Sedentary Time and Hospitalization in Canada's Middle-Aged and Older Adults

By

Lucio Goncalves Lustosa

A thesis submitted to the
School of Graduate and Postdoctoral Studies in partial
fulfillment of the requirements for the degree of

Master of Health Sciences in Kinesiology

Faculty of Health Sciences

University of Ontario Institute of Technology (Ontario Tech University)

Oshawa, Ontario, Canada

April, 2021

THESIS EXAMINATION INFORMATION

Submitted by: **Lucio Goncalves Lustosa**

Master of Health Science in Kinesiology

Thesis title: Sedentary Time and Hospitalizations in Canada's Middle-aged and Older Adults

An oral defense of this thesis took place on April 14, 2021 in front of the following examining committee:

Examining Committee:

Chair of Examining Committee	Manon Lemond PhD
Research Supervisor	Shilpa Dogra, PhD
Examining Committee Member	David Rudoler, PhD
Thesis Examiner	Olga Theou, PhD; Dalhousie University

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

ABSTRACT

Sedentary Time (ST) is a widespread behaviour in all age groups, especially in older adults. It is associated with chronic conditions, falls and poor physical function. Our purpose was to investigate the association between ST and hospitalization in middle-aged and older adults, considering falls and physical function. Canadian Longitudinal Study on Aging data on physical function, self-reported ST, and hospitalization were used in logistic regression models. Falls-related hospitalization was negatively associated with ST in middle-aged females such that higher ST was associated with lower odds of hospitalization. Emergency department visits were positively associated with ST in middle-aged males, while higher time in the Timed Up and Go test (worst fitness) was positively associated with all types of hospitalization in different groups. The associations between ST and hospitalization imply the need to investigate sex-specific recommendations in regards to falls and hospitalization prevention. Future intervention research is required.

Keywords: sedentary time; hospitalization; older adults; falls; physical function

AUTHOR'S DECLARATION

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

I authorize the University of Ontario Institute of Technology to lend this thesis to other institutions or individuals for the purpose of scholarly research. I further authorize University of Ontario Institute of Technology to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research. I understand that my thesis will be made electronically available to the public.

The research work in this thesis that was performed in compliance with the regulations of Ontario Tech's Research Ethics Board under **REB Certificate number 16120**.

Lucio Goncalves Lustosa

_____

STATEMENT OF CONTRIBUTIONS

The identification and design of the research project is contribution of Professor Shilpa Dogra, PhD. We count with contributions of Professor David Rudoler, PhD and Professor Olga Theou, PhD. Data analysis support was provided by John Cullen PhD.

DEDICATION

To Claudia, Lívia and Fábio.

ACKNOWLEDGEMENTS

Professor Shilpa Dogra, PhD. I cannot acknowledge and thank you enough for the innumerable things you have done. All the learning of these months is now part of who I am. Thank you.

Professor David Rudoler, PhD, and Professor Olga Theou, PhD. Many thanks for your time, attention and contributions to this work.

John Cullen. Thanks for your time, kindness and cooperation.

The professors of all our courses. It was a nice and fun apprenticeship. I have really learned it.

Government of Canada and CLSA. For undertaking the CLSA project.

All Kin Lab students, the crew of "J" building, and my fellow students for making me feel part of the whole thing and for your friendship.

Professor Mauro Heleno Chagas. For the first and subsequent support for this endeavour.

All the loved ones. For the support and affection.

Raumsol. For always have something else to teach me.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 3

LIST OF ABBREVIATIONS

ADL	activities of daily living
CLSA	Canadian Longitudinal Study on Aging
GDP	gross domestic product
MET	metabolic equivalent
MVPA	moderate to vigorous physical activity
ST	sedentary time
TUG	Timed up-and-go test

Chapter 1: Introduction

1.1 Introduction

Canada's population is aging as indicated by the 2016 census figures, which show that adults 65 years and older represent 17% of the country's inhabitants (1). Statistics Canada projects that in 2068 older adults will comprise between 21.4% and 29.5% of the total Canadian population. Furthermore, centenarians could be the fastest-growing share of society, increasing from 10,000 individuals in 2018 to 90,200 in 2065, making up approximately 0.2% of all Canadians (2).

Data from the Canadian Institute for Health Information show that, although older adults represented 17% of Canadians, they were responsible for 44% of health care expenditure (2017) (3). From a per capita perspective, this represents approximately four times the spending in comparison with the younger population (3, 4). A 2019 report identified that hospitals are responsible for the largest share of health care system costs (26.6%) with older adults accounting for 40% of acute hospitalizations (3-5). This "overuse" of hospitals by older adults has undesirable outcomes for the health care system and for the patients, affecting their health and quality of life.

Besides being the heaviest hospital users, older adults are also the most vulnerable group to hospitalization-related complications such as loss of independence, impairment in activities of daily living (ADL), complications linked to treatment, necessity for additional treatment after discharge, premature death, and more (6-8). Research suggests that the reduced capacity to perform ADLs experienced by older adults during hospitalization is particularly pervasive, with 78% of the participants aged 82.7 years having a new ADL disability after discharge, and these disabilities were still frequent 6 months after hospitalization (9). There is evidence that 23.9% of patients above 80 years

will lose at least one ADL function after a length of stay of 11.1 days in a geriatric ward (9-11), and that 31% of the patients aged 74 and older who are hospitalized for 6 days will experience a decline in ADL, resulting in a higher rate of death (37.5%) within 3 months after discharge (12). This reduced ADL capacity is likely a direct result of changes to physical function. In fact, previous research has demonstrated that after 10 days of bed rest, healthy older adults (65±5 years) decreased isotonic knee extensor strength by 13.2%, stair-climbing power by 14% and maximal aerobic capacity by 12% (8). Altogether, keeping older adults out of the hospital may be the best way to avoid such significant losses. Of note, a growing body of research suggests that these declines in physical function and capacity to perform ADLs can be attenuated by reducing sedentary time (ST) (13-16).

ST, defined as waking time spent in any behaviour characterized by an energy expenditure ≤ 1.5 METs while in a sitting or reclining posture, is a highly prevalent behaviour in older adults (17). It is associated with several chronic conditions, all-cause and cardiovascular disease mortality (18, 19). Importantly, it is also associated with ADLs impairments and physical function related outcomes (14, 16).

This thesis investigated if ST could be used as a novel predictor of hospitalization in older adults. The research question being addressed is "***Is the risk of hospitalization higher in middle-aged and older adults who accumulate high volumes of sedentary time?***". Research indicates that reducing ST may be more feasible than achieving physical activity guidelines, as breaking ST with light activity intervals seems a minor behaviour change compared to adopting an exercise program. Therefore, ST reduction strategies might have a more meaningful impact on hospitalization and healthcare

spending and might be the first step to a more active life. Throughout this thesis, I will review the literature, analyze data from the Canadian Longitudinal Study on Aging, and discuss opportunities for the use of ST in preventing hospitalizations in Canada.

REFERENCES

1. Canada S. Census Program 2020 [Available from: https://www12.statcan.gc.ca/census-recensement/index-eng.cfm?HPA=1.

2. Canada S. Population projections: Canada, provinces and territories, 2018 to 2068. 2019.

3. Canadian Institute for Health Information C. National Health Expenditure Trends, 1975 to 2019. Ottawa, ON: CIHI; 2019.

4. Canadian Institute for Health Information C. Canadian Institute for Health Information, Health Care Cost Drivers: The Facts. Ottawa, ON.2011.

5. Canadian Institute for Health Information C. Canadian Institute for Health Information, Health Care in Canada: A Focus on Seniors and Aging. Ottawa, ON.; 2011.

6. Hoenig HM, Rubenstein LZ. Hospital-Associated Deconditioning and Dysfunction. Journal of the American Geriatrics Society. 1991;39(2):220-2.

7. Allen C, Glasziou P, Del Mar C. Bed rest: a potentially harmful treatment needing more careful evaluation. Lancet. 1999;354(9186):1229-33.

8. Kortebein P, Symons TB, Ferrando A, Paddon-Jones D, Ronsen O, Protas E, et al. Functional Impact of 10 Days of Bed Rest in Healthy Older Adults. The Journals of Gerontology: Series A. 2008;63(10):1076-81.

9. Dharmarajan K, Han L, Gahbauer EA, Leo-Summers LS, Gill TM. Disability and Recovery After Hospitalization for Medical Illness Among Community-Living Older Persons: A Prospective Cohort Study. Journal of the American Geriatrics Society. 2020;n/a(n/a).

10. Covinsky KE, Palmer RM, Fortinsky RH, Counsell SR, Stewart AL, Kresevic D, et al. Loss of Independence in Activities of Daily Living in Older Adults Hospitalized with Medical Illnesses: Increased Vulnerability with Age. Journal of the American Geriatrics Society. 2003;51(4):451-8.

11. Isaia G, Maero B, Gatti A, Neirotti M, Ricauda NA, Bo M, et al. Risk factors of functional decline during hospitalization in the oldest old. Aging Clinical and Experimental Research. 2009;21(6):453-7.

12. Wakefield BJ, Holman JE. Functional Trajectories Associated With Hospitalization in Older Adults. Western Journal of Nursing Research. 2007;29(2):161-77.

13. Santos DA, Silva AM, Baptista F, Santos R, Vale S, Mota J, et al. Sedentary behavior and physical activity are independently related to functional fitness in older adults. Experimental Gerontology. 2012;47(12):908-12.

14. Dogra S, Clarke J, Copeland J. Prolonged sedentary time and physical fitness among Canadian men and women aged 60 to 69. Health Reports. 2017;28(2):3-9.

15. Dogra S, Stathokostas L. Sedentary Behavior and Physical Activity Are Independent Predictors of Successful Aging in Middle-Aged and Older Adults. Journal of Aging Research. 2012;2012:190654.

16. Dunlop DD, Jing S, Arntson EK, Semanik PA, Jungwha L, Chang RW, et al. Sedentary Time in US Older Adults Associated With Disability in Activities of Daily Living Independent of Physical Activity. Journal of Physical Activity & Health. 2015;12(1):93-101.

17. Bames J BT, Benden ME, Biddle S, Bond D, Brassard P et al. . Letter to the Editor: Standardized use of the terms "sedentary" and "sedentary behaviours". Applied Physiology Nutrition and metabolism. 2012;37(3):540-2.

18. Katzmarzyk PT CT, Craig CL, Bouchard C. Sitting time and mortality from all causes, cardiovascular disease, and cancer. Med Sci Sports Exerc. 2009;41(5):998–1005.

19. Mekary R, Lucas M, Pan A, Okereke O, Willett W, Hu F, et al. Isotemporal Substitution Analysis for Physical Activity, Television Watching, and Risk of Depression. American Journal of Epidemiology. 2013.

Chapter 2: Literature Review

The following review will aim to uncover gaps in our knowledge about the association between sedentary time (ST) and hospitalization by reviewing current literature on ST, hospitalization, and falls leading to hospitalization in middle-aged and older adults. It will also review the possible attenuation effect of physical function on the association between ST and hospitalization as well the association of ST to falls leading to hospitalization.

2.1. Healthcare and Our Aging Demographic

2.1.1. Health Spending

The spending in the Canadian health-care system has been growing throughout the years, advancing more than gross domestic product (GDP) growth from the 1990s to the last decade (1). Estimates suggest that health-care spending will reach 11.6% of GDP in 2019, and according to the 2018 figures from the Organisation for Economic Co-operation and Development, the Canada per capita health spending of CA$6,448 was among the highest internationally, compared to for example to the United States (CA$13,722), Australia (CA$6,488) and United Kingdom (CA$5,275), when public and private-sector spending is added. Canada federal investments in health-care rely on economic growth and the consequent higher government revenues, but as the growth of GDP decreased through the last decades, the growth of health care spending followed the same trend, although it was expected an increase above inflation in the Canadian per capita health spending, averaging 1.4% yearly between 2014 and 2019 (1, 2).

In the provinces and territories, the health care budget represented approximately 37% of total provincial/territorial program expenditures in 2017(2). In Ontario, health-

care costs consumed 41% of the province's 2018-2019 budget, while health spending growth averaged 4.4% yearly in the last year-budget periods. Estimates project 4.6% health spending growth yearly from 2018-2019 to 2022-2023, if no program to reduce the existent provincial fiscal deficit is implemented, nevertheless, to comply with the elimination of the fiscal deficit, Ontario has to spend CAD$8.6 billion below the status quo projection by the 2022-2023 fiscal year, what means spending in average less CAD$560 per individual (3).

Federal health spending scatters among several categories, including health research and administration, but about 60% of total health care spending is committed to hospitals (26.6%), drugs (15.3%) and physicians (15.1%) (2). The same trend is observed in Ontario, where hospitals are responsible for 36% of total health costs, followed by physicians and practitioners, costing 23% of the overall provincial health-system budget (3). Stratifying the federal numbers by age group shows that health care costs increase with age, starting at 45 years, and more than tripling the per capita spending in the older edge of life span (2).The per capita spending for a person 65 to 69 years is $6,656, 70 to 74 years $8,467, 75 to 79 years $11,324 and $20,793 for people 80 years and older, and the provinces follow the same trend (2, 3). Figures from 2017 show older adults representing 16.85% of the population but responsible for 44% of health-care system costs and 40% of all acute hospitalizations. (1, 2, 4, 5).

The current conditions of the Canadian health-care system demand every possible effort to reduce costs and occupation. In Ontario, for instance, the hospital system is already overcharged with the growing population, the opioid crisis, and the difficulty of access primary care, which increases the demands for emergency department services and lead many of Ontario's hospitals to surpass 100% of their capacity (3). If we add to these figures unpredictable situations like the COVID19 epidemic, we can understand better why the scene necessitates knowledge-based action.

2.1.2. The impact of Hospitalization on Older Adults

There is a correlation between hospitalization and the loss of functional capacities, especially in the older adult population, as it might result in decreased independence, general health, quality of life and lead to premature death (6-8). Even patients in good physical conditions can be affected by hospitalization, as shown in a sample of healthy older adults (65±5 years, 6 women and 5 men) who experienced decreased isotonic knee extensor strength (13.2%), stair-climbing power (14%) and maximal aerobic capacity (12%) after only 10 days of bed rest. As an outcome of these decrements in physical capacities, inactive time increased 7.5% in comparison with the pre-intervention period, due to reductions in the time spent in low-intensity activities (9). In critically ill individuals the consequences of hospitalization might be even more dramatic.

