Associations between mobility capacity and walking performance in community-dwelling older people with outdoor walking limitations

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A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfillment of the requirement of the degree of

MASTER OF SCIENCE

College of Rehabilitation Sciences

University of Manitoba

Winnipeg

ABSTRACT

Introduction: Walking is the most common physical activity reported by Canadian adults. Community-ambulation requires many skills such as muscle strength, balance, endurance along with other factors. Clinicians use capacity tests to measure physical abilities to better understand the relationship between what people can do (capacity) and what people really do in their daily lives (performance). Our objective was to determine individual and collective relationships between mobility capacity and walking performance to better understand how to use and interpret tests of capacity in clinical situations.

Methods: This study was a secondary data analysis. Baseline data from 168 participants (≥63 years of age) of the GO-OUT study, conducted in 4 Canadian cities (Edmonton, Winnipeg, Toronto, and Montreal), were analyzed. The multiple linear regression analyses included mobility capacity tests (6-minute Walk Test (6MWT), comfortable 10-metre Walk Test (10mWT), 30-second Sit-to-Stand (30sSTS) and Mini-BESTest); and walking performance measures collected with 7-day accelerometry (peak 30-minute cadence, time walked in bouts and steps/day). Frailty status data were used to test for a moderation effect.

Results: Outcomes from multiple linear regression models with single capacity measures demonstrated that tests of capacity were positively related with walking performance measures, however they explained only a small amount of the variance in peak 30-minute cadence (24-28%), time walked in bouts (12-17%), and steps/day (18-22%). Analyses of the combined capacity measures using multiple linear regression demonstrated larger amounts of variance were explained in all walking performance measures (peak 30-minute cadence R^2 =37%, with 6MWT and 30sSTS significant; time walked in bouts R^2 =19%, with 10mWT significant; steps/day R^2=25%, with 30sSTS significant; all $p \leq 0.05$). Frailty did not moderate any relationships.

Conclusion: The 6MWT and 30sSTS are significantly associated with peak 30-minute cadence, which is said to represent the best natural effort in daily life. These two tests assess different aspects of physical capacity and physiotherapists may use them to better understand walking performance of their clients to plan and evaluate treatment progress.

Keywords: older adults, walking capacity, 6MWT, 10mWT, 30sSTS, Mini-BEST, walking performance, peak cadence, walk bouts, steps per day, frailty.

ACKNOWLEDGEMENTS

I am grateful for all the support given by my thesis advisor Dr. Sandra Webber. Her endless patience, and enthusiasm even in the middle of so much uncertainty caused by a pandemic were a great motivation throughout the course and research work. She guided me through the whole process teaching me what I needed to develop my research work and writing skills. Thank you for allowing me to learn so much from you. Your support has given me the opportunity to grow as a professional and has given my family the opportunity to live and experience the Canadian culture.

Also, I would like to thank my committee members, Dr. Ruth Barclay and Dr. Nancy Salbach. They gave me the opportunity to conduct this research using data collected for the GO-OUT study, and promptly provided their input whenever needed. Their critical input on my manuscript writing was very important to develop my research. Thank you for your availability and shared knowledge.

I need to recognize the support I received from other people involved in the GO-OUT study who were always available to respond to any inquiry or needed input. Our statistician Loring Chuchmach was always ready to help and guide through data analysis.

Finally, my gratitude to my family and close friends in Brazil who are praying and cheering for the success of this journey. Last but not least, I want to thank my husband Rafael Cardoso Gil and my children Isadora and Davi for their continuous, tireless support, and courage to embark in this challenge with me. Thank you for your trust.

DEDICATION

"You are the light of the world. A city set on a mountain cannot be hidden. Nor do they light a lamp and then put it under a bushel basket; it is set on a lampstand, where it gives light to all in the house. Just so, your light must shine before others, that they may see your good deeds and glorify your heavenly Father."- Mt 5, 12.

I dedicate this to my loving husband Rafael,

our daughter Isadora, and our son Davi.

You are my most precious treasure. Love you.

