (65-79 years, 80-89 years, ≥90) and sex (female, male). Three variables were used to represent place: LTC facility size (small: less than 30 beds, medium: 31-99 beds, large: >99); BC health region (interior, Fraser, Vancouver Coastal, Vancouver Island, Northern); and LTC facility location (urban, rural). Urban was defined as having a population of at least 1,000 and a density of 400 or more people per square kilometer; areas outside an urban area were classified as rural, which may include mid and large size towns with a population density of <400/kilometer. [194] This Statistics Canada definition of rural-urban location has been widely used [194] including in the CCRS. [191] Time was represented by 5 one-year time intervals (2010-2014).

Additional independent variables based on initial RAI-MDS 2.0 assessments were also assessed. Health behaviors included current smoking (yes/no) and current alcohol consumption (yes/no). BMI was categorized as underweight (less than 18.5 kg/m$^2$), normal (18.5 kg/m$^2$-25kg/m$^2$), overweight (25 kg/m$^2$ - 30 kg/m$^2$), and obese (over 30 kg/m$^2$). Current comorbidities assessed (yes/no) were diabetes mellitus (DM), rheumatoid arthritis (RA), osteoporosis, dementia, and Parkinson's disease (PD). Two measurements of physical falls were also considered: (i) having fallen within the last month prior to a HF event (yes/no), and (ii) having fallen during the last six months (yes/no; excluding first 30 days prior to a HF event). The information was retrieved electronically from the CCRS data using the International Classification of Diseases, 10$^{th}$ Revision, Canada (ICD-10) codes for all independent variables.

## 3.3 Statistical analysis

All analyses were performed with SAS 9.4.[195] Initial descriptive statistics involved determining the overall frequency distribution of study variables, followed by a series of chi-square analyses examining the distribution of variables by HF presence/absence.[196]

To address the first research question, the crude HF rate was calculated, and then stratified HF rates were calculated by age, sex, place, and time. The HF IR was defined as the ratio of the number of people who experience HFs to the total person-years of follow-up. The stratified IRs utilized the same ratio but limited the numerator and denominator to the strata-specific numbers under consideration. For example, the sex-stratified HF IR for males was calculated as the ratio of the number of HFs among males to the person-years of follow-up for males.

A series of binary logistic regression analyses were conducted [196] to answer the second research question. In the first stage, univariate logistic regressions were applied with each risk factor as an independent variable and HF as the dependent variable; variables with a p-value of <=0.25 were retained for additional consideration. In the second stage, variables meeting the criteria were simultaneously entered into the analysis; variables with the highest p-value were removed one at a time, and the analysis repeated with the newly reduced set of variables. This iterative process was repeated until only risk factors with p-values < 0.05 remained in the model. In the third stage, all potential 2-way interactions were examined; each interaction was added to the model one at a time, with the intention of retaining any with a p <0.05.  In the final modeling stage, variables previously excluded were entered again one at a time to assess for potential confounding. Finally goodness-of-fit was assessed with the Hosmer-Lemeshow calibration method and multicollinearity was investigated by examining Variance Inflation Factor (VIF) values. [197]

# CHAPTER 4

## 4.0 Results

The chapter begins with initial descriptive results, focusing initially on the overall distribution of study participants according to person, place, and time variables. The incidence of hip fracture stratified by person, place, time, health behaviors, and clinical conditions is then presented.  In the remainder of the chapter, results are shown according to the research questions.

## 4.1 Sample characteristics

Overall, 1,897 LTCF residents (6%) out of a sample cohort of 33,739 (100%) experienced HFs during the study period (2010–2014). The median time to initial HF events after entering a LTCF was 0.83 (95% CI: 0.77-0.89) years. There was no loss to follow-up as residents transferred to other LTCFs or to homes were excluded from the sample in this study (Fig 3.1).

Table 4.1 shows the frequency distribution of participants by person, place, and time characteristics and by health behaviors and various clinical measures in Table 4.2. Approximately 20% of seniors entered the cohort in each year of the study, the majority being female (62%), and 80 years of age or older (74%). The vast majority of participants resided in urban settings in large or medium size facilities. The greatest proportion of residents were situated in the Fraser Health region (29%) and the lowest proportion (4%) in the Northern Health region. Very low proportions of the cohort were current smokers or alcohol drinkers, and just over one-half had a normal BMI. The most prevalent clinical condition was dementia (63%), followed by rheumatoid arthritis (30%), diabetes (21%) and osteoporosis (18%), An equal proportion of participants had fallen in the last month or the last six months prior to a hip fracture event (19%).

**Table 4.1:** Frequency distribution of study cohort across time, person, and place risk factors

| Variable | | Category | Number | Percent |
|---|---|---|---|---|
| **Time** | Years | 2010 | 6809 | 19.9 |
| | | 2011 | 6859 | 20.1 |
| | | 2012 | 6786 | 19.9 |
| | | 2013 | 6948 | 20.3 |
| | | 2014 | 6770 | 19.8 |
| **Person** | Age groups | 65-79 years | 8813 | 25.8 |
| | | 80-89 years | 16463 | 48.2 |
| | | >=90 years | 8896 | 26.0 |
| | Sex | Female | 21030 | 61.5 |
| | | Male | 13142 | 38.5 |
| **Place** | Facility size | Large | 19688 | 57.6 |
| | | Medium | 13809 | 40.4 |
| | | Small | 671 | 2.0 |
| | | Interior Health | 7803 | 23.1 |
| | Health region | Fraser Health | 9837 | 29.1 |
| | | Vancouver Coastal Health | 7411 | 21.9 |
| | | Vancouver Island Health | 7482 | 22.0 |
| | | Northern Health | 1304 | 3.9 |
| | | Rural | 3738 | 10.9 |
| | Location | Urban | 27059 | 79.2 |
| | | Missing | 3375 | 9.9 |

**Table 4.2:** Frequency distribution of study cohort by health behaviors and clinical risk factors

| Variable | Category | | Number | Percent |
|---|---|---|---|---|
| **Health behavior** | Current smoking | Yes | 1066 | 3.1 |
| | | No | 29398 | 86.0 |
| | | Missing | 3708 | 10.9 |
| | Current alcohol consumption | Yes | 37 | 0.1 |
| | | No | 34135 | 99.9 |
| **Clinical** | BMI | Under weight | 4116 | 12.0 |
| | | Normal | 17502 | 51.2 |
| | | Over-weight | 8329 | 24.4 |
| | | Obese | 4225 | 12.4 |
| | Diabetes (DM) | Yes | 7161 | 21.0 |
| | | No | 27011 | 79.0 |
| | Rheumatoid Arthritis (RA) | Yes | 9840 | 29.8 |
| | | No | 23142 | 70.2 |
| | Osteoporosis | Yes | 6023 | 18.3 |
| | | No | 26959 | 81.7 |
| | Dementia | Yes | 21070 | 62.7 |
| | | No | 12523 | 37.3 |
| | Parkinson's disease (PD) | Yes | 2005 | 6.1 |
| | | No | 30977 | 93.9 |
| | Fall in the last 30 days before hip fracture event | Yes | 6518 | 19.1 |
| | | No | 27654 | 80.9 |
| | Fall in the last 6 months (excluding first 30 days) before hip fracture event | Yes | 6535 | 19.1 |
| | | No | 27637 | 80.9 |

Table 4.3 shows bivariate associations between hip fracture and various independent variables. HF was associated with female sex, older age, and residing in a medium/small facility. There were no statistically significant associations of hip fracture with health region, current smoking, or current alcohol use.