Studies of older adults comparing pre and post-hospitalization suggest that hospital stay has an important impact on functional outcomes. For example, measures of functional changes in patients 79.5 years and older admitted to a hospital, showed that

17% of these patients experienced a decline in their functional status during hospitalization, and the risk of this decline increased with age such that in patients 90 years and older the risk was 44% (10). Loss of physical function was also observed in 23.9% of geriatric ward patients (mean age 85.6 years), hospitalized for 11.1 days, with the length of hospital stay significantly and independently associated with functional decline (11). Older adults who decline in physical function during hospitalization have a higher rate of mortality (41.3%) one year after discharge compared with those who did not decline or recovered function during hospital stay (17.8%) (12). Following the same path of investigation, 31% of patients aged 74 years hospitalized for 6 days, declined in ADL function during hospitalization, of whom 35.7% died 90 days after discharge compared with 6.5% deaths among those who improved or had no changes in ADL function during hospital stay (13). Finally, it was demonstrated that approximately 30% of older adults 82.7 years, who lived independently before hospitalization, developed functional disabilities at discharge that were not fully recovered 6 months after a hospital stay (14).

The impact of hospitalization on the health and function of older adults is significant. Research aimed at understanding modifiable factors that can prevent hospitalization in this population are needed.

2.1.3. The Health-Care Cost of Falls

Falls are a major concern related to the older adult population. Falls-related hospitalizations account for 85% of the injury-related hospitalization among the oldest Canadians (≥ 65 years old), resulting in an average hospital stay nine days longer when

compared with all other causes of older adults' hospitalization (21 vs 12 days), although there is evidence suggesting a difference longer than 34 days (45 vs 11 days) (15, 16). Additionally, falls are also responsible for 95% of hip fractures among older adults, with a death rate of 20%. The health care cost of older adults' falls is not negligible either; 2004 figures estimated that older adults falls costed more than $2 billion to the health-care system, 3.7 times the cost for individuals between 25 and 64 years old (16).

Falls and falls-related hospitalizations are higher among older adults with poor physical function and lower levels of physical activity (17-19). This may be a modifiable factor that can help reduce preventable hospitalization of older adults.

2.2. A possible solution: sedentary time

2.2.1. Sedentary Time in older adults

Sedentary Behaviour (SB) is defined as "any waking behaviour characterized by an energy expenditure ≤ 1.5 METs while in a sitting or reclining posture" (20) and ST is the time spent in this behaviour, which should not be confused with physical inactivity, defined as not achieving the recommended amount of moderate to vigorous physical activity (MVPA) (20). An individual can be concomitantly physically active and sustain unhealthy amounts of ST, or conversely, can present lower levels of ST being at the same time physically inactive. For example, an older adult can participate in a moderate to vigorous exercise program every morning and spend the rest of their waking time watching TV, browsing on the computer, and reading. In this case, although physically active due to the exercise program, this individual is highly sedentary. On the other hand, a person can be busy throughout the day with chores that demand little effort, sitting only

for short periods, but never achieving MVPA. In this scenario, although the individual is not sedentary, they are physically inactive due to not achieving the physical activity guidelines.

The evidence accrued until now indicates that ST is a widespread health problem. A pooled analysis of accelerometer data derived from studies carried out in four European countries (England, Norway, Portugal, and Sweden) demonstrated that ST comprises 61% of the waking time of people between 20 and 75 years old. In this study, 71% of the participants had a sitting time ≥ 7.5h/day, and 22.8% seated ≥ 10h/day (21). Corroborating this data, analyses from the Canadian Health Measure Survey, containing objective and self-reported data, show that women and men between 60 and 69 years accumulate a mean of 9.91 hours of ST/day (22). Additionally, one Norwegian cross-sectional study demonstrated that ST increases from 6-year-olds throughout life until an older age, with an addition of 0.5 minutes per year from adulthood in both sexes. This study also shows that girls are more sedentary than boys, but men are more sedentary than women among adults (+18 minutes per day, 95% CI: 13, 23) and older adults (+24 minutes per day, 95% CI: 15, 33) (23). It is possible that the increasing volume of ST throughout life worsens the conditions present in the older population or contributes to enlarge the number of issues faced by older adults.

A decrease in ST and an increase in physical activity are well-established factors associated with better health outcomes and reduced health care costs (24-26). Although efforts to improve the ST and the physical activity profile of Canadians via campaigns and programs (27, 28), only about 16% of the population meet the physical activity guidelines (29). This maybe can be explained by the considerable behaviour change

necessary to comply with the proposed physical activity guidelines, as one needs to transition from a sedentary and inactive lifestyle into one containing enough amounts of movement at exercise levels. Thus, reducing ST may be an easier way to improve the movement profile and physical function of the population as it starts simply with breaking up prolonged sitting activities with light intensity activities.

ST is a widespread problem affecting the older population as they are the age group which accumulates the greatest amounts of sitting and the highest risks derived from it.

2.2.2. The Health Outcomes of Sedentary Time

Although physical activity and physical inactivity seem to influence many health outcomes, ST is a separate behaviour potentially harmful to human health and quality of life. It has been demonstrated that ST is an independent factor to increase the risk of chronic conditions, all-cause mortality, cardiovascular disease, metabolic syndrome in women and men, regardless of age and physical activity level (30, 31).

Several studies have measured the accumulated amount of ST in individuals using indirect methods like interviews and questionnaires, direct methods like accelerometers and inclinometers, or both at once. Although direct-measures have been demonstrated to be more precise and resulting in greater values than self-reported ST (32), most of the studies suggest a negative association of ST with health and quality of life (33). For example, time watching television is associated with an increased risk of type 2 diabetes, each increment of 2h/day watching TV was associated with a 20% increase in the risk of diabetes in men (CI 95% 8% - 32%) (10 years follow-up, n=51,529, 40 to 75 years) (34)

and 14% in women (95% CI 5% - 23%) (6 years follow-up, n=50,277, 49 to 67 years) (35). TV time is also positively related to the risk of obesity in women (RR 1.29 CI95% 1.01 – 1.66), as every 2h/d increase in TV led to a 23% increase in the risk of obesity in women (95% CI 17%-30%) (35). Watching TV instead of exercising at a moderate-to-vigorous level is associated with an increased risk of depression, and substituting 60 minutes/day of brisk/very brisk walking with 60 minutes/day of TV watching, was associated with an 18% increase in the risk of developing depression (10 years follow-up, n=32,900, 55 to 69 years) (36).

Similarly, among individuals with chronic obstructive pulmonary disease, ST was associated with lower forced expiratory volume (β: -0.18, CI: -0.28, − 0.08), higher odds of self-perceived poor health (OR = 2.70, CI: 1.72, 4.24), poor mental health (OR = 1.99, CI: 1.29, 3.06) and unhealthy aging (OR = 3.04, CI: 1.96, 4.72) (n=4156, 51 to 74 years) (37), and meta-analytical data shows associations of increased risk of cardiovascular disease with more than 10h/d of ST (pooled HR 1.08; 95% CI 1.00-1.14) (38). In addition to chronic disease outcomes, ST is also related to ADL disability, with each hour of ST per day increasing the odds of disability by 50% independent of chronic conditions and time spent in MVPA (OR=1.52, 95% CI, 1.10 – 2.10) (n=2286, 60 to ≥ 80 years) (31).

Evidence suggests that several chronic conditions and disabilities are related to ST in older individuals, indicating the necessity of addressing it as a public health concern.

2.2.3. Sedentary Time and Hospitalization

Data shows that ST and physical inactivity are responsible for 3.7% of overall health care costs, without including several known related conditions like obesity,

osteoporosis and depression (25). In 1999, 25.5% of the costs of treating coronary artery disease, stroke, hypertension, colon cancer, breast cancer, type 2 diabetes and osteoporosis, were attributable to physical inactivity and/or ST (24). More recent Canadian data estimates that physical inactivity is responsible for 23% of hypertension and 38% of type 2 diabetes occurrence in men, and 15% of breast cancer and 39% of type 2 diabetes cases in women (25). The data also demonstrates that physical activity has a protective effect for the development of chronic conditions in the order of 43% for type 2 diabetes, 26% for hypertension, 36% for osteoporosis, 27% for colon cancer, 17% for breast cancer, 30% for heart disease and 29% for stroke (25). Besides the importance for the individuals, the figures mentioned above give an idea about the impact of ST on health costs, and the importance of the knowledge about ST to the development of strategies and programs aiming to improve the public health spending and to the reduction of provincial fiscal deficits.

Despite the prevalence of ST in older adults, only a few studies have investigated the association of ST with the risk of hospitalization. A prospective study with a sample of Australians men and women ≥ 45 years old (mean 63 sd 11 years) followed up for 2.7 years, demonstrated that sitting less than 8 hours/day has a protective effect on the risk of hospitalization (HR 0.86, 95% CI 0.83 – 0.89) (39). Additionally, baseline accelerometry data accompanied by 15 years follow-up, showed that accumulating higher amounts of ST (average 8h12min/day) increases the risk of more in-hospital days (IRR = 2.38, 95% CI: 1.20–4.74) among Sweden with age between 18 and 75 years (45.3±14.5 years) (40). Albeit few, the available data leads to the understanding that ST has an influence on the

use and cost of hospitalization, which have important impacts on older adult's health care costs and quality of life.

Among older adults, muscle weakness is one of the major risk factors for falls (41, 42) and although ST is associated with lower strength and cardiorespiratory fitness levels (31) , only a few studies associate ST with falls, and one study found a negative association between these two factors (43). A possible explanation for this finding is that older adults may accumulate large amounts of daily ST, deflecting them from stand-up activities probable of leading them to a fall (44), which worsens their health profile because of excessive sitting time. Nevertheless, meta-analytical data show an association of ST with falls in older adults (OR 1.41, 95% CI 1.10, 1.82) similar to the association of falls with medications like antihypertensive agents, sedatives and hypnotics, antidepressants, and non-steroidal anti-inflammatory drugs (18). In addition, evidence suggests that reducing ST improves physical function scores (11.1 ± 0.3 to 11.6 ± 0.1 points over 12 weeks) and pain related with quality-of-life in older adults (from 80 pts [58, 90] to 90 pts [78, 100] at 12 weeks, p = .012) (45), what can have positive consequences for the risk of falls among this population.

There appears to be an association between ST and hospitalization risk, however, further research is needed to better understand the impact of physical function on this association in older adults.

2.3. Rationale, Purpose and Hypotheses

2.3.1. Rationale

Excessive ST is associated with falls, cardiovascular disease, Type 2 diabetes, depression, and many other health issues. Additionally, in older adults it can result in disability, loss of independence and premature death, all leading to higher health-care use, hospitalization, and increased costs for the health care system.

Elucidating the association of ST with hospitalization, falls leading to hospitalization and the possible attenuation effect of physical functions in these associations, helps to widen the body of evidence necessary for more in-depth research on the topic. Understanding the harms caused by excessive ST may help the formulation of knowledge-based programs, protocols, and initiatives to increase the health and quality of life of older adults. These actions may also reduce the financial and structural burden on the health system, which is paramount in face of the amounts of ST that people are accumulating, the burden of hospital utilization, and the increasing aging demographics.

2.3.2. Purposes

The overall purpose of this thesis is to examine the independent role of ST in the hospitalization of middle-aged and older adults, while considering relevant issues that pertain to older adults, such as falls and physical function.

2.3.3. Research questions and hypotheses

Research question 1**:** Is the risk of hospitalization higher in middle-aged and older adults who accumulate high volumes of sedentary time?

Hypothesis 1: it is hypothesized that high amounts of ST have an independent and positive association with the risk of hospitalization, particularly in individuals ≥ 65 years old.

Research question 2: Does sedentary time impact the risk of having a fall leading to hospitalization among older adults?

Hypothesis 2: Falls are the major cause of injure-associated hospitalization in older adults and it is also associated with lower levels of functionality. In addition, physical function is independently and negatively associated with high amounts of ST. These associations lead us to hypothesize that among individuals ≥ 65 years old, accumulating high amounts of ST drive to higher incidence of falls resulting in hospitalization.

Research question 3: Does physical function attenuate the risk of hospitalization among middle-aged and older adults who accumulate high volumes of sedentary time?

Hypothesis 3: Physical function has an independent and negative association with ST and with hospitalization. Thus, it is hypothesized that the independent association of high amounts ST with hospitalization is attenuated in individuals with higher profiles of physical function.

REFERENCES

1. Canadian Institute for Health Information C. Canadian Institute for Health Information, Health Care Cost Drivers: The Facts. Ottawa, ON.2011.

2. Canadian Institute for Health Information C. National Health Expenditure Trends, 1975 to 2019. Ottawa, ON: CIHI; 2019.

3. Financial Accountability Office of Ontario F. Ontario Health Sector 2019 Updated Assessment of Ontario Health Spending. 2019. p. 21.

4. Canada S. Population projections: Canada, provinces and territories, 2018 to 2068. 2019.

5. Canadian Institute for Health Information C. Canadian Institute for Health Information, Health Care in Canada: A Focus on Seniors and Aging. Ottawa, ON.; 2011.

6. Asher A. The Dangers of Going to Bed. British Medical Journal. 1947;1(4543):967-8.

7. Hoenig HM, Rubenstein LZ. Hospital-Associated Deconditioning and Dysfunction. Journal of the American Geriatrics Society. 1991;39(2):220-2.

8. Allen C, Glasziou P, Del Mar C. Bed rest: a potentially harmful treatment needing more careful evaluation. Lancet. 1999;354(9186):1229-33.

9. Kortebein P, Symons TB, Ferrando A, Paddon-Jones D, Ronsen O, Protas E, et al. Functional Impact of 10 Days of Bed Rest in Healthy Older Adults. The Journals of Gerontology: Series A. 2008;63(10):1076-81.

10. Covinsky KE, Palmer RM, Fortinsky RH, Counsell SR, Stewart AL, Kresevic D, et al. Loss of Independence in Activities of Daily Living in Older Adults Hospitalized with Medical Illnesses: Increased Vulnerability with Age. Journal of the American Geriatrics Society. 2003;51(4):451-8.

11. Isaia G, Maero B, Gatti A, Neirotti M, Ricauda NA, Bo M, et al. Risk factors of functional decline during hospitalization in the oldest old. Aging Clinical and Experimental Research. 2009;21(6):453-7.

12. Boyd CM, Landefeld CS, Counsell SR, Palmer RM, Fortinsky RH, Kresevic D, et al. Recovery of Activities of Daily Living in Older Adults After Hospitalization for Acute Medical Illness. Journal of the American Geriatrics Society. 2008;56(12):2171-9.