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List of Abbreviations

CI – Confidence Intervals

CHAMPS - Community Health Activities Model Program for Seniors

GO-OUT – Getting Older adults OUTdoors

LFE - Low frequency extension

Mini-BESTest – Mini Balance Evaluation System Test

SMART - Specific, Measurable, Achievable, Realistic and Timely

6MWT – Six-minute walk test

10mWT – Ten-metre walk test

30sSTS – 30-second Sit to Stand

LLCI – Lower-level confidence interval

ULCI – Upper-level confidence interval

Chapter 1 - Literature review

1.1 Introduction

In Canada, older adults from various ethno-cultural backgrounds consider it important to maintain physical and cognitive skills, and to maintain an active social life with age.[1] Physical and cognitive skills are essential to perform activities of daily living and leisure, including walking. Community ambulation is one the most common forms of physical activity among older adults, and it requires physical capacities that tend to decrease as people age.[2–5]

Among the physical abilities necessary to walk are muscle strength, balance, aerobic endurance, motor coordination, and cognitive competence. Maintenance and/or improvement of physical capacities and cognitive functioning, and promotion of healthy aging are among the benefits of physical activity and exercise in older adults.[6] It has been demonstrated that even in older adults with degenerative diseases such as Parkinson's disease, higher levels of physical capacity (e.g. leg strength, balance, walking speed) indicate higher levels of everyday life activity (performance).[7–9] This suggests that changes in physical capacity lead to changes in performance. Which in turn, also suggests that people with higher physical capacity may also present with higher walking performance. However, research has shown that even if people are physically capable of doing something it does not mean that they will perform to their full capacity in daily life. Research about relationships between walking capacity and performance have shown different results depending on the measures and specific associations studied. The ability to balance on one leg has been positively associated with the number of steps and the amount of time older people spend outdoors.[10] Studies in older adults after stroke have shown the ability to walk in the community is related to their walking endurance, balance skills and motor function rather than their walking speed.[2,11] Other studies have found no association between physical capacity and walking performance in non-frail older adults.[12] This suggests that other factors such as frailty, may influence the relationships between physical capacity and walking performance.

Health care professionals, such as physiotherapists, often use physical capacity tests to try to understand individuals' abilities to walk in everyday life.[13] As such, physical capacity tests are an important component of assessments and inform treatment programs aimed at keeping older adults as active and mobile as possible.[14] In this study, we examined relationships between physical capacity and walking performance in a sample of 168 older adults with outdoor walking limitations who participated in the GO-OUT study. Mobility capacity tests included the 6-minute Walk Test (6MWT), comfortable 10-metre Walk Test (10mWT), 30-second Sit-to-Stand (30sSTS) and Mini-BESTest; and the walking performance measures consisted of peak 30-minute cadence, time walked in bouts and steps/day. In addition to determining individual relationships between the measures of capacity and performance, we were interested in identifying which capacity measure, or combinations of measures, explained the greatest variance in walking performance, and the relative influence of frailty in the relationships.

1.2 Health, aging, and active living

Basic healthcare to prevent and treat diseases has evolved over time, and, as a result of having more resources available people are living longer. In Canada, life expectancy for people born in 1950 was 71.8 years for women and 65.9 years for men, whilst for people born in 2019, the life expectancy is 84.2 years for women and 80.1 years for men.[15] The increase in life expectancy and changes in lifestyle, motivated in part by advances in technology (earlier disease diagnostics, effective treatments for acute and chronic conditions),[16] have brought new challenges for healthcare. As more people live longer with more comorbidities than a century ago, some difficulties and specific needs related to aging have become evident.[17,18] For example, as people age, they sometimes require specific health care assistance, psychological attention, additional opportunities for socialization, and adaptations in their homes to help with maintaining independence and prevent injuries.[19,20] People wish to have long and healthy lives, and they wish to be able to participate actively in things that are important to them.