**Table 4.3:** Frequency distribution of hip fracture stratified by demographic, geographical, and behavioral risk factors

| Variables | | Hip fracture No | | Hip fracture Yes | | p-value |
|---|---|---|---|---|---|---|
| | | N | % | N | % | |
| Age | 65-79 | 8436 | 95.7 | 377 | 4.3 | <.0001 |
| | 80-89 | 15431 | 93.7 | 1032 | 6.3 | |
| | >=90 | 8391 | 94.3 | 505 | 5.7 | |
| Sex | Female | 19656 | 93.5 | 1374 | 6.5 | <.0001 |
| | Male | 12602 | 95.9 | 540 | 4.1 | |
| Facility Size | Large | 18649 | 94.7 | 1039 | 5.3 | |
| | Medium | 12972 | 93.9 | 837 | 6.1 | 0.0047 |
| | Small | 633 | 94.3 | 38 | 5.7 | |
| Health Region | Interior Health | 7362 | 94.3 | 441 | 5.7 | |
| | Fraser Health | 9299 | 94.5 | 538 | 5.5 | |
| | Vancouver Coastal Health | 7010 | 94.6 | 401 | 5.4 | 0.3904 |
| | Vancouver Island Health | 7050 | 94.2 | 432 | 5.8 | |
| | Northern Health | 1219 | 93.5 | 85 | 6.5 | |
| Location | Rural | 3257 | 94.4 | 211 | 5.6 | |
| | Urban | 25564 | 94.5 | 1495 | 5.5 | 0.0047 |
| | Missing | 3167 | 93.8 | 208 | 6.2 | |
| Current smoking | Yes | 1012 | 94.9 | 54 | 5.1 | 0.4799 |
| | No | 27737 | 94.3 | 1661 | 5.7 | |
| | Missing | 3509 | 94.6 | 199 | 5.4 | |
| Current alcohol | Yes | 36 | 97.3 | 1 | 2.7 | 0.4430 |
| | No | 32222 | 99.9 | 1 | .002 | |

Table 4.4 shows that lower BMI and a diagnosis of diabetes were associated with a lower risk of HF, whereas a diagnosis of osteoporosis, dementia, or a fall in the last month were associated with an increased risk. No relationship emerged between HF and rheumatoid arthritis, Parkinson's disease, or a fall in the last 6 months.

**Table 4.4:** Hip fracture frequency distribution stratified by individual clinical risk factors.

| Variables | | Hip fracture No | | Hip fracture Yes | | p-value |
|---|---|---|---|---|---|---|
| | | N | % | N | % | |
| Clinical | | | | | | |
| BMI | Under weight | 3850 | 93.5 | 266 | 6.5 | < 0.0001 |
| | Normal | 16385 | 93.6 | 1117 | 6.4 | |
| | Over-weight | 7943 | 95.4 | 386 | 4.6 | |
| | Obese | 4080 | 96.6 | 145 | 3.4 | |
| Diabetes | Yes | 6833 | 95.4 | 328 | 4.6 | < 0.0001 |
| | No | 25425 | 94.1 | 1586 | 5.9 | |
| Rheumatoid arthritis | Yes | 9310 | 94.6 | 530 | 5.4 | 0.2774 |
| | No | 21826 | 94.3 | 1316 | 5.7 | |
| Osteoporosis | Yes | 5625 | 93.4 | 398 | 6.6 | 0.0002 |
| | No | 25511 | 94.6 | 1448 | 5.4 | |
| Dementia | Yes | 19694 | 93.5 | 1376 | 6.5 | < 0.0001 |
| | No | 12019 | 96.0 | 504 | 4.0 | |
| Parkinson's disease | Yes | 1902 | 94.9 | 103 | 5.1 | 0.3553 |
| | No | 29234 | 93.9 | 1743 | 5.6 | |
| Fall in the last month (30 days) prior to hip fracture event) | Yes | 6112 | 93.8 | 406 | 6.2 | 0.0143 |
| | No | 26146 | 94.6 | 1508 | 5.4 | |
| Fall in last 6 months (excluding first 30 days prior to hip fracture event) | yes | 6182 | 94.6 | 353 | 5.4 | 0.4357 |
| | No | 26076 | 93.9 | 1561 | 5.6 | |

Total study subjects (N=33,739)

## 4.2 Research question one

*What is the incidence of hip fracture for residents aged 65 years and older living in LTCFs in BC, Canada, patterned by time (2010-2014), person-level factors, and place?*

### 4.2.1 Crude and stratified incidence rates

The crude HF IR over the five-year period was 3418/100,000 person-years. As illustrated in Figure 4.1, there was a general downward trend in the incidence of HFs when stratified by study period, with incidences ranging from 3850.5/100,000 person-years in 2010 to 3146.4/100,000 person-years by 2014.
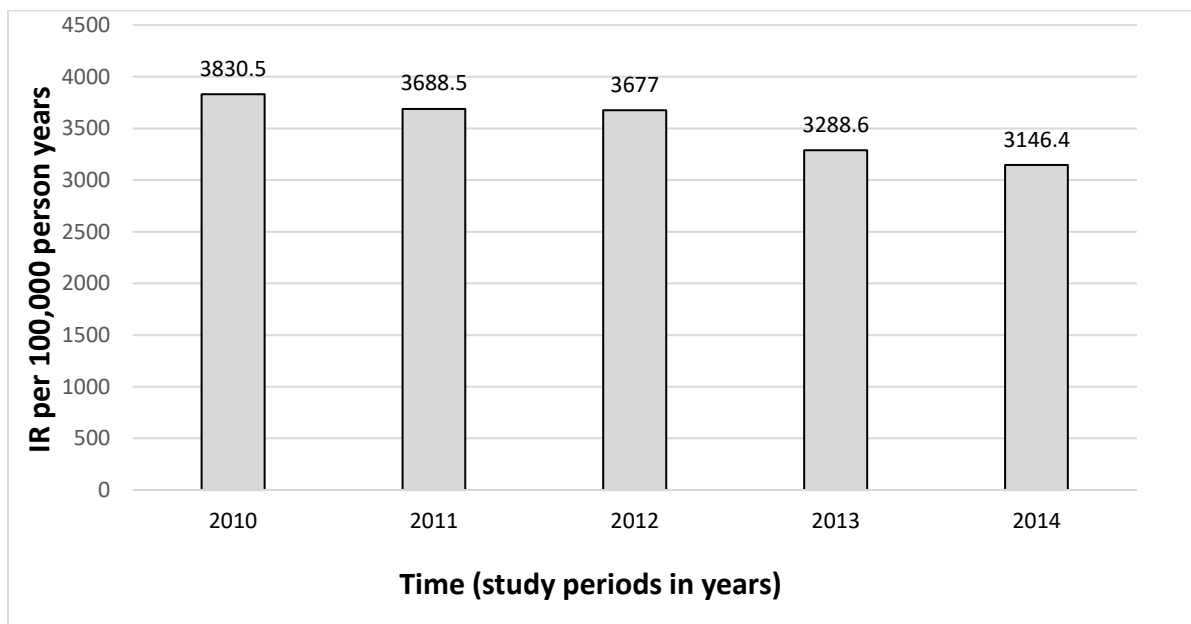