13. Wakefield BJ, Holman JE. Functional Trajectories Associated With Hospitalization in Older Adults. Western Journal of Nursing Research. 2007;29(2):161-77.

14. Dharmarajan K, Han L, Gahbauer EA, Leo-Summers LS, Gill TM. Disability and Recovery After Hospitalization for Medical Illness Among Community-Living Older Persons: A Prospective Cohort Study. Journal of the American Geriatrics Society. 2020;n/a(n/a).

15. Zecevic AA, Chesworth BM, Zaric GS, Huang Q, et al. Estimating the Cost of Serious Injurious Falls in a Canadian Acute Care Hospital. Canadian Journal on Aging. 2012;31(2):139-47.

16. Canada PHAo. Seniors` falls in Canada - second report. Ottawa, ON: Public Health Agency of Canada; 2014.

17. Chun SH, Cho B, Yang H-K, Ahn E, Han MK, Oh B, et al. Performance on physical function tests and the risk of fractures and admissions: Findings from a national health screening of 557,648 community-dwelling older adults. Archives of Gerontology and Geriatrics. 2017;68:174-80.

18. Thibaud M, Bloch F, Tournoux-Facon C, Brèque C, Rigaud AS, Dugué B, et al. Impact of physical activity and sedentary behaviour on fall risks in older people: a systematic review and meta-analysis of observational studies. European Review of Aging and Physical Activity. 2012;9(1):5-15.

19. Viccaro LJ, Perera S, Studenski SA. Is Timed Up and Go Better Than Gait Speed in Predicting Health, Function, and Falls in Older Adults? Journal of the American Geriatrics Society. 2011;59(5):887-92.

20. Bames J BT, Benden ME, Biddle S, Bond D, Brassard P et al. . Letter to the Editor: Standardized use of the terms "sedentary" and "sedentary behaviours". Applied Physiology Nutrition and metabolism. 2012;37(3):540-2.

21. Loyen A, Clarke-Cornwell AM, Anderssen SA, Hagströmer M, Sardinha LB, Sundquist K, et al. Sedentary Time and Physical Activity Surveillance Through Accelerometer Pooling in Four European Countries. Sports Medicine. 2017;47(7):1421-35.

22. Dogra S, Clarke J, Copeland J. Prolonged sedentary time and physical fitness among Canadian men and women aged 60 to 69. Health Reports. 2017;28(2):3-9.

23. Hansen BH, Kolle E, Steene-Johannessen J, Dalene KE, Ekelund U, Anderssen SA. Monitoring population levels of physical activity and sedentary time in Norway across the lifespan. Scandinavian Journal of Medicine & Science in Sports. 2019;29(1):105-12.

24. Katzmarzyk Peter GN, Shephard Roy. The economic burden of physical inactivity in Canada. Canadian Medical Association Journal. 2000;163(11):1435-40.

25. Janssen I. Health care costs of physical inactivity in Canadian adults. Appl Physiol Nutr Metab. 2012;37:803-6.

26. Bounajm F, Thy Dinh, and Louis Thériault. Moving Ahead: The Economic Impact of Reducing Physical Inactivity and Sedentary Behaviour. Research Update. Ottawa: The Conference Board of Canada; 2014.

27. Minister of Public Works and Government Services Canada. The Healthy Heart Kit. Physical Inactivity and Heart Disease. In: Canada MoPWaGS, editor. Ottawa: Minister of Public Works and Government Services Canada; 1999.

28. Public Health Agency of Canada. Physical Activity, Sedentary Behaviour and Sleep (PASS) Indicators: Quick Stats, children (aged 5 to 11) and youth (aged 12 to 17), Canada, 2017 edition. In: Canada PHAo, editor. Ottawa: Public Health Agency of Canada; 2017.

29. Clarke J CR, Janssen I, Tremblay M. Accelerometer-measured moderate-tovigorous physical activity of Canadian adults, 2007 to 2017. Statistics Canada, Catalogue. 2019;30(8):3-10.

30. Katzmarzyk PT CT, Craig CL, Bouchard C. Sitting time and mortality from all causes, cardiovascular disease, and cancer. Med Sci Sports Exerc. 2009;41(5):998–1005.

31. Dunlop DD, Jing S, Arntson EK, Semanik PA, Jungwha L, Chang RW, et al. Sedentary Time in US Older Adults Associated With Disability in Activities of Daily Living Independent of Physical Activity. Journal of Physical Activity & Health. 2015;12(1):93-101.

32. Harvey JA, Chastin SFM, Skelton DA. How Sedentary Are Older People? A Systematic Review of the Amount of Sedentary Behavior. Journal of aging and physical activity. 2015;23(3):471-87.

33. Aviroop Biswas BPIO, MD, MSc; Guy E. Faulkner, PhD; Ravi R. Bajaj, MD; Michael A. Silver, BSc; Marc S. Mitchell, MSc;, and David A. Alter M, PhD. Sedentary

Time and Its Association With Risk for Disease Incidence, Mortality, and Hospitalization in Adults. Annals of Internal Medicine. 2015;162(2):123-32.

34. Hu FB, Leitzmann MF, Stampfer MJ, Colditz GA, Willett WC, Rimm EB. Physical Activity and Television Watching in Relation to Risk for Type 2 Diabetes Mellitus in Men. Archives of Internal Medicine. 2001;161(12):1542-8.

35. Hu FB, Li TY, Colditz GA, Willett WC, Manson JE. Television Watching and Other Sedentary Behaviors in Relation to Risk of Obesity and Type 2 Diabetes Mellitus in Women. JAMA. 2003;289(14):1785-91.

36. Mekary R, Lucas M, Pan A, Okereke O, Willett W, Hu F, et al. Isotemporal Substitution Analysis for Physical Activity, Television Watching, and Risk of Depression. American Journal of Epidemiology. 2013.

37. Dogra S, Good J, Buman MP, Gardiner PA, Copeland JL, Stickland MK. Physical activity and sedentary time are related to clinically relevant health outcomes among adults with obstructive lung disease. BMC Pulmonary Medicine. 2018;18(1):98.

38. Pandey A, Salahuddin U, Garg S, Ayers C, Kulinski J, Anand V, et al. Continuous Dose-Response Association Between Sedentary Time and Risk for Cardiovascular Disease: A Meta-analysis. JAMA Cardiology. 2016;1(5):575-83.

39. Tran B, Falster MO, Douglas K, Blyth F, Jorm LR. Health Behaviours and Potentially Preventable Hospitalisation: A Prospective Study of Older Australian Adults. Plos one. 2014;9(4):e93111.

40. Dohrn I-M, Welmer A-K, Hagströmer M. Accelerometry-assessed physical activity and sedentary time and associations with chronic disease and hospital visits - a prospective cohort study with 15 years follow-up. International Journal of Behavioral Nutrition and Physical Activity. 2019;16(1):125.

41. Sim M, Prince RL, Scott D, Daly RM, Duque G, Inderjeeth CA, et al. Utility of four sarcopenia criteria for the prediction of falls-related hospitalization in older Australian women. Osteoporosis International. 2019;30(1):167-76.

42. Pijnappels M, van der Burg JCE, Reeves ND, van Dieën JH. Identification of elderly fallers by muscle strength measures. European Journal of Applied Physiology. 2008;102(5):585-92.

43. Bea JW, Thomson CA, Wallace RB, Wu C, Seguin RA, Going SB, et al. Changes in physical activity, sedentary time, and risk of falling: The Women's Health Initiative Observational Study. Prev Med. 2017;95:103-9.

44. Rosenberg DE, Bellettiere J, Gardiner PA, Villarreal VN, Crist K, Kerr J. Independent Associations Between Sedentary Behaviors and Mental, Cognitive, Physical, and Functional Health Among Older Adults in Retirement Communities. J Gerontol A Biol Sci Med Sci. 2016;71(1):78-83.

45. Barone Gibbs B, Brach JS, Byard T, Creasy S, Davis KK, McCoy S, et al. Reducing Sedentary Behavior Versus Increasing Moderate-to-Vigorous Intensity Physical Activity in Older Adults:A 12-Week Randomized, Clinical Trial. Journal of Aging and Health. 2017;29(2):247-67.

Chapter 3

Manuscript: Sedentary Time and Hospitalization in Canada`s Middle-aged and Older Adults

3.1 Abstract

Background: Sedentary Time (ST) is a widespread behaviour in all age groups, with older adults accumulating the highest amounts of sitting. It is associated with chronic health conditions, falls and poor physical function, but the evidence on the association of sitting time with the risk of hospitalization is scarce. *Purpose:* The purpose of our study was to investigate the association of ST and hospitalization in middle-aged and older adults, considering related factors such as falls and physical function (Timed Up and Go (TUG) and grip strength). *Methods:* Performance-based assessments of physical function and self-reported data on ST, hospitalization, and covariates from the Canadian Longitudinal Study on Aging, Comprehensive cohort, were analyzed using logistic regressions. *Results:* Negative associations of ST and hospitalization were found for falls-related hospitalization in middle-aged females (OR 0.37 (0.16, 0.81). Emergency department visit was positively associated with higher levels of ST in middle-aged males (OR 1.14 (1.00, 1.30), while a positive association was observed between TUG with all types of hospitalization in different groups. *Discussion:* Our results corroborate previous findings associating higher levels of ST with lower risks of falls in females, and with increased risk of hospitalization in middle-aged and older adults, but poor physical function can be related to these amounts of sitting, indicating lower health levels. *Conclusion:* We conclude that higher ST has a protective association with the risk of falls-related hospitalization in middle-aged females, and at the same time represents an increased risk of emergency department visits in middle-aged males. These associations might be due to poorer physical function suggesting that sex-specific recommendations in

regards to ST for prevention of hospitalization and falls may be warranted, but future intervention research is required.

3.2 Introduction

Adults 65 years and older, herein referred to as older adults, represent 17% of the Canadian population (1), but are responsible for 44% of health system costs and 40% of hospitalizations (2-5). Projections suggest that by 2068, older adults will make up 21-30% of the Canadian population (4), suggesting a large increase in healthcare costs and hospital needs (6, 7). The major causes of hospitalization in older adults are pulmonary disease, cardiovascular disease, as well as bone and joint diseases (2). These chronic conditions contribute to lower levels of physical function (8-10) and increase the risk of falls (11-13), which are responsible for 90% of hip fractures and 85% of all injury-related hospital admissions. In addition, hospital stays due to falls-related injuries are 9 to 34 days longer than average hospitalization (14-17).

Hospital stays can be detrimental for older adults. Research suggests that hospitalization is associated with a loss in functional capacity after discharge, resulting in decreased independence, general health, quality of life, and premature death (18-20). Between 17% to 44% of older adults suffer losses in activities of daily living (ADLs) due to hospitalization, and these losses can persist more than 6 months after leaving the hospital (21-25). It is thought that the hospital-associated decline in older adults is at least partially attributable to physical inactivity during hospitalization (26, 27) and that higher levels of physical function pre-hospitalization can prevent hospital-associated function loss (28).

While an increase in physical function requires regular physical activity (29), only 16% of the Canadian population meets the physical activity guidelines (30). There is some evidence to suggest that breaking up ST may be an effective strategy for improving

physical function in older adults (31). ST, defined as the waking time spent in any behaviour characterized by an energy expenditure ≤ 1.5 metabolic equivalents while in a sitting or reclining posture (32), is a highly prevalent behaviour in all age groups, with older adults accumulating the highest amounts of sitting (31, 33-35). These high volumes of ST are associated with an increased risk of diabetes, obesity (36, 37), depression (38), all-cause mortality, cardiovascular disease and pulmonary disease, and metabolic syndrome regardless of age and physical activity level (39-42). Importantly, it is associated with an increased risk of falls in older adults (17). In fact, ST is also associated with ADL related disability in older adults, and this association is independent of chronic conditions and time spent in moderate to vigorous physical activity (40).

Older adults have an increased risk of falls and hospitalization. There is some evidence to suggest that higher physical function and better chronic disease management reduces the risk of these outcomes (13, 43). However, little research is available on the association between ST, a highly prevalent behaviour in older adults, and risk of hospitalization. Sitting less than 8h/day is associated with a reduced risk of hospitalization (44), while individuals who accumulate higher amounts of ST increase their risk of more in-hospital days (45). However, these studies did not separate the age groups by sex, which may be important based on previous research of sex-specific characteristics and physical function in each age group (46). In addition, they limited their analyses to a few chronic conditions, and hospitalizations linked with these conditions, which might have excluded factors like falls-related hospitalization, emergency department visits, and hospital admissions attributable to a broader diagnosis array. Thus, the purpose of this retrospective cohort study was to examine the

independent role of ST with the hospitalization of middle-aged and older adults, including falls-related hospitalization while considering the influence of physical function levels. We hypothesized that higher levels of ST would be associated with a higher risk of hospitalization and that higher physical function would attenuate the effect of ST. Understanding the possible association between ST and hospitalization could help to widen the body of evidence necessary for more in-depth research on the topic and inform the development of programs and policies to reduce preventable hospitalization, increase the health and quality of life of older adults, and inform the hospital-based interventions.

3.3. Methods

3.3.1. Data source and participants

The CLSA is a nationally representative, stratified, random sample of 51,338 Canadian females and males aged 45 to 85 years (at baseline). The purpose of this survey is to collect data on the health and quality of life of Canadians to better understand the processes and dimensions of aging. The study contains two samples: the CLSA Comprehensive, and the CLSA Tracking. Data from the Comprehensive sample, counting with approximately 30,000 participants recruited between 2012 and 2015, was used in our study. The data collection in this sample was made through in-home questionnaires, physical examinations, and biological samples. These participants live within a 25-50 km radius of one of the 11 data collection sites across Canada (Vancouver/Surrey (two sites), Victoria, Calgary, Winnipeg, Hamilton, Ottawa, Montreal, Sherbrooke, Halifax, and St. John's).

Inclusion in the CLSA was limited to those who were able to read and speak either French or English. Residents in the three territories and some remote regions, persons living on federal First Nations reserves and other First Nations settlements in the provinces, and full-time members of the Canadian Armed Forces were excluded. Individuals living in long-term care institutions (i.e., those providing 24-h nursing care) were excluded at baseline; however, those living in households and transitional housing arrangements (e.g., seniors' residences, in which only minimal care is provided) were included. Finally, those with cognitive impairment at the time of recruitment were excluded.

The protocol of the CLSA has been reviewed and approved by 13 research ethics boards across Canada. Changes to the CLSA protocol are reviewed annually. Written consent is obtained from all participants. The University of Ontario Institute of Technology Research Ethics Board approved this secondary analysis of the CLSA dataset (REB #16120).