Healthy aging means different things to different people. Healthy aging does not necessarily mean aging free of illnesses or impairments, but rather getting older living an active, independent life.[1,21] Some aspects are common to most people such as the importance of maintaining physical and cognitive abilities, and being able to engage with friends and family.[1] For example, stroke survivors have reported that it is very important that they continue to be able to socialize in the community to minimize isolation and dependence, and to maintain physical activity.[22]

Physical activity is a broad concept, and it is not a synonym for exercise.[23] Physical activity encompasses all energy-consuming activities that involve moving any part of the body by the skeletal muscles, including daily life activities (e.g., cleaning the house, shopping, active transportation such as walking or bicycling), and leisure activities (e.g., gardening, exercising).[24] In general, physical activity helps to lower risks of cardiovascular[25,26] and metabolic illnesses,[27] lower obesity levels,[28] prevent falls,[24] improve muscular strength,[29] develop aerobic capacity,[29] improve flexibility,[30,31] maintain healthy blood pressure,[32] and lower mortality.[24,32,33] Exercise is a type of physical activity, and requires activities that are planned, structured and repetitive with the purpose to maintain or improve at least one aspect of physical fitness (e.g., cardiovascular endurance, muscular endurance and strength, body composition and flexibility).[23] The benefits of maintaining an active lifestyle can help older people to remain independent with daily activities without suffering high levels of fatigue,[34] improve/maintain good mental health,[24] recover more quickly after an illness,[27] improve/maintain quality of life,[15,32] and promote social involvement.[15]

Physical activity is associated with many health benefits which highlights the importance of mobility for older people. Mobility is essential for independent living since indoor basic activities of daily life as well as outdoor activities rely on the way a person moves around their environment.[3] Broadly, mobility is a person's ability to move from one location to another (within or outside their home) by walking or using any method of transportation.[3,35] The mobility framework by Webber and colleagues[35] considers 5 main categories of determinants of mobility for older adults (cognitive, psychosocial, physical, environmental, and financial), and each category of determinants has factors that expand as older adults move further away from home.[35] Community ambulation (a specific form of mobility), refers to the ability to walk in different environments outdoors and indoors in private and public places.[2,36] Community ambulation is a form of physical activity, and it may also provide and/or allow social participation for some older adults.[36]

Community ambulation demands skills that are beyond those often required in a clinical environment (e.g., to walk a straight hallway),[37] because walking in the community requires the ability to start and stop walking, increase and decrease walking speed, as well as the ability to turn and sit.[38] Walking in the community also requires older adults to have sufficient walking endurance.[38] Indoor and outdoor environments present different challenges (e.g., the walking surfaces change), and factors such as cognitive competence, fear of perceived dangers,[39] frailty,[40] and physical function influence abilities. If any of these factors is impaired, walking performance is affected, and the consequence is reduced community ambulation.[2,3,4] For example, in a study by Rantakokko and colleagues,[39] (n=777) older adults with no walking impairments who felt unsafe walking outdoors were 4 times more likely to report difficulties walking 0.5 km and 3 times more at risk of reporting difficulties in walking 2 km compared to those without fear. Many factors, including age, can influence how often older adults move outdoors. A study of 560 people that compared population age groups showed older adults were less active and spent less time outdoors compared to other age groups.[25] However, outdoor physical activity is very important to maintain physical independence in older adults.[39,41]

1.3 Physical capacity

Physical capacity is the highest level of physical functioning of a person, measured at a certain moment in time in a standardized environment.[5,12,42] Some components of physical capacity are muscular strength, aerobic capacity, neuro-muscular speed, flexibility, balance, agility, coordination, and acuity of each of our senses.[5,12,43] While physical capacity often decreases with age and/or disease,[5] it can be modified by training (e.g., to improve strength, cardiorespiratory endurance, and gait speed).[22]

Previous studies have shown that physical function (e.g., the ability to do daily living activities such as walking, climbing stairs, gardening) decreases even in healthy individuals as they age.[24] Factors such as stroke, Parkinson's disease, frailty, and other comorbidities can accelerate reductions in physical function.[24,45] Limited physical capacity has many implications such as a reduction in the ability to live independently, greater social isolation, lower quality of life, higher risk for falls, and decreased life-expectancy.[32] Steffen and colleagues[46] studied outcomes of some tests of physical capacity (e.g., 6-Minute Walk Test, Berg Balance Test, Timed-Up and Go) in community-dwelling healthy older adults, and found age-related decreases in all measures for males and females. The study demonstrated a need to use age-specific data in order to make judgements regarding physical capacity in older adults because capacity results may vary substantially with age (e.g., between 60-90 years of age).[46] Measuring physical capacity can help clinicians understand changes that affect older peoples' ability to move.