**Fig 4.1**: Temporal trend of crude hip fracture incidence rate

The incidence of hip fracture increased with age and was higher in females compared to males (Table 4.5). Regarding place characteristics, incidence rates were highest in medium size facilities and in rural regions compared to urban regions.

**Table 4.5:** Hip Fracture incidence rates by age, sex, facility size, and rural/urban location

| Variables | | Levels | Hip fractures | Person-Years | Incidence rate |
|---|---|---|---|---|---|
| Person | Age | | | | |
| | | 65-79 years | 329 | 13901.6 | 2366.6 |
| | | 80-89 years | 982 | 26369.6 | 3723.9 |
| | | >=90 years | 586 | 15224.3 | 3849.0 |
| | Sex | Female | 1365 | 35710.9 | 3822.3 |
| | | Male | 532 | 19784.8 | 2688.9 |
| Facility size | | Large | 1024 | 31730.0 | 3227.2 |
| | | Medium | 835 | 22558.3 | 3701.5 |
| | | Small | 38 | 1207.4 | 3147.1 |
| | | Health regions | | | |
| Health Region | | Interior Health | 441 | 11797.7 | 3738.0 |
| | | Fraser Health | 538 | 17755.7 | 3030.0 |
| | | Vancouver Coastal Health | 401 | 12441.8 | 3223.0 |
| | | Vancouver Island Health | 432 | 11398.4 | 3790.0 |
| | | Northern Health | 85 | 2412 | 3524.0 |
| | | Rural-urban | | | |
| Location | | Rural | 210 | 5688.7 | 3692.0 |
| | | Urban | 1480 | 43760.7 | 3382.0 |
| | | Missing* | 207 | 6046.3 | 3423.5 |

Figure 4.2 displays incidence rates by health region. The highest HF incidence rate was reported in the Vancouver Island Health Authority and the lowest in the Fraser Health Authority.
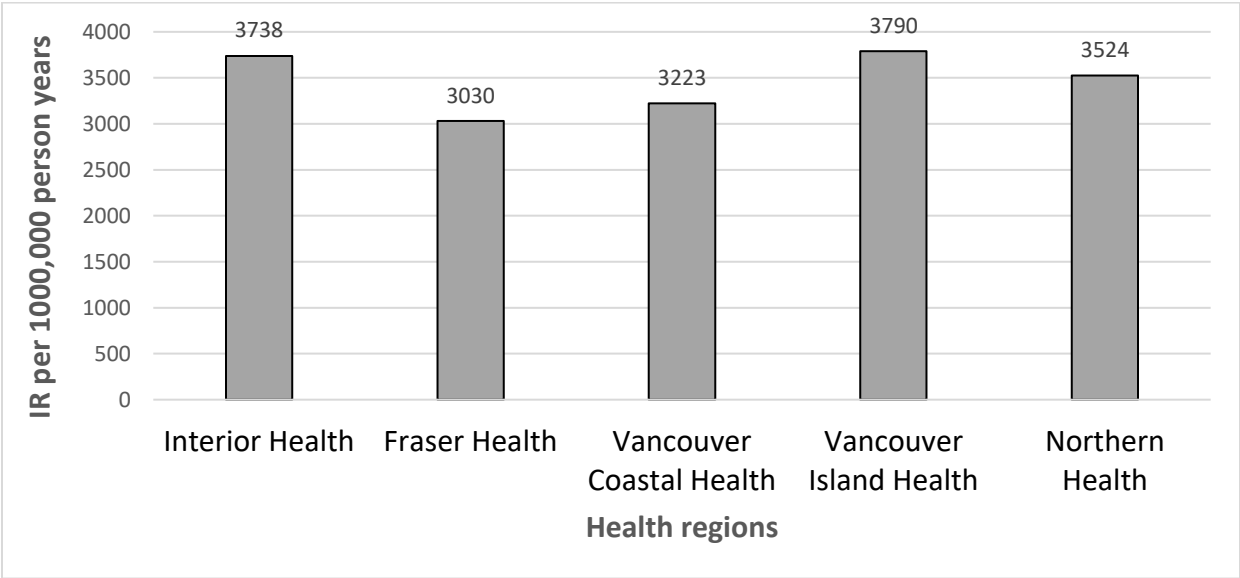


**Figure 4.2**: Hip fracture incidence rate across BC health regions

The remaining statistics in this section describe HF incidence rates stratified by a combination of person, place, and time characteristics.

Females showed a higher HF IR compared to males during each study period and in all three age groups, with the exception of 65-79 year olds in 2010. (Fig 4.3). Focusing on time trends (Figure 4.3), females in the youngest age group showed a fluctuating pattern starting from 2283/100,000-person years in 2010, rising to 3409/100,000-person years in 2011, followed by a return down to baseline, only to rise again in 2014. In contrast, 65-79 year old males showed a steady downward trend in IRs between 2010 and 2014.