3.3.2. Exposure variable

Sedentary Time at baseline. A modified version of the Physical Activity Scale for Elderly (PASE) was used to collect information about ST during leisure time. The PASE is a valid and reliable tool for measuring sitting time among older adults. It has been shown to have good test-retest reliability over a 3 to 7-week interval (0.75, 95% CI=0.69-0.80) and construct validity has also been established (47). Participants were asked; "Over the past 7 days, how often did you participate in sitting activities such as reading, watching TV, computer activities or doing handicrafts? (Never, Seldom - 1 to 2 days,

Sometimes - 3 to 4 days, Often - 5 to 7 days)" and "On average, how many hours per day did you engage in these sitting activities? (<30min, ≥30min to <1h, ≥1h to <2h, ≥2h to <4h, ≥4h)". The midpoint for each category of sitting days and hours was used to estimate the total weekly sitting time per individual. The variability presented in the data justified its categorization based on tertiles of Low ST (≤900min/week), Moderate ST (901 to <1250min/week), and High ST (≥1250min/week).

3.3.3. Outcome variables

Hospitalization at follow-up 1. All participants were asked “Have you been seen in an Emergency Department during the past 12 months?” (Yes / No / Don’t know / No answer / Refused), “Were you a patient in a hospital overnight during the past 12 months?” (Yes / No / Don’t know / No answer / Refused). Participants who answered yes to having had an injury due to a fall that limited their normal activities were asked: “Were you hospitalized for this injury?” (Yes / No / Don’t know / No answer / Refused).

3.3.4. Covariates

Physical function. Handgrip strength and the Timed Up and Go (TUG) test were used as measurements of physical function. *Handgrip strength* was measured using a wireless dynamometer and the higher value of three attempts was used for each participant (48); a higher score is indicative of higher strength. The *TUG test* scores the participant according to the shortest time taken to stand up, cover the two sides of a 3 metres long course, and sit down again. (49, 50). Thus, a higher time is indicative of worse physical function.

Baseline Basic and instrumental ADLs were measured using a modified version of the Older American Resources and Services (OARS) Multidimensional Assessment Questionnaire. ADL impairments were classified as "no ADL problems", "mild, moderate, severe, and total ADL problems" (51, 52). In our analyses, we separated individuals in the "impairment" group - formed of those who reposted having impairment in at least one ADL – and the "no impairment" group.

Baseline Chronic Conditions. Participants answered whether they have been diagnosed by a health professional with health conditions "*which are expected to last, or have already lasted, 6 months or more*". The questionnaire asked about more than 40 different conditions categorized in 8 groups, as well as separate questionnaires on specific conditions including diabetes, stroke, hypertension, and others. In our study, we included 21 conditions related to cardiovascular disease, pulmonary, metabolic and cancer diseases. Participants were categorized as having a chronic condition if they reported being diagnosed with diseases from one or more of the 4 groups ("any condition"). Those without a reported diagnosis in any of the 4 groups of diseases were categorized as "no condition".

Some *sociodemographic variables* collected at baseline were also used in our models. Age, sex, income (CAD <$20,000, ≥$20,000 to <$50,000, ≥$50,000 to <$100,000, ≥$100,000 to < $150,000, ≥$150,000), education (less than secondary school graduation, secondary school graduation, no post-secondary education, some post-secondary education, post-secondary degree/diploma), were included in our analysis.

3.3.5. Statistical analysis

Descriptive analysis stratified by age category (middle-aged ≤64, older adult ≥65) and sex (males and females) were conducted. From the 30,097 participants enrolled in the cohort, 2,332 were removed from the analysis because missing follow-up data, and one additional participant was removed because of missing demographic and socio-economic data. With the remaining 27,764 participants the pattern of missing data in the variables of interest was examined and the missing data appear to be missing at random. To estimate the crude relationship between ST at baseline to overnight hospitalization, emergency department visit, and falls-related hospitalization in the 12 months before follow-up, logistic regression models were used. The analysis was then adjusted for physical function scores, chronic conditions, and sociodemographic variables. The analytic weights provided by CLSA were used in the logistic regressions. These weights were proportional to the inflation weights used to adjust for sample misrepresentation in CLSA, but rescaled to the sample size and provincial region where each Data Collection Site is located. All analyses were conducted in R version 4.0.3 (The R Foundation for Statistical Computing) and RStudio version 1.3 1093 (RStudio, PCB), and statistical significance was set at 0.05.

3.4 Results

3.4.1. Participants characteristics.

From the 30,097 participants in the Comprehensive cohort of CLSA, complete data were available for 27,765 individuals. The age range of the total sample was 45 to 86

years, middle-aged participants comprised 59%, and females 51% of all participants. The characteristics of the participants are described in Table 1.

Table 1. Baseline characteristics of participants, by age group and sex.

	Total	Females ≤64y	Males ≤64y	Females ≥65y	Males ≥65y
	n = 27765	n = 8476	n = 7944	n = 5656	n = 5688
Mean Age (SD)	62.7 (10.1)	55.5 (5.4)	55.7 (5.4)	72.9 (5.7)	72.9 (5.6)
Income					
1 - Less than $20,000	4.70%	4.40%	3.30%	8.60%	3.30%
2 - $20,000 or more, but less than $50,000	20.20%	15.90%	11%	36.40%	23.50%
3 - $50,000 or more, but less than $100,000	33.40%	32.70%	29.20%	31.90%	42.10%
4 - $100,000 or more, but less than $150,000	18.80%	21.20%	25.50%	8.50%	16%
5 - $150,000 or more	16.60%	20.30%	27.50%	3.50%	9.10%
NA	6.20%	5.40%	3.60%	11.20%	6%
Education					
1 - Less than secondary school graduation	5%	2.50%	2.60%	10.10%	6.90%
2 - Secondary school graduation, no post-secondary education	9.10%	8.80%	7.20%	12.40%	9.10%
3 - Some post-secondary education	7.30%	6.70%	6.90%	8.60%	7.30%
4 - Post-secondary degree/diploma	78.40%	81.90%	83.20%	68.80%	76.30%
NA	0.20%	0.10%	0%	0.20%	0.40%
Activities of Daily Living (5 groups)					
1 - No functional impairment	90.60%	91.40%	96.90%	80%	91.50%
2 - Mild impairment	8%	7.30%	2.50%	17.90%	6.80%
3 - Moderate impairment	0.80%	0.70%	0.40%	1.40%	1.20%
4 - Severe impairment	0.20%	0.20%	0.10%	0.30%	0.20%
5 - Total impairment	0.10%	0.10%	0%	0.10%	0%
NA	0.30%	0.30%	0.20%	0.40%	0.40%
Chronic conditions (2 groups)					
No	31%	36.50%	40.80%	20.40%	19.50%
Yes	69%	63.50%	59.20%	79.60%	80.50%
NA	0%	0%	0%	0%	0%
Hospitalization Overnight					
No	90.80%	94%	93.30%	87.40%	85.70%
Yes	9.10%	5.90%	6.60%	12.30%	14.20%
NA	0.10%	0.10%	0.10%	0.20%	0.10%
Hospitalization Emergency Department Visit					
No	77.8%	79.60%	80.70%	73.70%	74.90%
Yes	22.10%	20.20%	19.20%	26%	24.90%
NA	0.20%	0.20%	0.10%	0.30%	0.20%
Hospitalization due to falls					

No	5.90%	7%	4.50%	7.10%	5%
Yes	0.90%	0.60%	0.30%	1.60%	1.20%
NA (no injure-related fall)	93.20%	92.40%	95.10%	91.30%	93.80%
Hospitalization Overnight + Emergency Department					
No	75.50%	78.10%	78.90%	70.60%	71.60%
Yes	24.50%	21.90%	21.10%	29.40%	28.40%
NA	0%	0%	0%	0%	0%
Sedentary time					
Low	21.60%	25.10%	26.40%	15.40%	15.80%
Moderate	39.10%	38.70%	39.70%	38.70%	39.30%
High	37.20%	33.90%	31.80%	44%	43%
NA	2.10%	2.30%	2.20%	1.90%	1.90%
Timed up-and-go test (mean and SD)					
	9.5 (3.3)	8.9 (2.5)	9.0 (2.9)	10.3 (3.7)	10.0 (4.2)
Grip strength test (mean and SD)					
	35.4 (11.8)	28.6 (5.6)	47.2 (9.2)	23.7 (5.2)	39.5 (8.5)

3.4.2. Associations of Sedentary Time and Hospitalization

Tables 2 to 5 present the odds ratios and confidence intervals for crude and adjusted models for associations with overnight hospitalization, emergency department visit, either, overnight hospitalization or emergency department visit, and falls-related hospitalization. All analyses were adjusted for ADL impairment, chronic conditions, education, income, TUG, and grip strength tests.

In the adjusted models, ST was associated with emergency department visits only in middle-aged males. No other associations of ST with hospitalization were found for overnight hospitalization, emergency department visit, and the associated analysis of overnight hospitalization and emergency department visits as shown in tables 2 to 4. For TUG and grip strength, each unit increase in the test result corresponded to a change in OR that is, each second increased in time for TUG (worsening the score), and each kilogram increase in grip strength (improving the score). Significant associations of TUG time with overnight hospitalization in older males (Table 2), and with emergency department visits in middle-aged females and older males (Table 3) were observed. Significant associations of grip strength with emergency department visits were found in young (positively) and older males (negatively) (Table 3). Significant associations of TUG time and grip strength with either type of hospitalization was also observed (Table 4).

Table 2. Crude and adjusted associations between sedentary time and overnight hospitalization by age and sex.

Overnight Hospitalization								
	Crude							
	Female ≤ 64y		Female ≥ 65y		Male ≤ 64y		Male ≥ 65y	
	OR	CI	OR	CI	OR	CI	OR	CI
Sedentary Time								
Low	1	Reference	1	Reference	1	Reference	1	Reference
Mod	0.91	(0.73, 1.13)	0.85	(0.65, 1.13)	1.20	(0.98, 1.47)	0.87	(0.66, 1.15)
High	1.24	(0.99, 1.54)	1.19	(0.91, 1.56)	1.23	(0.99, 1.52)	1.01	(0.77, 1.33)
Timed-Up-and Go test	1.09	(1.06,1.13)	1.14	(1.10, 1.17)	**1.04***	(1.01, 1.07)	1.11	(1.07, 1.15)
Grip Strength test	0.97	(0.96, 0.99)	**0.97***	(0.95, 0.99)	0.99	(0.99, 1.00)	0.97	(0.95, 0.98)
	Adjusted							
	Female ≤ 64y		Female ≥ 65y		Male ≤ 64y		Male ≥ 65y	
	OR	CI	OR	CI	OR	CI	OR	CI
Sedentary Time								
Low	1	Reference	1	Reference	1	Reference	1	Reference
Mod	0.87	(0.70, 1.09)	0.88	(0.66, 1.17)	1.13	(0.92, 1.39)	0.89	(0.67, 1.19)
High	1.04	(0.84, 1.31)	1.10	(0.84, 1.46)	1.05	(0.85, 1.31)	0.97	(0.74, 1.29)
Timed-Up-and Go test	1.04	(1.00, 1.07)	1.10	(1.07, 1.14)	1.01	(0.99, 1.04)	**1.06***	(1.03, 1.10)
Grip Strength test	0.99	(0.97, 1.00)	1.00	(0.98, 1.02)	1.01	(1.00, 1.01)	0.97	(0.96, 0.99)

* $p < 0.05$

Adjusted models include household income, education level, ADL disability and chronic conditions

Table 3. Crude and adjusted associations for sedentary time and emergency department visits by age and sex.

Emergency Department Visit								
	Crude							
	Female ≤ 64y		Female ≥ 65y		Male ≤ 64y		Male ≥ 65y	
	OR	CI	OR	CI	OR	CI	OR	CI
Sedentary Time								
Low	1	Reference	1	Reference	1	Reference	1	Reference
Mod	1.00	(0.88, 1.13)	0.84	(0.68, 1.03)	1.07	(0.94, 1.21)	0.89	(0.71, 1.12)
High	**1.17***	(1.03, 1.33)	1.10	(0.91, 1.35)	**1.24***	(1.09, 1.40)	0.99	(0.80, 1.24)
Timed-Up-and Go test	1.09	(1.07, 1.12)	1.09	(1.06, 1.12)	1.00	(0.99, 1.02)	1.07	(1.03, 1.10)
Grip Strength test	**0.99***	(0.98, 1.00)	0.98	(0.96, 0.99)	1.00	(0.99, 1.01)	0.98	(0.97, 0.99)
Adjusted								
	Female ≤ 64y		Female ≥ 65y		Male ≤ 64y		Male ≥ 65y	
	OR	CI	OR	CI	OR	CI	OR	CI
Sedentary Time								
Low	1	Reference	1	Reference	1	Reference	1	Reference
Mod	0.97	(0.86, 1.10)	0.86	(0.70, 1.06)	1.03	(0.91, 1.17)	0.91	(0.72, 1.14)
High	1.03	(0.91, 1.18)	1.04	(0.86, 1.28)	**1.14***	(1.00, 1.30)	0.97	(0.78, 1.22)
Timed-Up-and Go test	**1.04***	(1.01, 1,07)	1.06	(1.03, 1.09)	0.99	(0.98, 1.00)	**1.03***	(1.01, 1.07)
Grip Strength test	1.00	(0.99, 1.01)	0.99	(0.98, 0.101)	**1.01***	(1.00, 1.01)	**0.98***	(0.98, 0.99)

* p <0.05

Adjusted models include household income, education level, ADL disability and chronic conditions

Table 4. Crude and adjusted associations for sedentary time and any of overnight hospitalization and emergency department visits by age and sex.