According to Falck et al[6] physical activity and exercise are beneficial for older adults to maintain and/or improve physical capacities and cognitive functioning, and promote healthy aging. Among older adults, walking is the most common physical activity across all age groups and other demographic markers (e.g., ethnicity and income).[47] Although walking seems to be a simple physical activity, community ambulation is actually quite complex[48] and requires physical capacities related to aerobic capacity,[49] walking endurance,[22] gait speed,[22] balance,[50] and cognition.[35] It can be influenced by stride length,[5] speed,[5,46] cardiovascular health,[27] body weight,[33,51] impairments caused by diseases,[48] and comorbidities related to aging.[27] There are many ways to assess community ambulation, and depending on the method or type of test a different aspect of mobility may be analyzed.[5]

1.4 Measures of physical capacity relevant to community ambulation

1.4.1 Aerobic capacity

Aerobic capacity is a measure of the ability of the cardiopulmonary and vascular systems to take in and deliver oxygen to the muscles. Aerobic capacity and physical function can be improved by regular participation in aerobic activities such as walking.[51,52,53] In 1968, Cooper was the first to publish a test to measure aerobic capacity, the 12-minute walk test. Later, the 6-Minute Walk Test (6MWT) and the 2-Minute Walk Test were developed to be used for the same purpose.[52,53]

The 6MWT can be used for individuals of all ages and is commonly used to measure changes resulting from exercise-based interventions.[46,54] The 6MWT is a sub-maximal exercise test which is relatively easy to apply and requires almost no equipment. The primary outcome is the total distance walked in 6 minutes.[46] When compared to treadmill tests, one of the advantages of using the 6MWT is that participants can regulate their walking speed,[55] stop in the middle of the test to rest, and resume walking.[56] The outcome can identify a participant's aerobic capacity[57] relative to their age group or it can be compared to previous test outcomes to determine if there is a significant change in pulmonary and/or cardiovascular system functioning.[46,58] Diverse factors affect 6MWT results such as age, gender, height, weight, and ethnicity.[53] Men can generally walk further than women, and with age, people tend to walk shorter distances.[53]

The 6MWT is a common test used in studies to measure walking capacity in different populations. In Nordanstig and colleagues' study[55] on predicting walking performance in people with intermittent claudication, participants performed a number of indoor and outdoor capacity tests and completed some questionnaires. The 6MWT outcomes showed the greatest correlation ($r = 0.78$; 95% CI, 0.64-0.87) with outdoor walking capacity (measure of the total walking distance during a 40-minute outdoor walk test) compared to the other measurements (comfortable and fast gait speed, Berg Balance Scale, Fugl Meyer, and Stroke Impact Scale). Fulk et al[11] found that aerobic capacity measured by the 6MWT was a strong individual predictor of steps/day in people with stroke. They categorized participants to be home ambulators (100-2499 steps/day), limited community ambulators (2500-7499) and full community ambulators (≥7500 steps/day). The researchers found that individuals poststroke who completed 6MWT distances ≥ 205 m fell into the limited community ambulators category based on their steps/day data, and those who walked distances ≥ 288 m were unlimited community ambulators.[11] Although Fulk and colleagues[11] found that people who were able to walk more than 288m in the 6MWT generally walked more than 7500 steps/day (i.e., were categorized as full community ambulators), other authors[59,60] suggest that community ambulation requires the ability to walk longer distances. Salbach and colleagues[59] found in a systematic review that for older adults to be able to visit common community locations (e.g., physician offices, banks, stores) they needed to be capable of walking distances varying between 20 and 381m. If the destination was a place such as a superstore or a hardware store, they needed to be able to walk more than 600m during a single visit.