Females 80-89 years of age and those in the eldest age group showed approximately similar IRs from 2010–2014 (just above or below 4000/100,000 person years). Conversely, IRs in males in these two age groups fluctuated. For instance, males aged 80-89 years showed IRs of approximately 4200/100,000-person years in 2010, followed by a significant decline to approximately 2700/100,000 person years in 2014. However, males in the eldest age group (>=90 years) showed a dramatic increase from 2100/100,000 person years in 2010 to >4600/100,000 person years in 2011, followed by the steady downward pattern just below or above 3000/100,000 person-years.
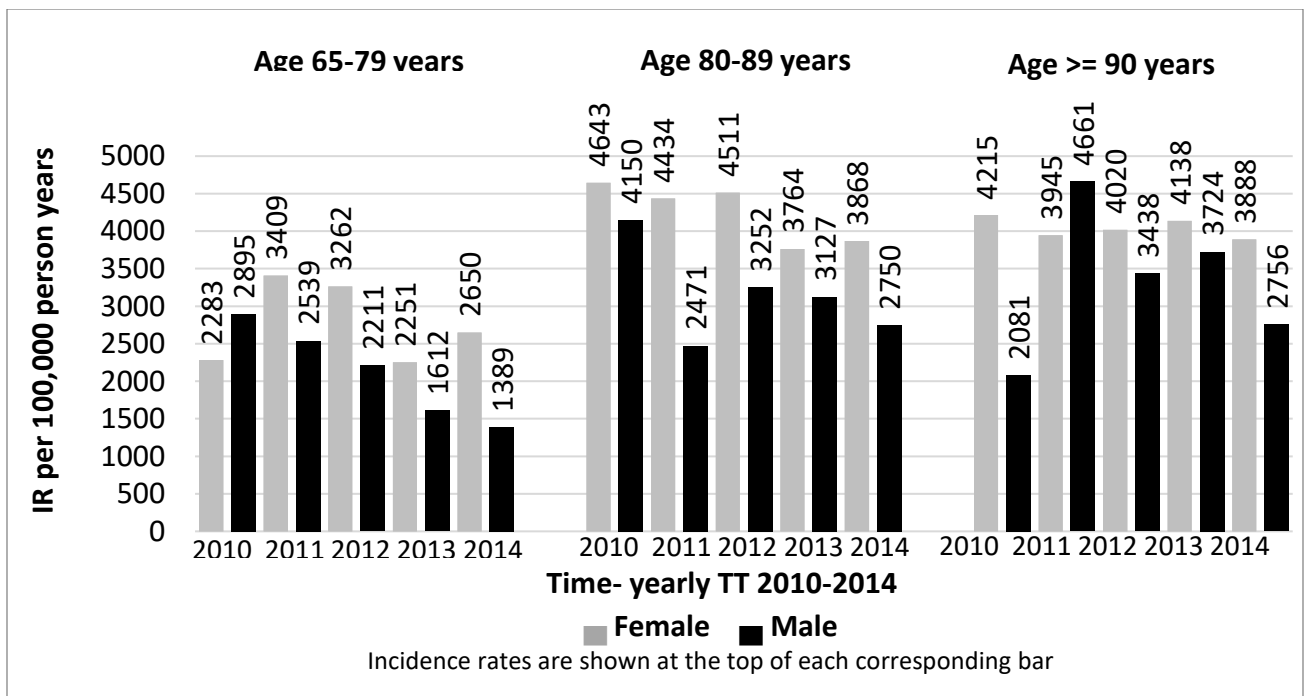


**Figure 4.3:** Hip fracture incidence rate stratified by year, age and sex

Figure 4.4 displays HF IRs stratified by facility size, rural/urban location, and age. In **large size facilities** among those 65-79 years of age, both rural and urban localities displayed IRs at 2500/100,000 person years or less, which were lower than the other age groups. For rural dwellers aged 80-89 years of age, the IR was considerably higher than their urban counterparts.

In **medium size facilities** (Figure 4.4), the lowest IRs were observed among those 65-79 years old in rural areas, followed by urban areas. Among those 80-89 years old in medium size facilities, HF IRs were also lower in rural than urban facilities; however, among residents 90 years and older residing in medium size facilities, HF IRs were greater in rural settings compared with urban ones.

**In small size facilities** (Figure 4.4), the youngest age groups showed the lowest IRs. Of all groups, the highest HF IR was reported in those age 90+years, residing in small facilities located in rural BC. Among those in small facilities, HF IRs were lower in urban dwellers compared to rural across all age categories.
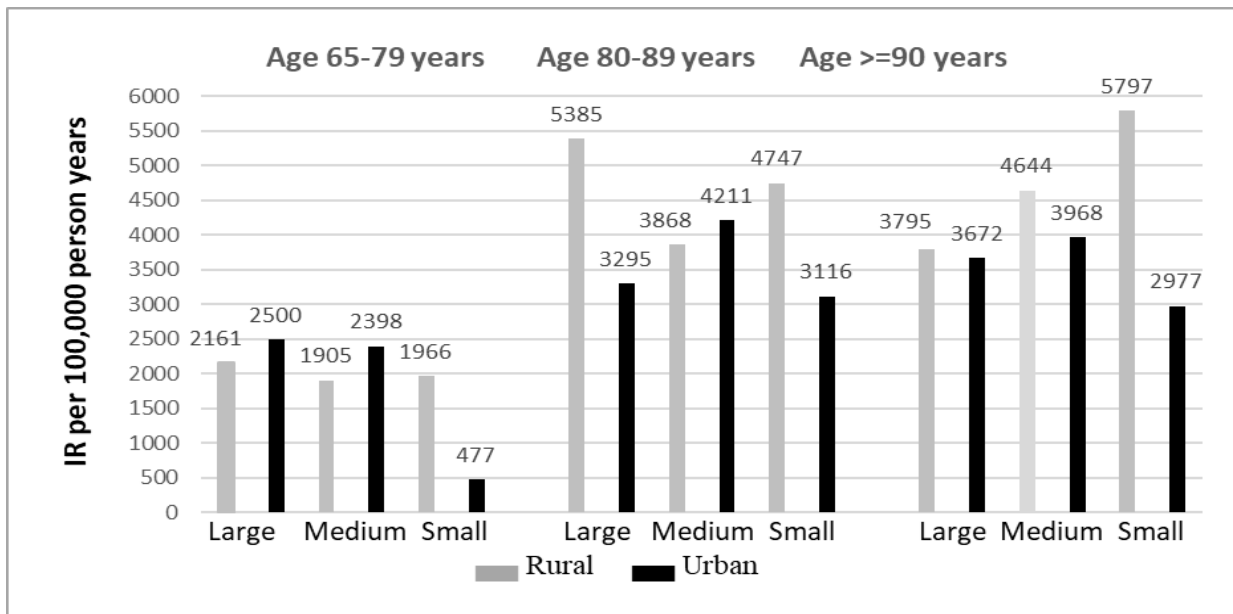