Overnight Hospitalization & Emergency Department Visit								
	Crude							
	Female ≤ 64y		Female ≥ 65y		Male ≤ 64y		Male ≥ 65y	
	OR	CI	OR	CI	OR	CI	OR	CI
Sedentary Time								
Low	1	Reference	1	Reference	1	Reference	1	Reference
Mod	1.03	(0.91, 1.16)	0.84	(0.69, 1.03)	1.08	(0.96, 1.22)	0.91	(0.74, 1.13)
High	**1.21***	(1.07, 1.37)	1.14	(0.94, 1.38)	**1.20***	(1.06, 1.36)	1.02	(0.82, 1.26)
Timed-Up-and Go test	1.10	(1.07, 1.13)	1.10	(1.07, 1.13)	1.01	(0.99, 1.03)	1.08	(1.05, 1.11)
Grip Strength test	**0.99***	(0.98, 1,00)*	**0.98***	(0.97, 0.99)	1,00	(1.00, 1.01)	0.98	(0.97, 0.99)
Adjusted								
	Female ≤ 64y		Female ≥ 65y		Male ≤ 64y		Male ≥ 65y	
	OR	CI	OR	CI	OR	CI	OR	CI
Sedentary Time								
Low	1	Reference	1	Reference	1	Reference	1	Reference
Mod	1.00	(0.88, 1.13)	0.86	(0.71, 1.05)	1.04	(0.92, 1.17)	0.93	(0.75, 1.16)
High	1.07	(0.42, 1.21)	1.07	(0.89, 1.31)	1.10	(0.97, 1.25)	0.99	(0.80, 1.23)
Timed-Up-and Go test	**1.04***	(1.02, 1.07)	1.07	(1.04, 1.10)	1.00	(0.98, 1.01)	**1.04***	(1.01, 1.08)
Grip Strength test	1.00	(0.99, 1.01)	0.99	(0.98, 1.01)	**1.01***	(1.00, 1.01)	0.98	(0.97, 0.99)

* p <0.05

Adjusted models include household income, education level, ADL disability and chronic conditions

Table 5 shows the results for falls-related hospitalization. Our adjusted analyses show a negative association between ST and falls-related hospitalization. Middle-aged females in the high ST group had a 63% lower risk of being hospitalized due to a fall than females of the same age in the low ST group. Although crude models presented associations of higher levels of ST with hospitalization in older males, the association of sitting time and falls-related hospitalization in middle-aged females were the only ones found when adjusted models were applied. The adjusted model also showed an association of TUG time with 17% increased risk of falls-related hospitalization in older females.

Table 5. Crude and adjusted associations for sedentary time and falls-related hospitalization by age and sex.

Falls-related hospitalization								
	Crude							
	Female ≤ 64y		Female ≥ 65y		Male ≤ 64y		Male ≥ 65y	
	OR	CI	OR	CI	OR	CI	OR	CI
Sedentary Time								
Low	1	Reference	1	Reference	1	Reference	1	Reference
Mod	0.78	(0.41, 1.47)	0.82	(0.38, 1.26)	1.11	(0.45, 2.82)	1.45	(0.43, 6.30)
High	**0.45***	(0.21, 0.94)	0.81	(0.39, 1.79)	1.52	(0.64, 3.81)	**3.43***	(1.13, 14.14)
Timed-Up-and Go test	1.00	(0.86, 1.13)	1.19	(1.09, 1.29)	1.08	(0.91, 1.26)	**1.14***	(1.02, 1.29)
Grip Strength test	1.01	(0.96, 1.05)	0.95	(0.90, 1.00)	1.00	(0.96, 1.03)	0.96	(0.92, 1.00)
Adjusted								
	Female ≤ 64y		Female ≥ 65y		Male ≤ 64y		Male ≥ 65y	
	OR	CI	OR	CI	OR	CI	OR	CI
Sedentary Time								
Low	1	Reference	1	Reference	1	Reference	1	Reference
Mod	0.70	(0.36, 1.36)	0.69	(0.30, 1.64)	1.10	(0.44, 2.83)	1.44	(0.42, 6.44)
High	**0.37***	(0.16, 0.81)	0.63	(0.28, 1.46)	1.47	(0.60, 3.77)	2.95	(0.93, 12.54)
Timed-Up-and Go test	1.02	(0.87, 1.19)	**1.17***	(1.07, 1.31)	1.09	(0.88, 1.34)	1.08	(0.97, 1,24)
Grip Strength test	1.01	(0.96, 1.06)	0.98	(0.92, 1.03)	1.00	(0.97, 1.04)	0.98	(0.93, 1.02)

* $p < 0.05$

Adjusted models include household income, education level, ADL disability and chronic conditions

3.5 Discussion

Our goal was to investigate the associations of ST and physical function with hospitalization in middle-aged and older adults. Emergency department visits were positively associated with ST in middle-aged males (OR 1.14 (1.00, 1.30)) while falls-related hospitalization was negatively associated with ST in middle-aged females (OR 0.37 (0.16, 0.81). We found an association of TUG with overnight hospitalization in older males (OR 1.06 (1.03, 1.10)), and with emergency department visit in middle-aged females (OR 1.04 (1.01, 1.07)) and older males (OR 1.03 (1.01, 1.07)). In older females TUG time was also associated with increased risk of falls-related hospitalization (OR 1.17 (1.07, 1.31)). Together, these findings point to an important sex differences that may suggest a need for sex-specific ST guidelines to avoid falls-related hospitalization, also pointing to the importance of physical function for the prevention of hospitalization in general.

In contrast to our hypothesis, ST was not positively associated with increased risk of hospitalization in our sample of middle-aged and older individuals except for middle-aged males. Our findings are in contrast with a previous cohort study including more than 265,000 females and males with a mean age of 63years (SD 11y), in which sitting less than 8h/day reduced in 14% the risk of hospitalization regardless of sex and age (HR 0.86, CI 0.83-0.89) (44). In fact, our results corroborate the findings in middle-aged and older females of a previous study in which increased levels of ST over 6 years were associated with a decrement in the risk of falls (OR 0.98 (0.98, 0.99)), while the maintenance of physical activity during 6 years increased the risk of falling by 30% (53).

This suggests that a fear of falling may be facilitating ST; and that functional fitness may be an important target in falls prevention.

It has been demonstrated that lower muscle strength and decreased physical function, measured via TUG and grip strength, increase the risk of falls-related hospitalization in older females (38% and 27% respectively) (11). Also, higher levels of ST and lower levels of strength are related to falls in older adults (13, 17, 54). The reduced risk of falls-related hospitalization promoted by higher levels of ST, together with our findings that lower scores in TUG can increase the odds of this same type of hospitalization by 17% in older females, may imply that weaker individuals, who are at higher risk of falling (13), tend to avoid activities in which they could suffer a fall by spending more time in sitting positions. This is in accordance with evidence suggesting that the fear of falling in weaker older adults is associated with augmented ST in this group (55), nevertheless, other studies demonstrate that lower physical function and ST may be independently related (31), what might suggest an inverse causation, that is, that excessive ST is the factor causing the weakness instead of its consequence. This also raises questions about the causative factor and the possibility of interdependency between these events, warranting more investigations on this association. Considering the evidence relating ST to chronic conditions, mortality, and physical function, the possible interdependency between factors can be one of the reasons why our analysis did not demonstrate associations of ST with hospitalization in all groups, although it is associated with reasons for hospital admission and emergency department visits.

There are several limitations of the present study that must be considered. First, misclassification bias could play a role due to the self-reported questionnaire used to

assesses ST, chronic conditions, and hospitalization. Evidence shows, for example, that when compared with device-measured data, self-reported ST tends to be 30-50% lower due to difficulties with recall (56). Thus, future studies aiming to clarify the associations of ST with hospitalization should seek more precise and objective methods to measure ST, health care use and the presence of chronic conditions. Activity monitors can be used to measure ST, along with certified professional reports and official registers to obtain information about participants' health conditions and health care use. Second, the questions on the survey asked about sitting accumulated during leisure activities instead of assessing the total daily sitting time; this made it challenging to understand whether individuals had high sedentary time compared to other samples where device measured total sedentary time was used. Lastly, our study may be also subject to selection bias, once the participants of the sample used in our analyses were able to leave home and visit one of the CLSA Data Collection Sites, besides passing through a long assessment and sampling session, indicating the necessity of good levels of health and function in the participants of this cohort. Future studies about the associations of ST with hospitalization may use data from the whole CLSA sample, maybe comparing its Comprehensive and Tracking cohorts although this does not allow for use of objective physical function assessments.

In conclusion, our findings suggest that ST has a positive association with emergency department visits in middle-aged males, and a negative association with the risk of falls-related hospitalization in middle-aged and older females, but these associations might be related to poorer physical function in these groups. This understanding is fostered by the body of literature in the field and by our finding of a

statistically significant positive association of TUG time with falls-related hospitalization in older females and with emergency department visits in older males. Our analysis suggests that sex-specific recommendations in regards to ST and physical activities for fall prevention are warranted, but more studies are needed to consolidate this understanding.

REFERENCES

1. Canada S. Census Program 2020 [Available from: https://www12.statcan.gc.ca/census-recensement/index-eng.cfm?HPA=1.

2. Canadian Institute for Health Information C. Inpatient Hospitalization, Surgery and Newborn Statistics, 2018–2019. Ottawa, ON: CIHI: Canadian Institute for Health Information; 2020.

3. Canadian Institute for Health Information C. Canadian Institute for Health Information, Health Care in Canada: A Focus on Seniors and Aging. Ottawa, ON.; 2011.

4. Canada S. Population projections: Canada, provinces and territories, 2018 to 2068. 2019.

5. Canadian Institute for Health Information C. National Health Expenditure Trends, 1975 to 2019. Ottawa, ON: CIHI; 2019.

6. Financial Accountability Office of Ontario F. Ontario Health Sector 2019 Updated Assessment of Ontario Health Spending. 2019. p. 21.

7. Canadian Institute for Health Information C. Canadian Institute for Health Information, Health Care Cost Drivers: The Facts. Ottawa, ON.2011.

8. Rozzini R, Frisoni G, Ferrucci L, Barbisoni P, Bertozzi B, Trabucchi M. The effect of chronic diseases on physical function. Comparison between activities of daily living scales and the Physical Performance Test. Age and Ageing. 1997;26(4):281-7.

9. Bayliss EA, Bayliss MS, Ware JE, Steiner JF. Predicting declines in physical function in persons with multiple chronic medical conditions: What we can learn from the medical problem list. Health and Quality of Life Outcomes. 2004;2(1):47.

10. Lange-Maia BS, Karavolos K, Avery EF, Strotmeyer ES, Karvonen-Gutierrez CA, Appelhans BM, et al. Contribution of common chronic conditions to midlife physical function decline: The Study of Women's Health Across the Nation. Womens Midlife Health. 2020;6:6.

11. Sim M, Prince RL, Scott D, Daly RM, Duque G, Inderjeeth CA, et al. Utility of four sarcopenia criteria for the prediction of falls-related hospitalization in older Australian women. Osteoporosis International. 2019;30(1):167-76.

12. Viccaro LJ, Perera S, Studenski SA. Is Timed Up and Go Better Than Gait Speed in Predicting Health, Function, and Falls in Older Adults? Journal of the American Geriatrics Society. 2011;59(5):887-92.

13. Moreland JD, Richardson JA, Goldsmith CH, Clase CM. Muscle Weakness and Falls in Older Adults: A Systematic Review and Meta-Analysis. Journal of the American Geriatrics Society. 2004;52(7):1121-9.

14. Zecevic AA, Chesworth BM, Zaric GS, Huang Q, et al. Estimating the Cost of Serious Injurious Falls in a Canadian Acute Care Hospital. Canadian Journal on Aging. 2012;31(2):139-47.

15. Canada PHAo. Seniors` falls in Canada - second report. Ottawa, ON: Public Health Agency of Canada; 2014.

16. Chun SH, Cho B, Yang H-K, Ahn E, Han MK, Oh B, et al. Performance on physical function tests and the risk of fractures and admissions: Findings from a national health screening of 557,648 community-dwelling older adults. Archives of Gerontology and Geriatrics. 2017;68:174-80.

17. Thibaud M, Bloch F, Tournoux-Facon C, Brèque C, Rigaud AS, Dugué B, et al. Impact of physical activity and sedentary behaviour on fall risks in older people: a systematic review and meta-analysis of observational studies. European Review of Aging and Physical Activity. 2012;9(1):5-15.

18. Asher A. The Dangers of Going to Bed. British Medical Journal. 1947;1(4543):967-8.

19. Hoenig HM, Rubenstein LZ. Hospital-Associated Deconditioning and Dysfunction. Journal of the American Geriatrics Society. 1991;39(2):220-2.

20. Allen C, Glasziou P, Del Mar C. Bed rest: a potentially harmful treatment needing more careful evaluation. Lancet. 1999;354(9186):1229-33.

21. Covinsky KE, Palmer RM, Fortinsky RH, Counsell SR, Stewart AL, Kresevic D, et al. Loss of Independence in Activities of Daily Living in Older Adults Hospitalized with Medical Illnesses: Increased Vulnerability with Age. Journal of the American Geriatrics Society. 2003;51(4):451-8.

22. Isaia G, Maero B, Gatti A, Neirotti M, Ricauda NA, Bo M, et al. Risk factors of functional decline during hospitalization in the oldest old. Aging Clinical and Experimental Research. 2009;21(6):453-7.

23. Boyd CM, Landefeld CS, Counsell SR, Palmer RM, Fortinsky RH, Kresevic D, et al. Recovery of Activities of Daily Living in Older Adults After Hospitalization for Acute Medical Illness. Journal of the American Geriatrics Society. 2008;56(12):2171-9.

24. Wakefield BJ, Holman JE. Functional Trajectories Associated With Hospitalization in Older Adults. Western Journal of Nursing Research. 2007;29(2):161-77.

25. Dharmarajan K, Han L, Gahbauer EA, Leo-Summers LS, Gill TM. Disability and Recovery After Hospitalization for Medical Illness Among Community-Living Older Persons: A Prospective Cohort Study. Journal of the American Geriatrics Society. 2020;n/a(n/a).

26. Kortebein P, Symons TB, Ferrando A, Paddon-Jones D, Ronsen O, Protas E, et al. Functional Impact of 10 Days of Bed Rest in Healthy Older Adults. The Journals of Gerontology: Series A. 2008;63(10):1076-81.

27. Baldwin C, van Kessel G, Phillips A, Johnston K. Accelerometry Shows Inpatients With Acute Medical or Surgical Conditions Spend Little Time Upright and Are Highly Sedentary: Systematic Review. Physical Therapy. 2017;97(11):1044-65.

28. Bodilsen AC, Klausen HH, Petersen J, Beyer N, Andersen O, Jørgensen LM, et al. Prediction of Mobility Limitations after Hospitalization in Older Medical Patients by Simple Measures of Physical Performance Obtained at Admission to the Emergency Department. Plos one. 2016;11(5):e0154350.

29. Copeland JL, Good J, Dogra S. Strength training is associated with better functional fitness and perceived healthy aging among physically active older adults: a cross-sectional analysis of the Canadian Longitudinal Study on Aging. Aging Clinical and Experimental Research. 2019;31(9):1257-63.