Since 6MWT results can be used to determine if a person has improved or declined in aerobic capacity,[58] some studies have attempted to determine the minimum change necessary to be considered clinically meaningful. Rasekaba and colleagues[53] suggested that for community-dwelling older adults an increase as little as 20m in the 6MWT final distance can be considered clinically important, however improvements larger than 50 meters are considered more substantial.[53,61]

1.4.2 Gait speed

Gait speed is another measure of physical capacity commonly used in people of different ages to determine how fast an individual walks a predetermined distance. It can be measured through reliable and inexpensive tests in studies of different populations (e.g., Parkinson's disease,[62] chronic obstructive pulmonary disease,[63] post-stroke,[64] chronic kidney disease,[65] cardiopathy,[66] symptomatic peripheral disease,[67] and community-dwelling older adults[46]). Gait speed is considered to be a functional vital sign, indicative of general health, important in determining safe discharge from hospital, and predictive of the need for institutionalization and/or treatment implementation.[68,69]

Gait speed is an intricate behavior[48] which is negatively associated with cognitive impairment,[62,68,69] physical disability,[68] depressive symptoms,[70,71] falls,[68] diseases,[48,60,63,64,65,68,69,73] quality of life,[63] frailty,[68] and mortality.[68,69] Gait speed is considered an important factor in determining rehabilitation needs, and reduced physical function.[69,75] How quickly one is able to walk is also important for safe performance of daily life activities[22] because some activities have time constraints,[60] requiring a person to walk at a speed that is above a "comfortable pace", and some activities require sudden changes in speed to avoid obstacles[46] (e.g., when crossing a busy street or walking in a congested area).[60] Low gait speed can be associated with a reduced ability to walk long distances within the community[48] and low social participation.[60] Gait speed is a capacity measure that is relatively easy to test, and many clinicians use the 10 metre Walk Test (10mWT), the 4 metre Walk test (4mWT) or other similar tests to evaluate this aspect of physical function.[41,59, 63,75]

Steffen and colleagues[46] suggest the average gait speed for people over 60 years of age ranges from 1.15 – 1.44 m/s for women and from 1.21 – 1.59m/s for men. The literature shows a number of ways to qualify walkers based on gait speed capacity, such as the classification to predict community walking capacity proposed by Perry and colleagues in 1995.[77] These authors proposed that older adults with stroke who walk at a gait speed <0.4m/s are household walkers, 0.4 – 0.8m/s are limited community walkers, and >0.8m/s are unlimited community walkers. Abellan Van Kan and colleagues[68] classified independent community-dwelling older adults as slow walkers (<0.6 m/s), intermediate walkers (0.6 ≥ 1.0 m/s), or fast walkers (≥1.0 m/s), and demonstrated that individuals who were slow walkers were at increased risk for decreased physical and cognitive function, hospitalisation and mortality when compared to fast walkers.[62]

Salbach and colleagues[59] reported in a systematic review that gait speeds required to safely cross streets with traffic lights and timed crossings varies substantially (from 0.44 – 1.32 m/s) in different regions and different countries. In large cities, streets tend to be wider than in smaller centres, so gait speeds need to be sustained for longer distances. In Ontario the provincial traffic manual uses walking speeds of 1.0 and 1.25m/s as reference values to determine timing for walk signals.[59] Therefore, the minimum gait speed capacity reported by Salbach et al[59] (0.44 m/s) is too slow for older adults to cross streets safely in Ontario. The minimum distance required to cross a street is thought to be 10 meters, making the 10mWT a relevant walking test for older adults.[59]

Similar to other measures of physical capacity, gait speed decreases with age.[46] People older than 80 years of age tend to have gait speeds that are 10 – 12% slower than younger adults and a sudden reduction in the capacity to walk quickly can be an early sign of cognitive impairment or dementia.[62,68] Simonsick and colleagues[33] found that older women who walked a minimum of 8 blocks/week maintained their usual walking speed over one year, however rapid walking speed decreased similar to women who did not walk at least 8 blocks/week, suggesting that walking 8 blocks/week was not enough to preserve faster walking speeds.[33]