**Figure 4.4:** Hip fracture incidence rate stratified by age, rural-urban status, and facility size

Shown in Figure 4.5 are HF IRs stratified by sex, facility size, and rural/urban location. Females had a higher HF IR than males, regardless of LTCF size and geographic location. Among females in large and small size facilities, HF IRs were higher in rural locations than urban, whereas among those in medium facilities, HF rates did not vary substantially by urban/rural status. In males (Figure 4.5), the facility size-specific HF IRs did not vary substantially by urban/rural status.
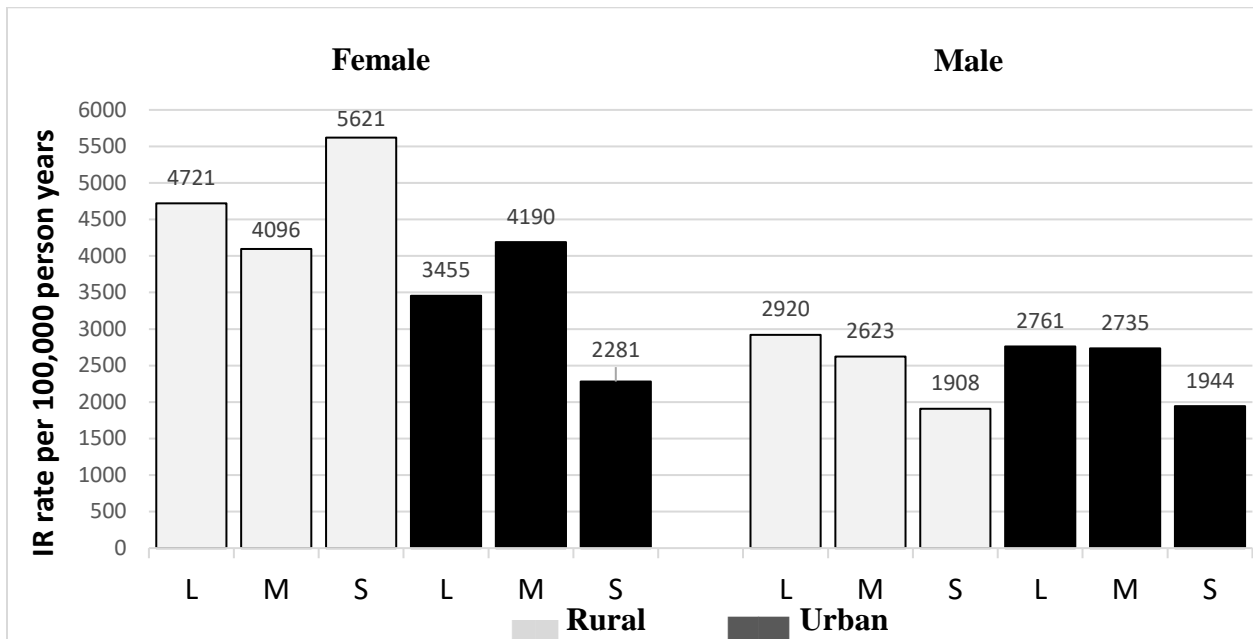


**Figure 4.5:** Hip fracture incidence rate stratified by sex, rural-urban status, and facility size

L=large, M=medium, S=small

## 4.3 Research Question Two

*What person-level factors (age, sex), health behaviors (smoking and alcohol consumption), place factors (facility size, rural-urban locations, and health regions), and clinical factors (e.g., BMI, DM, RA, osteoporosis, dementia, PD, and falls) are associated with HFs in adults aged 65 years and older living in LTCFs in BC, Canada?*

### 4.3.1 Logistic regression results

Table 4.6 exhibits the results of the unadjusted bivariate regression analyses. The following variables met the p<=0.25 criteria for multivariable modeling: age, sex, BMI, diabetes, osteoporosis, dementia, and falls in the last six months.

**Table 4.6:** Results of bivariate logistic regression analyses

| Variable | | OR | 95%CI | P value |
|---|---|---|---|---|
| Person | | | | |
| Age | 80-89 vs 65-79 | 1.30 | 1.132, 1.482 | 0.0002 |
| | >=90 vs 65-79 | 1.50 | 1.329, 1.684 | <.0001 |
| Sex | Female vs male | 1.62 | 1.464, 1.788 | <.0001 |
| Place | | | | |
| Facility Size | Large vs small | 0.96 | 0.691, 1.336 | 0.8126 |
| | Medium vs small | 1.10 | 0.794, 1.539 | 0.5518 |
| Health behavior | | | | |
| Current smoking | No Info vs non-Smoker | 0.95 | 0.815, 1.105 | 0.5021 |
| | Smoker vs non-Smoker | 0.91 | 0.699, 1.198 | 0.5187 |
| Current Alcohol | Yes vs No | 0.44 | 0.06, 3.196 | 0.4157 |
| Clinical | | | | |
| BMI | Under weight vs Obese | 2.01 | 1.638, 2.469 | <.0001 |
| | Normal vs Obese | 1.96 | 1.647, 2.34 | <.0001 |
| | Over-weight vs Obese | 1.43 | 1.178, 1.731 | 0.0003 |
| Diabetes | Yes vs No | 0.78 | 0.692, 0.878 | <.0001 |
| Rheumatoid Arthritis | Yes vs No | 0.95 | 0.858, 1.051 | 0.3203 |
| Osteoporosis | Yes vs No | 1.23 | 1.104, 1.383 | 0.0002 |
| Dementia | Yes vs No | 1.31 | 1.197, 1.436 | <.0001 |
| Parkinson's | Yes vs No | 0.88 | 0.722, 1.082 | 0.2333 |
| Fall in the last month (30 days) prior to hip fracture | Yes vs No | 1.15 | 1.027, 1.282 | 0.0153 |
| Fall in the last six months (excluding 30 days prior to hip fracture) | Yes vs No | 0.94 | 0.838, 1.059 | 0.3200 |

Level of significance = <0.25. OR: odds ratio, CI: Confidence interval.

Table 4.7 displays the final adjusted multivariable model, showing a higher risk of HF to be associated with older age (90+yrs vs 65-79yrs), female sex, an underweight, normal weight, or over weight BMI compared to obese, a diagnosis of dementia, and having fallen in the last month. No statistically significant interactions were found. Inspection of the variance inflation factors indicated that multicollinearity was not an issue in this data. The results of the Hosmer-Lemeshow test indicated a good fit between the data and model.

**Table 4.7:** Results of multivariate logistic regression analyses

| Variable | Level | Odds ratio | 95% Confidence interval | P value |
|---|---|---|---|---|
| **Person** | | | | |
| Age | 80-89 vs 65-79 | 1.14 | 0.989, 1,308 | 0.0709 |
| | >=90 vs 65-79 | 1.34 | 1.182 1.508 | <.0001 |
| Sex | Female vs male | 1.61 | 1.449, 1.782 | <.0001 |
| **Clinical** | | | | |
| | Under weight vs Obese | 1.81 | 1.465, 2.227 | <.0001 |
| BMI | Normal vs Obese | 1.82 | 1.522, 2.175 | <.0001 |
| | Over-weight vs Obese | 1.36 | 1.118, 1.653 | 0.0021 |
| Dementia | Yes, vs No | 1.46 | 1.326, 1.616 | <.0001 |
| Fall in the last month (30 days) prior to hip fracture event | Yes, vs No | 1.15 | 1.028, 1.289 | 0.0147 |

# CHAPTER 5

## 5.0 Discussion

In this chapter, the results of the study are summarized and integrated with the current research literature and organized primarily according to the research questions. The last part of this chapter discusses study strengths and limitations, followed by future recommendations to enhance understanding of HFs in Canadian LTCFs.