30. Clarke J CR, Janssen I, Tremblay M. Accelerometer-measured moderate-tovigorous physical activity of Canadian adults, 2007 to 2017. Statistics Canada, Catalogue. 2019;30(8):3-10.

31. Dogra S, Clarke J, Copeland J. Prolonged sedentary time and physical fitness among Canadian men and women aged 60 to 69. Health Reports. 2017;28(2):3-9.

32. Bames J BT, Benden ME, Biddle S, Bond D, Brassard P et al. . Letter to the Editor: Standardized use of the terms "sedentary" and "sedentary behaviours". Applied Physiology Nutrition and metabolism. 2012;37(3):540-2.

33. Loyen A, Clarke-Cornwell AM, Anderssen SA, Hagströmer M, Sardinha LB, Sundquist K, et al. Sedentary Time and Physical Activity Surveillance Through Accelerometer Pooling in Four European Countries. Sports Medicine. 2017;47(7):1421-35.

34. Hansen BH, Kolle E, Steene-Johannessen J, Dalene KE, Ekelund U, Anderssen SA. Monitoring population levels of physical activity and sedentary time in Norway across the lifespan. Scandinavian Journal of Medicine & Science in Sports. 2019;29(1):105-12.

35. Santos DA, Júdice PB, Magalhães JP, Correia IR, Silva AM, Baptista F, et al. Patterns of accelerometer-derived sedentary time across the lifespan. Journal of Sports Sciences. 2018;36(24):2809-17.

36. Hu FB, Leitzmann MF, Stampfer MJ, Colditz GA, Willett WC, Rimm EB. Physical Activity and Television Watching in Relation to Risk for Type 2 Diabetes Mellitus in Men. Archives of Internal Medicine. 2001;161(12):1542-8.

37. Hu FB, Li TY, Colditz GA, Willett WC, Manson JE. Television Watching and Other Sedentary Behaviors in Relation to Risk of Obesity and Type 2 Diabetes Mellitus in Women. JAMA. 2003;289(14):1785-91.

38. Mekary R, Lucas M, Pan A, Okereke O, Willett W, Hu F, et al. Isotemporal Substitution Analysis for Physical Activity, Television Watching, and Risk of Depression. American Journal of Epidemiology. 2013.

39. Katzmarzyk PT CT, Craig CL, Bouchard C. Sitting time and mortality from all causes, cardiovascular disease, and cancer. Med Sci Sports Exerc. 2009;41(5):998–1005.

40. Dunlop DD, Jing S, Arntson EK, Semanik PA, Jungwha L, Chang RW, et al. Sedentary Time in US Older Adults Associated With Disability in Activities of Daily Living Independent of Physical Activity. Journal of Physical Activity & Health. 2015;12(1):93-101.

41. Aviroop Biswas BPIO, MD, MSc; Guy E. Faulkner, PhD; Ravi R. Bajaj, MD; Michael A. Silver, BSc; Marc S. Mitchell, MSc;, and David A. Alter M, PhD. Sedentary Time and Its Association With Risk for Disease Incidence, Mortality, and Hospitalization in Adults. Annals of Internal Medicine. 2015;162(2):123-32.

42. Pandey A, Salahuddin U, Garg S, Ayers C, Kulinski J, Anand V, et al. Continuous Dose-Response Association Between Sedentary Time and Risk for Cardiovascular Disease: A Meta-analysis. JAMA Cardiology. 2016;1(5):575-83.

43. Sibley KM, Voth J, Munce SE, Straus SE, Jaglal SB. Chronic disease and falls in community-dwelling Canadians over 65 years old: a population-based study exploring associations with number and pattern of chronic conditions. BMC Geriatrics. 2014;14(1):22.

44. Tran B, Falster MO, Douglas K, Blyth F, Jorm LR. Health Behaviours and Potentially Preventable Hospitalisation: A Prospective Study of Older Australian Adults. Plos one. 2014;9(4):e93111.

45. Dohrn I-M, Welmer A-K, Hagströmer M. Accelerometry-assessed physical activity and sedentary time and associations with chronic disease and hospital visits - a prospective cohort study with 15 years follow-up. International Journal of Behavioral Nutrition and Physical Activity. 2019;16(1):125.

46. Valentine RJ, Misic MM, Rosengren KS, Woods JA, Evans EM. Sex impacts the relation between body composition and physical function in older adults. Menopause. 2009;16(3):518-23.

47. Washburn RA, Smith KW, Jette AM, Janney CA. The physical activity scale for the elderly (PASE): Development and evaluation. Journal of Clinical Epidemiology. 1993;46(2):153-62.

48. Frederiksen H, Hjelmborg J, Mortensen J, McGue M, Vaupel JW, Christensen K. Age Trajectories of Grip Strength: Cross-Sectional and Longitudinal Data Among 8,342 Danes Aged 46 to 102. Annals of Epidemiology. 2006;16(7):554-62.

49. Podsiadlo D, Richardson S. The Timed “Up & Go”: A Test of Basic Functional Mobility for Frail Elderly Persons. Journal of the American Geriatrics Society. 1991;39(2):142-8.

50. Bohannon RW. Reference Values for the Timed Up and Go Test: A Descriptive Meta-Analysis. Journal of Geriatric Physical Therapy. 2006;29(2):64-8.

51. Fillenbaum GG, Smyer MA. The Development, Validity, and Reliability of the Oars Multidimensional Functional Assessment Questionnaire1. Journal of Gerontology. 1981;36(4):428-34.

52. Fillenbaum GG. Screening the elderly. A brief instrumental activities of daily living measure. J Am Geriatr Soc. 1985;33(10):698-706.

53. Bea JW, Thomson CA, Wallace RB, Wu C, Seguin RA, Going SB, et al. Changes in physical activity, sedentary time, and risk of falling: The Women's Health Initiative Observational Study. Prev Med. 2017;95:103-9.

54. Pijnappels M, van der Burg JCE, Reeves ND, van Dieën JH. Identification of elderly fallers by muscle strength measures. European Journal of Applied Physiology. 2008;102(5):585-92.

55. Rosenberg DE, Bellettiere J, Gardiner PA, Villarreal VN, Crist K, Kerr J. Independent Associations Between Sedentary Behaviors and Mental, Cognitive, Physical, and Functional Health Among Older Adults in Retirement Communities. J Gerontol A Biol Sci Med Sci. 2016;71(1):78-83.

56. Harvey JA, Chastin SFM, Skelton DA. How Sedentary Are Older People? A Systematic Review of the Amount of Sedentary Behavior. Journal of aging and physical activity. 2015;23(3):471-87.

Chapter 4. General discussion

This thesis is the culmination of the second project undertaken during my master's program, since my original study, about hospital-associated deconditioning in older adults ("end p.j. paralysis"), an intervention that was planned to be performed in a hospital, had to be cancelled due to the current pandemic. For this first project, agreements had been made with the hospital clinical staff, most of the research materials were ready, and we were prepared to submit our documents to the hospital ethical research review board, aiming to initiate our data collection after ethical approval, in May 2020. But in March 2020 it became clear that this project would not be feasible over the next year.

Our former research questions included physical inactivity in hospitalized older adults and the evidence we accrued at that point suggested excessive sedentary time (ST) may be a problem in these patients. We therefore pivoted and decided to answer the following question "Is there an association between ST and hospitalization?" using an existing dataset. The Canadian Longitudinal Study on Aging provided an opportunity to answer the question using a large sample, with Canadian-specific data, and avoiding most of the problems created by the pandemic related to data collection. Thus, in the summer of 2020, we changed my thesis project.

The main purpose of this thesis was to investigate if ST has a positive and independent association with the hospitalization of middle-aged and older adults, including falls-related hospitalizations, considering the role of physical function in this association. We included other functional and health factors related to hospitalization, as well as social-economic characteristics also related to hospital admission in our analyses.

4.1Research questions

Our **first research question** was: *Is the risk of hospitalization higher in middle-aged and older adults who accumulate high volumes of sedentary time?* Based on evidence about the independent role of ST in several chronic conditions and health factors, we hypothesized that high amounts of ST would have an independent and positive association with the risk of hospitalization, particularly in individuals ≥ 65 years old. The analyses to answer this question included overnight hospitalization and emergency department visits, as asked of the participants. In an ideal database, we would have greater information on hospitalization, that is, participants would have answered if they were seen in a hospital in the past 12 months, and how often they were hospitalized, the reason for hospitalization, and more. Alternatively, and preferably, this data would be obtained directly from the health system registry. Also, ST would be device-measured instead of self reported.

The adjusted analyses show positive associations between ST and hospitalization only in middle-aged males for emergency department visits. In our crude models, we found some odds ratios for the association of ST to hospitalization to be statistically significant. Interestingly, some of these odds ratios remain at high numbers after adjustment but with wide confidence intervals. This, although normal, may suggest the existence of concealed confounders or limitations of the dataset influencing the analyses. Given that ST is independently associated with physical function, activities of daily living and chronic conditions, we can not disregard the chances that these covariates used in our analyses represent, at least in part, the influence of ST in the occurrence of overnight

hospitalization and emergency department visits. (Full tables containing the outcomes of our analyses can be found in the appendices).

Our **second research question** was: *Does sedentary time impact the risk of having a fall leading to hospitalization among older adults?* Being aware that lower muscle strength and decreased physical function, measured via the Timed Up and Go (TUG) and grip strength, increase the risk of falls-related hospitalization in older females (1); that higher levels of ST and lower levels of strength are related to falls in older adults (2-4); we hypothesized that high amounts of ST would lead to decrements of physical conditions sufficient to foster increased risk of falls, resulting in hospitalization in older individuals.

Contrary to our hypothesis, the analyses suggest that in middle-aged females, increased sitting time reduced the risk of hospitalization, which is in accordance with one study which suggests a reduction in the risk of falls among heavier sitters (5). Moreover, in the group of older females, our data also shows that higher TUG time is associated with increased risk of falls, which is well known (6) and reinforces the evidence suggesting that weaker individuals, fearing falls, tend to spend more time sat avoiding stood up and movement demanding activities (7). Nevertheless, as lower physical function and ST are independently associated (7), more investigations are necessary to determine if ST is the cause or the consequence of weakness.

Our **third research question** was: *Does physical function attenuate the risk of hospitalization among middle-aged and older adults who accumulate high volumes of sedentary time?* Provided that ST is independently associated with physical function, both factors are interrelated and associated with hospitalization, we hypothesized that

higher levels of physical function can attenuate the risk of hospitalization promoted by ST.

We did not observe consistent and positive associations between ST and hospitalization. The comparison between our crude and adjusted models suggests that physical function influences the relation of ST with hospitalization. However, given the limitations of the data, and the preliminary findings, we were unable to perform any analysis that directly addressed the issue of attenuation. Nevertheless, the odds ratios calculated for the association of TUG and hospitalization, consistently pointed to a positive association with all types of hospitalization. Surprisingly, in the analyses of falls-related hospitalization the confidence intervals suggested no significance, although lower body fitness and falls have a known and established association (1).

Besides including in our models TUG and Grip Strength test, we also included Activities of Daily Living assessment. Although all these three variables concern the physical function spectrum, collinearity tests demonstrated they were not importantly correlated. In different analysis performed, the highest variance inflation factor (VIF) encountered was under 1.200, showing low collinearity between the variables.

4.2 Methodological considerations

It is important to note that only 6.8% of the participants who reported being injured due to a fall had their data analysed for falls-related hospitalization. Also, the CLSA questionnaire does not include reasons for emergency department visits. Information on whether these visits were due to a fall would add less severe injuries and increase the number of participants in this sub-analysis. Of the 27,765 participants in our

sample, 1,888 reported being injured due to a fall in the 12 months before the follow-up data collection. Of these, 644 were middle-aged females in which high levels of ST were associated with 63% fewer odds of being hospitalized due to a fall. In view of this reduced number of participants, we performed a post hoc to determine whether we were adequately powered for this analysis. As the null hypothesis, we used data from the Public Health Agency of Canada showing that 1.6% of older adults are hospitalized due to a fall (8), and as the alternative hypothesis, we used data from a metanalysis associating ST with 37% higher risk of falls (3), what resulted in 2.2% risk of falls-related hospitalization. Using the OR of 0.37 found in our study, the G*Power software returned a power value of 0.96 for our finding of the association of ST with hospitalization in middle-aged females. Thus, it appears we were adequately powered for this analysis; although representativeness of this sample is limited.

The selection bias in our study sample may have led to more conservative findings than what would be expected in a sample representative of older adults who are not healthy enough to travel between 25km and 50km to attend one of the Data Collection Sites and participate in a long data collection session including physical function assessments. However, our findings are applicable to middle-aged and older populations with higher levels of mobility and independence.

Recall bias was also a limitation to our study, as data like ST, chronic conditions, hospitalization etc., were self-reported. Adding to this, CLSA used leisure time sitting activities as a measure of ST, which makes it difficult to ascertain if those with higher levels of leisure ST were the ones with more weekly total ST, as working, travelling, and idle time may also be spent in seated or reclined positions. As discussed in the

manuscript, ideally all data would be obtained via objective sources like device measurements for ST and official registers for hospitalizations, chronic conditions education, etc. Pertaining to ST, an alternative to device-measure assessments would be using questionnaires already employed in previous studies in which more accurate measures of ST were obtained, such as single item questionnaires about total sitting time (9).

4.3 Future considerations

Future studies should investigate the associations of ST with income, education level and marital status since they seem to be indicators of higher hospitalization. In addition, and following the example of Tran (2014) (10), may avoid including in their models any other physical variable than physical activities when studying the associations of ST with hospitalization because sitting time is associated with several physical function assessments as mentioned above. Also, future studies would be to investigate the associations of ST with health care use, including medical appointments, hospital admissions and prescription drugs, as evidence shows that ST has a generalized influence on health.

To gain a comprehensive understanding of the associations of ST with hospitalization, it would be interesting to start with a cross-sectional study assessing the ST of hospitalized patients and comparing them with non-hospitalized counterparts. This would provide insight into the sedentary behaviour characteristics of hospital patients and the possible differences between them and the non-hospitalized population. After the cross-sectional study, a cohort study would be performed including not only

hospitalizations but all aspects of health care use. This analysis would study the associations of ST, as a continuous variable, with the different types of health care utilization. Finally, a clinical trial could be developed aiming to assess the associations of ST with health care use, physical function, and wellbeing. This study would count with a sample of physically inactive individuals divided into two groups: one intervention group that would break the ST with bouts of light physical activities, and a control group that would sustain uninterrupted long bouts of ST. The results of this trial, performed after the insights provided by the two previous observational studies, would guide future research and the development of programs and services aiming to improve the health and quality of life of older adults and avoid preventable health care use.

4.4 Conclusion

In conclusion, our findings suggest that ST has a negative association with the risk of falls-related hospitalization in middle-aged females, but this association might be related to poorer physical functions in this group. This understanding is fostered by the body of literature in the field, by the TUG values that we have obtained and by our finding of a statistically significant and positive association of TUG time with falls-related hospitalization in older females. Together with our findings of positive associations of ST with emergency department visits in middle-aged males, our analysis suggests that sex-specific recommendations in regards to ST and physical activities for fall prevention and hospitalization are warranted, but more studies may be needed to consolidate this understanding.

REFERENCES

1. Sim M, Prince RL, Scott D, Daly RM, Duque G, Inderjeeth CA, et al. Utility of four sarcopenia criteria for the prediction of falls-related hospitalization in older Australian women. Osteoporosis International. 2019;30(1):167-76.

2. Moreland JD, Richardson JA, Goldsmith CH, Clase CM. Muscle Weakness and Falls in Older Adults: A Systematic Review and Meta-Analysis. Journal of the American Geriatrics Society. 2004;52(7):1121-9.

3. Thibaud M, Bloch F, Tournoux-Facon C, Brèque C, Rigaud AS, Dugué B, et al. Impact of physical activity and sedentary behaviour on fall risks in older people: a systematic review and meta-analysis of observational studies. European Review of Aging and Physical Activity. 2012;9(1):5-15.

4. Pijnappels M, van der Burg JCE, Reeves ND, van Dieën JH. Identification of elderly fallers by muscle strength measures. European Journal of Applied Physiology. 2008;102(5):585-92.

5. Dohrn I-M, Welmer A-K, Hagströmer M. Accelerometry-assessed physical activity and sedentary time and associations with chronic disease and hospital visits - a prospective cohort study with 15 years follow-up. International Journal of Behavioral Nutrition and Physical Activity. 2019;16(1):125.

6. Viccaro LJ, Perera S, Studenski SA. Is Timed Up and Go Better Than Gait Speed in Predicting Health, Function, and Falls in Older Adults? Journal of the American Geriatrics Society. 2011;59(5):887-92.

7. Rosenberg DE, Bellettiere J, Gardiner PA, Villarreal VN, Crist K, Kerr J. Independent Associations Between Sedentary Behaviors and Mental, Cognitive, Physical, and Functional Health Among Older Adults in Retirement Communities. J Gerontol A Biol Sci Med Sci. 2016;71(1):78-83.

8. Canada PHAo. Seniors` falls in Canada - second report. Ottawa, ON: Public Health Agency of Canada; 2014.

9. Bea JW, Thomson CA, Wallace RB, Wu C, Seguin RA, Going SB, et al. Changes in physical activity, sedentary time, and risk of falling: The Women's Health Initiative Observational Study. Prev Med. 2017;95:103-9.

10. Tran B, Falster MO, Douglas K, Blyth F, Jorm LR. Health Behaviours and Potentially Preventable Hospitalisation: A Prospective Study of Older Australian Adults. Plos one. 2014;9(4):e93111.

Appendices

A1. Output of the adjusted models, stratified by age category and sex, used to estimate the associations of ST with Overnight Hospitalization

ST groups, physical function tests, income bracket, education level, ADL impairment and diagnose of chronic conditions are show in rows. Reference categories were not included. Rows containing statistically significant p≤0.05 are shaded.

sex_r	age_grp_r	Term	estimate	std.error	statistic	p.value	conf.low	conf.high
F	<65	st_grpsModerate	0.870468	0.113731	-1.21976	0.222555	0.697133	1.089205
F	<65	st_grpsHigh	1.043602	0.11377	0.37513	0.707564	0.835831	1.306067
F	<65	TUG_TIME_COM	1.035161	0.017584	1.965225	0.049388	0.999586	1.072055
F	<65	GS_EXAM_MAX_COM	0.988659	0.007928	-1.43879	0.150209	0.973383	1.00411
F	<65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.715445	0.194937	-1.71773	0.085845	0.491588	1.057253
F	<65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.522034	0.18833	-3.4515	5.57E-04	0.364054	0.76281
F	<65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.496579	0.198704	-3.5229	4.27E-04	0.338823	0.739452
F	<65	hhldincome_r5 - $150,000 or more	0.493607	0.201564	-3.50268	4.61E-04	0.334874	0.739056
F	<65	education_r2 - Secondary school graduation, no post-secondary education	1.042692	0.28219	0.148149	0.882225	0.60982	1.853456
F	<65	education_r3 - Some post-secondary education	1.176936	0.288026	0.565625	0.571649	0.67926	2.112676
F	<65	education_r4 - Post-secondary degree/diploma	0.896972	0.252911	-0.42992	0.667256	0.560117	1.51697
F	<65	adls_2grpsimpairment	1.695818	0.137632	3.837531	1.24E-04	1.287247	2.209066
F	<65	cc_any_rYes	1.507357	0.099027	4.143895	3.41E-05	1.244075	1.834709
F	>=65	st_grpsModerate	0.878696	0.145593	-0.88821	0.374429	0.662789	1.173644
F	>=65	st_grpsHigh	1.103271	0.139399	0.705021	0.480797	0.843031	1.456942
F	>=65	TUG_TIME_COM	1.103066	0.017225	5.694868	1.23E-08	1.066415	1.141015
F	>=65	GS_EXAM_MAX_COM	0.996641	0.009519	-0.35347	0.723734	0.978184	1.015383
F	>=65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.975061	0.167182	-0.15107	0.879922	0.707024	1.362912
F	>=65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.789921	0.177108	-1.33152	0.183018	0.561301	1.124914
F	>=65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.700656	0.2316	-1.53601	0.124537	0.443109	1.100749
F	>=65	hhldincome_r5 - $150,000 or more	0.826278	0.291355	-0.65495	0.512498	0.457449	1.44092
F	>=65	education_r2 - Secondary school graduation, no post-secondary education	0.808026	0.185435	-1.14952	0.250343	0.561205	1.162201
F	>=65	education_r3 - Some post-secondary education	0.644105	0.218916	-2.00941	0.044494	0.416019	0.983374
F	>=65	education_r4 - Post-secondary degree/diploma	0.743017	0.148805	-1.99614	0.045918	0.557551	0.999746

F	>=65	adls_2grpsimpairment	1.285396	0.119908	2.093827	0.036275	1.013368	1.621892
F	>=65	cc_any_rYes	1.308459	0.13185	2.039055	0.041445	1.016022	1.704734
M	<65	st_grpsModerate	1.127271	0.104493	1.146477	0.251598	0.919716	1.385739
M	<65	st_grpsHigh	1.050852	0.110346	0.449506	0.653067	0.847016	1.305863
M	<65	TUG_TIME_COM	1.009331	0.012825	0.72422	0.468931	0.986388	1.03579
M	<65	GS_EXAM_MAX_COM	1.005266	0.004537	1.15774	0.24697	0.996358	1.014237
M	<65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.456698	0.207469	-3.77759	1.58E-04	0.305278	0.689637
M	<65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.411729	0.18992	-4.67244	2.98E-06	0.285961	0.602868
M	<65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.367379	0.195761	-5.11522	3.13E-07	0.252138	0.543866
M	<65	hhldincome_r5 - $150,000 or more	0.377196	0.195865	-4.97787	6.43E-07	0.258911	0.55868
M	<65	education_r2 - Secondary school graduation, no post-secondary education	1.290938	0.262452	0.973013	0.330547	0.781856	2.195939
M	<65	education_r3 - Some post-secondary education	0.848614	0.276653	-0.59335	0.552949	0.497564	1.4784
M	<65	education_r4 - Post-secondary degree/diploma	0.917112	0.232794	-0.37168	0.71013	0.592838	1.481672
M	<65	adls_2grpsimpairment	2.736086	0.175876	5.722945	1.05E-08	1.920529	3.831453
M	<65	cc_any_rYes	2.219605	0.094622	8.426507	3.56E-17	1.848117	2.678816
M	>=65	st_grpsModerate	0.893404	0.145592	-0.77419	0.438818	0.673745	1.192985
M	>=65	st_grpsHigh	0.970599	0.141791	-0.21046	0.833307	0.737753	1.286978
M	>=65	TUG_TIME_COM	1.06372	0.018832	3.280139	0.001038	1.025977	1.104468
M	>=65	GS_EXAM_MAX_COM	0.974331	0.006135	-4.23856	2.25E-05	0.96264	0.986078
M	>=65	hhldincome_r2 - $20,000 or more, but less than $50,000	1.04518	0.279787	0.157937	0.874506	0.616938	1.858019
M	>=65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.832273	0.278039	-0.66032	0.509048	0.493308	1.475456
M	>=65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.962182	0.294301	-0.131	0.895779	0.550629	1.755019
M	>=65	hhldincome_r5 - $150,000 or more	0.79466	0.320656	-0.71679	0.473507	0.428959	1.516674
M	>=65	education_r2 - Secondary school graduation, no post-secondary education	0.752718	0.23754	-1.19586	0.231751	0.471539	1.199239
M	>=65	education_r3 - Some post-secondary education	0.791878	0.252032	-0.92587	0.354515	0.480936	1.295084
M	>=65	education_r4 - Post-secondary degree/diploma	0.805604	0.182844	-1.18223	0.237114	0.567594	1.16389
M	>=65	adls_2grpsimpairment	1.434587	0.168592	2.140532	0.032312	1.023569	1.983898

M	>=65	cc_any_rYes	1.281964	0.137108	1.811663	0.070038	0.985554	1.688157

A2. Output of the adjusted models, stratified by age category and sex, used to estimate the associations of ST with Emergency Department Visit. ST groups, physical function tests, income bracket, education level, ADL impairment and diagnose of chronic conditions are show in rows. Reference categories were not included. Rows containing statistically significant p≤0.05 are shaded.

sex_r	age_grp_r	term	estimate	std.error	statistic	p.value	conf.low	conf.high
F	<65	st_grpsModerate	0.972212	0.064274	-0.43846	0.661056	0.857372	1.103089
F	<65	st_grpsHigh	1.034344	0.066517	0.507646	0.611702	0.908071	1.178634
F	<65	TUG_TIME_COM	1.039647	0.013218	2.9416	0.003265	1.013683	1.067437
F	<65	GS_EXAM_MAX_COM	1.001958	0.004592	0.42613	0.670013	0.992976	1.011011
F	<65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.667196	0.129512	-3.12459	0.001781	0.518338	0.861457
F	<65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.564729	0.123148	-4.64003	3.48E-06	0.444456	0.720486
F	<65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.472189	0.128506	-5.83922	5.24E-09	0.367648	0.608617
F	<65	hhldincome_r5 - $150,000 or more	0.484062	0.129446	-5.60497	2.08E-08	0.376206	0.625081
F	<65	education_r2 - Secondary school graduation, no post-secondary education	0.758675	0.170339	-1.62136	0.10494	0.544794	1.063
F	<65	education_r3 - Some post-secondary education	0.780893	0.176388	-1.40212	0.160878	0.553816	1.106529
F	<65	education_r4 - Post-secondary degree/diploma	0.711753	0.151833	-2.23945	0.025126	0.530786	0.963296
F	<65	adls_2grpsimpairment	1.5085	0.090088	4.563486	5.03E-06	1.26235	1.797242
F	<65	cc_any_rYes	1.464426	0.054938	6.943581	3.82E-12	1.315496	1.63166
F	>=65	st_grpsModerate	0.859442	0.105616	-1.43417	0.151523	0.699543	1.058516
F	>=65	st_grpsHigh	1.044661	0.102796	0.425039	0.670808	0.855157	1.279755
F	>=65	TUG_TIME_COM	1.057024	0.014274	3.885114	1.02E-04	1.028208	1.087198
F	>=65	GS_EXAM_MAX_COM	0.991322	0.007099	-1.22781	0.219519	0.977606	1.005198
F	>=65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.907898	0.131276	-0.73603	0.46171	0.703425	1.177258
F	>=65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.81086	0.13619	-1.53946	0.123692	0.622167	1.061501
F	>=65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.69632	0.171034	-2.11623	0.034325	0.497569	0.973307
F	>=65	hhldincome_r5 - $150,000 or more	0.969499	0.208292	-0.14871	0.881779	0.6417	1.453507
F	>=65	education_r2 - Secondary school graduation, no post-secondary	0.781867	0.14601	-1.68531	0.091929	0.58709	1.040925

		education						
F	>=65	education_r3 - Some post-secondary education	0.676627	0.166085	-2.35202	0.018672	0.487417	0.935181
F	>=65	education_r4 - Post-secondary degree/diploma	0.817355	0.117844	-1.71143	0.087001	0.649869	1.031729
F	>=65	adls_2grpsimpairment	1.265583	0.092652	2.542115	0.011018	1.054278	1.516126
F	>=65	cc_any_rYes	1.371052	0.094676	3.333225	8.58E-04	1.141123	1.654233
M	<65	st_grpsModerate	1.028154	0.063836	0.434947	0.663601	0.907496	1.165576
M	<65	st_grpsHigh	1.142547	0.066391	2.007202	0.044728	1.003319	1.301621
M	<65	TUG_TIME_COM	0.989847	0.006971	-1.4638	0.14325	0.976383	1.00401
M	<65	GS_EXAM_MAX_COM	1.006012	0.002806	2.135741	0.0327	1.000492	1.01156
M	<65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.78741	0.156487	-1.52732	0.126681	0.581098	1.073804
M	<65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.699713	0.146646	-2.43502	0.014891	0.526943	0.936916
M	<65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.631562	0.14888	-3.08677	0.002023	0.4735	0.849288
M	<65	hhldincome_r5 - $150,000 or more	0.591991	0.149224	-3.51326	4.43E-04	0.443548	0.796637
M	<65	education_r2 - Secondary school graduation, no post-secondary education	0.854944	0.17232	-0.90947	0.363102	0.611659	1.202818
M	<65	education_r3 - Some post-secondary education	0.771581	0.174778	-1.48368	0.137894	0.549162	1.090393
M	<65	education_r4 - Post-secondary degree/diploma	0.74262	0.150027	-1.98346	0.047317	0.556185	1.002287
M	<65	adls_2grpsimpairment	1.932697	0.138388	4.761378	1.92E-06	1.468444	2.527691
M	<65	cc_any_rYes	1.664781	0.053794	9.474963	2.67E-21	1.498787	1.850684
M	>=65	st_grpsModerate	0.90864	0.116402	-0.82306	0.410476	0.724376	1.143513
M	>=65	st_grpsHigh	0.969708	0.114275	-0.26918	0.787791	0.776391	1.215442
M	>=65	TUG_TIME_COM	1.034422	0.015461	2.188873	0.028606	1.005933	1.067463
M	>=65	GS_EXAM_MAX_COM	0.984794	0.004875	-3.14315	0.001671	0.975405	0.994229
M	>=65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.724228	0.222151	-1.45238	0.146395	0.471	1.127842
M	>=65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.564384	0.21967	-2.604	0.009214	0.368934	0.874948
M	>=65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.673405	0.232215	-1.70277	0.088611	0.429143	1.068749
M	>=65	hhldincome_r5 - $150,000 or more	0.461653	0.254712	-3.03457	0.002409	0.28072	0.763492
M	>=65	education_r2 - Secondary school graduation, no post-secondary education	0.805932	0.198438	-1.08727	0.276916	0.545927	1.189549