## 5.1 Proportion of study population with hip fracture

In the current study, 6.0% of LTCF residents experienced a HF during the five year study period, which is slightly lower than the 7.3% recently reported in a Saskatchewan study[13] Although the study period for the Saskatchewan study (2008–2012) was similar to this study, there were some methodological differences that may explain the discrepancy. For example, the Saskatchewan study included participants under the age of 65 years, included both community and LTCF dwelling adults, used a different method of calculating incidence, and used provincially administered databases.[13] In contrast, the current study restricted participants to age 65 years and older, was conducted solely with LTCF residents, and utilized data from CIHI-DAD and CCRS. In addition, the method used for calculating IRs in this study was standardized; that is, person-years was calculated by following a resident from the first day of the enrolment each year until the last day of the year.

Similar studies beyond Canada have also reported varying HF IRs. For example, a study from the United States reported 3.3% of residents in nursing homes acquired HFs. [198] The lower proportion in this study may be due to the exclusion of residents who stayed for less than 100 days; there is evidence suggesting that the risk of HFs is highest in the early days of admission to LTCFs.[149] However, the results of this study are consistent with two other non-Canadian studies that reported a HF incidence of 6% and 6.2%, from the United States[52] and Germany[168] respectively. The results of these studies are comparable to the current study, which is possibly due to the similar criteria of inclusion of residents from the first day of entry in the LTCF.

## 5.2 Temporal trends in hip fracture

In this study, the results showed an overall 18% decrement in HF IRs between 2010 and 2014, with an average annual percentage decrease of 3.6%. There is only one study (other than the present study), conducted in Ontario, that has reported time trends of HFs in LTCFs.[12] However, a number of methodological differences are present between this study and the Ontario one. The Ontario study analyzed both community and LTCF populations and included only osteoporotic fractures, with several other bony fractures (vertebral, wrist etc.), [12] whereas the current study analysed only HFs (first event only) among those with osteoporosis and/or

other co-morbidity as well. Despite such differences, some similarities were observed in the Ontario study when comparison was restricted to LTCF residents.[12] More specifically, the Ontario study showed an overall downward trend in HF IRs between 2002 and 2012 with a similar in magnitude to this study; that is, the age-sex standardized IR of 267 per 10,000 person-years in 2002 declined to <196 per 10,000 person-years in 2012, with the average annual percentage decreasing by 3.49%. However, the HF IR reported in the Ontario study was lower than that reported here. [12] Variation in HF IRs could possibly be explained by differences in data sources and inclusion criteria. Regarding the latter, only 18% of LTCF residents in this study had a confirmed diagnosis of osteoporosis, whereas, all participants were osteoporotic in the Ontario study. Therefore, the comparatively higher IR in the current study may be due to the inclusion of all other causes of HFs in LTCFs not just those specific to osteoporosis.

The current study revealed a more nuanced picture of the HF time trends when stratified by age and sex. Over time, HF IRs steadily decreased but remained higher in females compared to males. Overall, HFs were lower in 65-79 years old residents than in the other two age groups. Females in the two older age groups showed a less pronounced decrease over time. On the other hand, male residents in these two age groups generally showed a lower incidence of HFs and an accelerated downward trend. The Ontario study [12] showed a comparable downward time trend by sex. Unfortunately, their results were not stratified by age group and, thus, cannot be fully compared with the results of the present study. The observed decreasing HF IRs over time in this study and in the one from Ontario are consistent with other Canadian studies of HFs among community dwelling older adults.[42,83]

**5.2.1 The rationale for the decreasing hip fracture incidence rate over time**

Numerous factors may contribute to decreasing HF IRs over time. These factors include rapidly changing advancements and innovations in health care management,[51,53] enhanced avoidable risk prevention techniques, improved staff education, enhanced modification of the physical environment,[53,54] and the application of hip protectors.[55] There have also been improvements to the therapeutic efficacy of bisphosphonates and supplementation programs

for calcium and vitamin D.[56] Finally, reductions in alcohol consumption,[60] smoking,[59] and improvements in osteoporosis management[56,199] may also contribute to decreasing trends.

## 5.3 Hip fracture by place characteristics

Rural-urban location and facility size are factors introduced only recently into research on HFs in LTCF populations. The current study reported an overall lower incidence of HFs in urban locations compared to rural. It is important to note that TTs were not evaluated simultaneously by place, age, and sex due to the low proportions of rural (11%) and small size facilities (2%) and the 10% missing data.

In the current study, HF IRs by age, facility location (rural-urban), and facility size exhibited both similarities and differences. In the youngest age group, the overall IR was lower compared to the other two age groups regardless of sex, and IRs were slightly lower in urban areas regardless of facility size. In general, the two older age groups showed comparable rates in all facility sizes, with the exception of large size rural facilities in the 80-89 group and small size rural facilities in the >=90 age group. Overall, this pattern showed the leveling of HF IRs after 80 years of age. Lower IRs in the younger ages might be due to the influence of better health status, the absence of frailty, and better mobility, in addition to a lower prevalence of risk-prone morbidities such as dementia and falls.[199] The pioneering study on this topic from Saskatchewan[13] reported a slightly higher IR in 65–79 year old adults in rural areas, as compared to urban dwellers in medium and large size facilities. For residents in the 80-89 and >=90 years age groups, lower rates were observed in rural facilities, with rates gradually increasing due to increases in age and size of facilities in urban areas. In contrast, the current study showed overall higher rates in all facility sizes and age groups in rural locations compared to urban.

In this study, higher HF IRs were observed among females across all rural-urban locations and facility sizes compared to males. In all three facility sizes, male residents exhibited similar rates by rural-urban location, whereas female residents exhibited similar rates in medium size facilities for both locations. In contrast, the highest rates were seen in small rural facilities and the lowest rates in small urban areas, while large rural faculties showed higher rates compared to large urban facilities for females. In the study from Saskatchewan[13] females in rural facilities

exhibited higher IRs than those in medium and large size urban facilities, with the exception of >=90 years old males, who exhibited higher IRs. By increasing age and facility size, all individuals were getting higher IRs in both rural-urban locations. Discrepant findings may be due to a number of methodological differences between the two studies. In the Saskatchewan study, there was no stratification by facility size within rural settings (i.e., rural represented a single facility size while urban represented medium and large). In contrast, the current study represented three sizes of facilities for both urban and rural locations. Other possible reasons are the inclusion of a second fracture in the Saskatchewan study, differences in the calculation of person-years, and different definitions of rural-urban area. Regarding the latter, in contrast to the present study, the Saskatchewan study operationalized rural/urban status based on the 2016 population centre approach. [13]

Why might facility size and urban/rural location impact HF IRs? Urban facilities may have lower rates due to better infrastructure, availability of specialists, staff expertise, and greater availability of preventive measures (e.g., prescriptions for bisphosphonates, vitamin D and calcium supplementation). [200] Helena Temkin et al [173] examined the performance of rural-urban facilities by constructing an ecological model based on three types of factors: individual, organizational, and environmental (e.g., geographic location of the facilities and availability of services). These authors found that health outcomes were generally better in the urban facilities. The same report also revealed that people in rural areas may be less privileged than their urban counterparts, which in turn may influence HF IRs.[173] Other possible explanations may include differences in population characteristics that exist between geographical locations[137] availability of health care services, numbers of staff members, and differences in their educational background and expertise.[173,199] Also, LTCFs can be viewed as a system that revolves around two fundamental dynamics: 1) structural indicators (e.g., staff ratios, room size, and availability of equipment); and 2) processes (e.g. patient management with respect to screening, evaluation, and treatment). These two crucial factors may impact health care management and outcomes individually and collectively.[174] Also, the number and expertise of human resources, including physicians, clinical associates, nursing staff, and other supporting staff plays a significant role in the health outcome of the residents.[178,201] Measuring and monitoring these factors in LTCFs,

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although important, is a daunting task, given the complexity of retrieving and analysing information for such a large cohort as in the current study. Future research should employ methods of data collection (e.g., questionnaires sent to individual facilities) in addition to RAI-MDS based CCRS data to provide a more comprehensive and detailed listing of potential exposures.

Differences in study design, study population, types of data, inclusion-exclusion criteria, and other factors may also have resulted in differing results between this study and previous research. Further, the urban-rural status for each resident in the current study was based on location of the LTCF, as opposed to the resident's actual residence before admission to the facility. It is important to note that the median stay of residents was 0.8 years in the current study and, in general, it is typically no longer than 2 to 3 years in LTCFs.[202] Therefore, the effect of rural-urban location on their overall health could have been limited if they grew up in a rural location but, at the time of the study, were residing in an urban LTCF or vice versa. It is important to note the data used in the present study are publicly available and, therefore, to protect the confidentiality of study participants, residence information was not made available in the CCRS.

**5.3.1 Hip fracture by health region**

The Northern health region in BC is the largest, most remote, and bears the harshest weather. The Vancouver Coastal and Vancouver Island health regions, along with the Fraser region, are situated around the coastal area and have a more or less similar geographical environment. The Interior health region is the second largest and is situated in a valley.[203] Despite such diversity, HF IRs did not vary substantially by region, and are generally consistent with those reported in the Saskatchewan study, which revealed little variation between the 13 health regions, with the exception of one remote region.[13] These results suggest that residents, regardless of region, may be exposed to similar controlled internal environments within the LTCFs, have less exposure to the external world, and experience a common sedentary living style (i.e., bedridden status).

## 5.4 Beyond descriptive: Risk factors based on multivariable modeling

The results of the multivariable analyses indicated the risk of HFs in LTCFs in BC increased with older age (80+yrs vs 65-79yrs), female sex, an underweight, normal weight, or overweight BMI compared to obese, a diagnosis of dementia, and having fallen in the last month.

### 5.4.1 Age and sex

In the current study, HFs followed a directly proportional relationship with increasing age. Although no previous research has been published assessing the association between person-level factors and HFs in the Canadian LTCF population, these results are consistent with previous published descriptive studies.[11,13,52] Age is associated with a number of factors that may increase the risk of HFs such as frailty,[11,71] dementia, and cognitive impairment,[144,146] osteoporosis,[20,131,204] falls,[25,63,169] side effects of medicines, particularly the use of neuroleptics,[156,160] and lower vitamin D and nutritional deficiencies.[118,133]

Overall, females had a 61% increased risk of HFs compared to males in this study, a pattern consistently observed in previous research,[11–14] including in community dwellers.[10,42,83] However, caution in interpretation should be exercised as these reports were based largely on descriptive studies. Factors that may increase the risk of HFs in females might be a higher prevalence of frailty, [80] compromised hormonal and nutritional status, particularly vitamin D and calcium [84,86] with resultant weakened bones, [88,89] and a higher risk of osteoporosis.[10,134] The postmenopausal state and socioeconomic status may also influence vulnerability to HF.[84]

### 5.4.2 Clinical risk factors

Compared to residents with an obese classification, those with low, normal and overweight BMIs in this study showed an increased risk of HFs. The low BMI finding is in concordance with other studies of community dwelling older adults.[114,117] Similar results were also reported in one meta-analysis in which a BMI of less than 20kg/m$^2$ (compared to 25 kg/m$^2$) was associated with an increased risk of HFs. [205] The average BMI of LTCF residents is 23.2 ± 5.5 kg/m², [154] which puts many residents at risk. [118] Furthermore, in institutionalized populations, the high proportion of participants with a low BMI is compounded by the associated risk of

frailty.[118] Although frailty was not assessed in this study, it may be an underlying risk factor for HFs among LTCF residents.[93] A direct link between low BMI with osteoporosis could be another plausible explanation of these results; that is, the combination of both exposures makes bones significantly more brittle, thereby increasing the risk of HFs. [205]

Compared to obese individuals, an increased risk of HF was also observed in those classified as normal or overweight. A number of community-based studies have reported higher BMI to be associated with a decreased risk of HFs.[206,207] Obesity/high BMI may be protective for HF possibly due to greater fat mass that provides cushioning to the hip by adipose tissue that may reduce impact forces when falling.[208] It is important to note, however, that not all research has reported obesity as a protective factor and some has reported the risk of HF to increase in obese individuals as compared to those of normal weight.[209] The complexity of the relationship between BMI and HF is well acknowledged in the literature, including variations observed by sex, age, and ethnicity.[117,209] Recent research has also examined the potential role of other factors in the BMI-HF association, such as the level of various micronutrients[210] and the distribution of body fat. [211] The positioning of obesity as a protective factor is also problematic from a public health perspective given evidence linking obesity with an increased risk of other serious health conditions such as metabolic disorder, cardiovascular diseases, and diabetes. [212]

Dementia was also been shown to be a statistically significant risk factor for HF, with a 46% higher risk of HF in those with dementia compared to those without, results which are consistent with previous research.[144,146] Dementia among institutionalized older adults is associated with nutritional deficiency and compromised neuro-physiological function (e.g., peripheral neuropathies) that increase balancing and gait problems leading to HFs. [149] The use of multiple pharmaceuticals among those with dementia is frequent and compounded by other risks, such as delirium and syncopal attacks.[148] People with dementia are also at a higher risk of falls due to associated gait problems.[147] The possibility of a fundamental cause of falls among older adults with dementia may be explained by a link between cognition and disturbed gait that might lead to falls resulting in HFs.[147] These sequelae of dementia would increase the risk of fall-related HFs in this vulnerable population.[147,148]