M	>=65	education_r3 - Some post-secondary education	1.064211	0.205005	0.30357	0.761456	0.711682	1.591135
M	>=65	education_r4 - Post-secondary degree/diploma	0.939738	0.154927	-0.40119	0.688282	0.69666	1.279702
M	>=65	adls_2grpsimpairment	1.322812	0.145362	1.924571	0.054283	0.991058	1.753081
M	>=65	cc_any_rYes	1.111205	0.104351	1.010483	0.312264	0.9077	1.36679

A3. Output of the adjusted models, stratified by age category and sex, used to estimate the associations of ST with Overnight Hospitalization & Emergency Department Visit. ST groups, physical function tests, income bracket, education level, ADL impairment and diagnose of chronic conditions are show in rows. Reference categories were not included. Rows containing statistically significant p≤0.05 are shaded.

sex_r	age_grp_r	Term	estimate	std.error	statistic	p.value	conf.low	conf.high
F	<65	st_grpsModerate	0.996052	0.062569	-0.06322	0.949591	0.881327	1.126347
F	<65	st_grpsHigh	1.065158	0.06474	0.975032	0.329545	0.938383	1.209518
F	<65	TUG_TIME_COM	1.041956	0.013112	3.134422	0.001722	1.01612	1.069548
F	<65	GS_EXAM_MAX_COM	1.001375	0.004464	0.30769	0.758318	0.992645	1.010171
F	<65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.736401	0.127866	-2.39298	0.016712	0.573905	0.947662
F	<65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.584155	0.122015	-4.40591	1.05E-05	0.460688	0.743485
F	<65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.506322	0.12688	-5.36398	8.14E-08	0.395437	0.650453
F	<65	hhldincome_r5 - $150,000 or more	0.510616	0.12789	-5.25561	1.48E-07	0.398006	0.657273
F	<65	education_r2 - Secondary school graduation, no post-secondary education	0.813924	0.168414	-1.22252	0.221513	0.586644	1.136018
F	<65	education_r3 - Some post-secondary education	0.865712	0.173928	-0.8291	0.40705	0.616976	1.22085
F	<65	education_r4 - Post-secondary degree/diploma	0.767893	0.150706	-1.75245	0.079697	0.57379	1.036733
F	<65	adls_2grpsimpairment	1.575727	0.087665	5.186978	2.14E-07	1.32526	1.868948
F	<65	cc_any_rYes	1.485613	0.05331	7.425003	1.13E-13	1.338739	1.649924
F	>=65	st_grpsModerate	0.86211	0.102112	-1.45303	0.146214	0.706401	1.05428
F	>=65	st_grpsHigh	1.074901	0.099505	0.725876	0.467915	0.885386	1.307972
F	>=65	TUG_TIME_COM	1.065017	0.014088	4.471199	7.78E-06	1.036273	1.095038
F	>=65	GS_EXAM_MAX_COM	0.994957	0.006855	-0.73749	0.460826	0.981664	1.008408
F	>=65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.910131	0.127779	-0.73695	0.461153	0.709611	1.171389
F	>=65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.80567	0.13232	-1.63301	0.102466	0.622572	1.046157
F	>=65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.677191	0.165567	-2.35435	0.018555	0.489141	0.936446
F	>=65	hhldincome_r5 - $150,000 or more	0.940204	0.202393	-0.30464	0.760637	0.630017	1.394177
F	>=65	education_r2 - Secondary school graduation, no post-secondary education	0.795911	0.141812	-1.60965	0.107474	0.602613	1.050947
F	>=65	education_r3 - Some post-secondary education	0.702381	0.160149	-2.20593	0.027389	0.512193	0.959997
F	>=65	education_r4 - Post-secondary degree/diploma	0.831198	0.11495	-1.60842	0.107743	0.664368	1.04282

F	>=65	adls_2grpsimpairment	1.285094	0.089926	2.789316	0.005282	1.076536	1.531665
F	>=65	cc_any_rYes	1.38194	0.090804	3.562479	3.67E-04	1.158537	1.654122
M	<65	st_grpsModerate	1.039305	0.061473	0.627136	0.53057	0.921567	1.172724
M	<65	st_grpsHigh	1.09984	0.064375	1.478297	0.139328	0.969594	1.24796
M	<65	TUG_TIME_COM	0.995858	0.007102	-0.58451	0.558879	0.982442	1.010648
M	<65	GS_EXAM_MAX_COM	1.007017	0.002716	2.574764	0.010031	1.00167	1.012392
M	<65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.737287	0.15244	-1.99932	0.045573	0.548074	0.996753
M	<65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.6716	0.142563	-2.7924	0.005232	0.509426	0.891321
M	<65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.610336	0.144633	-3.41377	6.41E-04	0.461053	0.813249
M	<65	hhldincome_r5 - $150,000 or more	0.572108	0.14495	-3.85255	1.17E-04	0.431922	0.76281
M	<65	education_r2 - Secondary school graduation, no post-secondary education	0.871591	0.168294	-0.81664	0.414136	0.628274	1.216038
M	<65	education_r3 - Some post-secondary education	0.751017	0.17115	-1.67296	0.094335	0.538119	1.053283
M	<65	education_r4 - Post-secondary degree/diploma	0.757064	0.146784	-1.89604	0.057955	0.570222	1.014528
M	<65	adls_2grpsimpairment	2.163605	0.134419	5.741572	9.38E-09	1.658685	2.810885
M	<65	cc_any_rYes	1.737266	0.052072	10.60675	2.77E-26	1.569288	1.924695
M	>=65	st_grpsModerate	0.930455	0.111833	-0.64455	0.519221	0.748236	1.160158
M	>=65	st_grpsHigh	0.988262	0.10994	-0.1074	0.914475	0.797744	1.227778
M	>=65	TUG_TIME_COM	1.044665	0.015724	2.779055	0.005452	1.01465	1.078258
M	>=65	GS_EXAM_MAX_COM	0.983744	0.004682	-3.50096	4.64E-04	0.974733	0.992791
M	>=65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.771301	0.218887	-1.18635	0.235485	0.504163	1.191735
M	>=65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.624745	0.216249	-2.17532	0.029606	0.410584	0.960626
M	>=65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.72039	0.228334	-1.43633	0.150909	0.462078	1.133236
M	>=65	hhldincome_r5 - $150,000 or more	0.558519	0.246689	-2.36113	0.018219	0.34499	0.909041
M	>=65	education_r2 - Secondary school graduation, no post-secondary education	0.783749	0.189677	-1.28464	0.198919	0.540108	1.136873
M	>=65	education_r3 - Some post-secondary education	1.001106	0.197188	0.005606	0.995527	0.679787	1.473648
M	>=65	education_r4 - Post-secondary degree/diploma	0.887069	0.148671	-0.80603	0.420227	0.664908	1.191647
M	>=65	adls_2grpsimpairment	1.330998	0.141119	2.02616	0.042748	1.006612	1.751154

M	>=65	cc_any_rYes	1.147283	0.100161	1.371765	0.170137	0.944536	1.399028

A4. Output of the adjusted models, stratified by age category and sex, used to estimate the associations of ST with Falls-Related Hospitalization. ST groups, physical function tests, income bracket, education level, ADL impairment and diagnose of chronic conditions are show in rows. Reference categories were not included. Rows containing statistically significant p≤0.05 are shaded.

sex_r	age_grp_r	Term	estimate	std.error	statistic	p.value	conf.low	conf.high
F	<65	st_grpsModerate	0.696166	0.338033	-1.0714	0.283991	0.357984	1.357415
F	<65	st_grpsHigh	0.368241	0.410669	-2.43266	0.014988	0.159702	0.809289
F	<65	TUG_TIME_COM	1.023579	0.078433	0.297132	0.766366	0.870885	1.186757
F	<65	GS_EXAM_MAX_COM	1.007937	0.025811	0.306309	0.75937	0.958486	1.060678
F	<65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.555738	0.620329	-0.94701	0.343633	0.171289	2.045751
F	<65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.3243	0.611162	-1.84253	0.065397	0.102876	1.181808
F	<65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.315387	0.645342	-1.78813	0.073755	0.092322	1.213796
F	<65	hhldincome_r5 - $150,000 or more	0.338704	0.641623	-1.68733	0.09154	0.100318	1.297427
F	<65	education_r2 - Secondary school graduation, no post-secondary education	2.821247	1.069286	0.969974	0.33206	0.457617	43.24328
F	<65	education_r3 - Some post-secondary education	0.473149	1.322917	-0.56568	0.571613	0.029138	9.310854
F	<65	education_r4 - Post-secondary degree/diploma	1.157435	1.006649	0.145241	0.884521	0.225354	16.6034
F	<65	adls_2grpsimpairment	0.806895	0.529936	-0.40488	0.685565	0.257035	2.113897
F	<65	cc_any_rYes	0.712466	0.304482	-1.11344	0.265518	0.392111	1.300729
F	>=65	st_grpsModerate	0.692812	0.425831	-0.86184	0.388777	0.304406	1.635621
F	>=65	st_grpsHigh	0.63008	0.414163	-1.11528	0.26473	0.283773	1.456749
F	>=65	TUG_TIME_COM	1.174741	0.051155	3.148232	0.001643	1.068175	1.305015
F	>=65	GS_EXAM_MAX_COM	0.975993	0.029542	-0.82254	0.410767	0.920295	1.033638
F	>=65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.771743	0.519866	-0.49841	0.618199	0.287091	2.252794
F	>=65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.917134	0.549083	-0.15754	0.874821	0.321981	2.828123
F	>=65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.852912	0.716449	-0.22207	0.824263	0.202495	3.482596
F	>=65	hhldincome_r5 - $150,000 or more	1.165986	0.758904	0.202353	0.83964	0.249039	5.11058
F	>=65	education_r2 - Secondary school graduation, no post-secondary education	3.613485	0.604099	2.126594	0.033454	1.154966	12.67913
F	>=65	education_r3 - Some post-secondary education	1.036091	0.735061	0.048234	0.961529	0.231037	4.392338
F	>=65	education_r4 - Post-secondary degree/diploma	1.655177	0.538737	0.93535	0.349608	0.612493	5.20812

F	>=65	adls_2grpsimpairment	1.245134	0.354299	0.618808	0.536043	0.611655	2.468018
F	>=65	cc_any_rYes	0.826297	0.360639	-0.52906	0.596761	0.415397	1.723542
M	<65	st_grpsModerate	1.097548	0.466645	0.199464	0.8419	0.443312	2.832454
M	<65	st_grpsHigh	1.467769	0.462462	0.829784	0.406661	0.601618	3.771711
M	<65	TUG_TIME_COM	1.08538	0.106507	0.769245	0.441748	0.877369	1.33678
M	<65	GS_EXAM_MAX_COM	1.002714	0.018935	0.143149	0.886173	0.966302	1.041012
M	<65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.438397	1.047702	-0.78709	0.431232	0.05572	4.225858
M	<65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.523026	0.91598	-0.70757	0.479209	0.101895	4.344514
M	<65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.374323	0.946002	-1.03873	0.298933	0.068633	3.272688
M	<65	hhldincome_r5 - $150,000 or more	0.480142	0.94136	-0.77938	0.435758	0.089728	4.194964
M	<65	education_r2 - Secondary school graduation, no post-secondary education	3726580	752.0286	0.02012	0.983947	5.35E-09	2.07E+9
M	<65	education_r3 - Some post-secondary education	808144	752.0288	0.018088	0.985569	5.10E-09	1.49E+2
M	<65	education_r4 - Post-secondary degree/diploma	1760238	752.0284	0.019123	0.984743	1.15E-16	NA
M	<65	adls_2grpsimpairment	0.802358	1.086073	-0.20275	0.839332	0.053838	5.032465
M	<65	cc_any_rYes	0.785891	0.372371	-0.64703	0.51761	0.380056	1.655196
M	>=65	st_grpsModerate	1.444555	0.679032	0.541656	0.588056	0.415997	6.437633
M	>=65	st_grpsHigh	2.952177	0.644584	1.679445	0.093065	0.930347	12.53696
M	>=65	TUG_TIME_COM	1.077381	0.0677	1.100932	0.270926	0.97212	1.235107
M	>=65	GS_EXAM_MAX_COM	0.975758	0.021882	-1.12149	0.262081	0.933821	1.017893
M	>=65	hhldincome_r2 - $20,000 or more, but less than $50,000	0.332806	0.873134	-1.26005	0.207651	0.059917	1.984812
M	>=65	hhldincome_r3 - $50,000 or more, but less than $100,000	0.535793	0.848491	-0.73543	0.462076	0.1022	3.092621
M	>=65	hhldincome_r4 - $100,000 or more, but less than $150,000	0.490877	0.910997	-0.78108	0.434755	0.082333	3.152551
M	>=65	hhldincome_r5 - $150,000 or more	0.246504	1.114779	-1.25619	0.209047	0.023706	2.138377
M	>=65	education_r2 - Secondary school graduation, no post-secondary education	0.78356	0.855851	-0.28499	0.775653	0.143274	4.4159
M	>=65	education_r3 - Some post-secondary education	0.483707	1.10698	-0.65609	0.511768	0.040089	3.844766
M	>=65	education_r4 - Post-secondary degree/diploma	0.886474	0.694001	-0.17364	0.862152	0.242833	3.92176
M	>=65	adls_2grpsimpairment	1.789275	0.509705	1.141466	0.253676	0.638904	4.784806

M	>=65	cc_any_rYes	0.658061	0.465833	-0.8983	0.369025	0.269389	1.704107