Having fallen in the last month was associated with a 15% increased risk of HF in the current study, which although statistically significant, appears to be of a smaller magnitude when compared to other research.[24,63,139,169] There are several points to consider as possible explanations for the smaller effect compared to other reports. For instance, in the current study, information on falls was collected from the RAI-MDS 2.0 and based on a resident's verbal answers in response to the question asked to them or to their caregiver. In addition, an input of the event of a fall was carried out by the supporting staff, either by direct observation or from the patient's previous medical records at the time of LTCF admission. Thus, misclassification of a fall event cannot be ruled out in this study. Ganza et al. have reported considerable misinformation for falls among the elderly.[213] Similarly, personal preferences for nondisclosure of falls to physicians have been reported.[214] Also, nursing staff could have missed witnessing a fall or a slight fall may have been recorded as a simple trip. Finally, falls commonly occur during walking [25] and a considerable number of LTCF residents are immobile; therefore, restricted movement due to immobility may have prevented them from experiencing a fall resulting in a lower incidence of HFs.

### 5.4.3 Factors unassociated with hip fracture

In the current study, several factors such as place (facility size), health behavior (alcohol, smoking), DM, RA, osteoporosis, and PD did not show statistically significant associations with HFs in the multivariable analysis. Considering the fact that this study, unlike many previous descriptive studies, examined multiple factors at the same time, thus controlling for confounding effects, this researcher is confident that there are no significant statistical associations. It is important to note, however, that initial results of the unadjusted analyses conducted for this thesis, corresponding to the first research question, did report similar associations to those of previous descriptive studies.

However, it is possible that the results in this study were impacted by the lack of information on severity or stage of the diseases. For example, DM has been associated with falls and gait disturbances; these symptoms are particularly common in those with an advanced stage of uncontrolled DM resulting in associated neuro-sensory abnormalities. These symptoms are

not frequent in early or well-controlled DM,[121] so precise quantified assessments of disease severity or stage of the diseases may be needed to show associations with HFs. In addition, RA [129,130] and PD [157,161] have shown associations with HFs in later (severe) stages ; the same rationale is thus applicable to all morbidities. The importance of disease severity is illustrated in the new HF risk assessment tool (FRAiL)[215] for LTCF populations. In the FRAiL tool, quantified values are used for conditions including DM, dementia, falls, frailty, and activity levels. The present study also reported a much lower prevalence of osteoporosis (18%) compared with other studies.[133,134] This may be a result of the fact that relatively few older adults in Canada have access to the diagnostic test for osteoporosis (DEXA).[106] Similarly, episodes of falls were likely underestimated in the data for this study. Previous research suggests that falls combined with osteoporosis dramatically increase the risk of HFs among older adults. [20,24,133] Hence, it is possible that the underestimation of both conditions may have diluted the observed measures of association. Similarly, alcohol and smoking were not significantly associated with HFs, likely due to their low prevalence in this LTCF population. Previous research with community samples has shown these two health behaviors to be associated with an increased risk of HFs;[16, 94, 97] unfortunately, lifetime use of these substances by participants was not available for this study.

## 5.5 Limitations

Information on HF events for this study was retrieved from the CIHI DAD, which stores information for events occurring in acute care centers. Hence, it is quite possible that some HFs may have been missed. For example, some terminally ill residents classified under "Do Not Resuscitate" (DNR) status, despite acquiring HFs, are treated in LTCFs conservatively and not transferred to an acute care hospital. Such events might be missed or uncaptured, which would result in an underestimation of IRs in this study.

In the current study, IRs for individual types of HFs were not analysed. Instead, all three types (S72.0, S72.1, and S72.2) from ICD-10-CA were combined. Although assessment of individual HF types was not an objective of this study, such specifics could have been beneficial for healthcare providers.

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Nearly 80% of the study participants resided in urban LTCFs compared to 11% in rural, which may have impacted the results. Additionally, rural-urban location was assigned on the basis of LTCF location rather than where participants may have lived most of their lives; considering the short average stay in LTCFs, it might not truly represent rural-urban influences on HF IRs. This preliminary work warrants further study at a broader level (multi-provincial) and also, with information on residents' lifetime living environments prior to admission to LTCFs. The actual residence of LTCF dwellers are not available due to confidentiality reason so it was not retrievable for this analysis.

While alcohol and smoking are considered significant risk factors for HFs, most of the residents were not current drinkers or smokers; also, no information was available regarding lifetime use of these substances.

Several clinical conditions (DM, RA, and PD) associated with HFs in previous research showed no association in this study. As mentioned previously, information on the severity of these conditions would have been potentially informative, as would data on other variables, such as physical activity levels. Similarly, this study did not include other pertinent contributors to HFs such as vitamin D use, use of bisphosphonates, and hip protectors. Lastly, this study did not include any potentially pertinent facility factors such as building structure, staffing, staff education, and care patterns, which may have an effect on HF rates.

## 5.6 Strengths

This study was conducted using CIHI DAD, including CCRS (based on RAI-MDS 2.0), which have been validated in several studies.[188,192] CIHI-DAD is a population-based data source that stores information on all residents in LTCFs in BC ensuring minimal selection bias and enhanced generalizability of the results. The focus on incidence of HFs, rather than prevalence, is also a strength of this study. In addition to descriptive analyses, multivariable analysis of the predictors of HFs were conducted, thus reducing the influence of confounding on the results. This study is replicable and can be applied to future studies in Canada.

This is the first Canadian study conducted solely on HFs in residents of LTCFs that examines trends by person, place, and time. From an administrative and health care management perspective, the current study provides new information for HF epidemiology in terms of facility size, rural-urban locations, and distribution among females and males in different age groups of older adults.

## 5.7 Conclusion and future directions

The results of this study provide important information on current time trends and risk factors in HFs among LTCF residents. The changing HF rates have important implications for public health and policymakers. The province of BC can use these results to prioritize healthcare resources for vulnerable older adults living in LTCFs. For example, health professionals can use this information to target treatment to those at highest risk (e.g., residents 80 years or older, women, those with dementia, lower BMI, and frequent fallers).

This study provided preliminary information about the potential impact of rural-urban location and facility size on HF IRs and it can be viewed as the starting point for future studies on this topic beyond a single province. In addition, future research should incorporate more detailed exposure information regarding residents' pre-LTCF health behaviors (e.g., smoking and alcohol use) activity of daily living, disease severity, health professional characteristics, and facility infrastructure (e.g., gymnasiums, physiotherapy room, and number of residents in each room).

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