1.4.3 Balance

Balance is the ability of an individual to maintain equilibrium during a specific task and involves the motor system,[78] anticipatory postural control,[71,78] sensory integration,[71] functional stability limits,[78] reactive postural control,[79] cognitive influences,[71,78,79] verticality,[79] dynamic stability and static stability.[79] Static balance and dynamic balance are important for postural control, the former keeps the body stable and oriented in a fixed posture when the body is at rest, and the latter allows the body to maintain stability and orientation while it is moving.[78] Balance is important for community ambulation because it is a physical capacity necessary to deal with common challenges such as the need for postural transitions, to adapt to walk under rough weather conditions (e.g., strong wind, low temperatures, rain, ice and snow), to handle different terrain characteristics, and carry loads.[3,79] Whenever balance is compromised, the body needs to adapt (e.g., to prevent a fall) by adjusting the neuromusculoskeletal system immediately. Corrections to maintain balance affect the way a person stands and walks by changing the base of support, stride length and gait speed.[71]

Balance impairments are common among different populations (e.g., survivors of stroke, people with brain injuries) including aged populations.[80] More than 30% of Canadians over 65 years of age and more than 50% of those over 80 years of age are affected by balance impairments.[17] Aging is linked to progressive decreases in physical and cognitive functions. Therefore muscle strength, lower limb coordination and balance control can also be reduced and affect walking ability in older people.[81]

Some implications related to balance limitations are increased risk of falls, loss of independence, hospitalization, increase in the number of fractures, loss of mobility, and reduced life expectancy.[78] In general, balance tests are able to detect impairments and measure changes so the results can be used for comparison to plan and modify treatment.[78] Balance can be improved by customized training after assessment of postural control, based on physiotherapy best practices.[80]

It is important to identify factors that modify balance capacity to design specific treatments to preserve independence and mobility of older people.[78] Sibley and colleagues[79] reviewed the literature between 1986 and 2014 and identified 66 tests of capacity that evaluated at least one component of balance. The Single-Leg Stance test and Berg Balance Test are examples of capacity tests to assess balance abilities.[78,80] Some physical capacity evaluations are not specific to evaluate balance but include a balance component as part of a functional test, such as the Timed-Up and Go (TUG) test and the Sit-to-Stand test. The Balance Evaluation Systems Test (BESTest) is a comprehensive balance evaluation that consists of 36 items that evaluate different components related to postural control related to static, dynamic, and reactive balance. The Mini-BESTest is a shortened version of the BESTest and was designed to include only dynamic balance components to facilitate clinical use.[79]

The Mini-BESTest has been shown to be a valuable tool for health care professionals to evaluate balance capacity and predict risk of falls in many populations and age groups.[82] It was created from combining individual balance tests (Berg Balance Test, the Dynamic Gait Index, Single-Limb Stance Test, Functional Reach, Timed Up and Go, and modified Clinical Test of Sensory Interaction on Balance) and allows clinicians to assess dynamic balance and to differentiate fallers and non-fallers using only one test.[83] The Mini-BESTest assesses components related dynamic balance control: anticipatory postural adjustments, reactive postural control, sensory integration, dynamic stability in gait.[83,84] It does not have items related to biomechanical constraints or stability limits/verticality sections because these items are not used to measure dynamic balance.[84] The test includes 14 tasks that the evaluator rates on a 3-point scale (0 = unable/severe, 1 = moderate, 2 = normal).[49,82,85]

There is no consensus in the literature regarding reference values for the Mini-BESTest. Magnani et al[82] established cut-off values for the Mini-BESTest in order to predict falls in Brazilian older adults (60-102 years). Based on their study of 264 community-dwelling older adults (60-69 years of age), they reported that a 1-point reduction in the Mini-BESTest was associated with a 14% increase in the risk for falls in the next 6 months. One-point reductions in scores for those 70-79 years of age, 80-89 years of age and ≥ 90 years of age were also associated with increased risk for falls (33%, 34%, and 23% respectively). The maximum possible score on the Mini-BESTest is 28 points. Individuals who scored lower than 25 points (60 – 69 years), 23 points (70 – 79 years), 22 points (80 – 89 years) and 17 points (≥90 years of age) also had increased risk for falls in the 6 months follow up.[82]

In order to determine reference values for the Mini-BESTest in Canadian healthy older adults, O'Hoski and colleagues[84] tested 79 participants (50 – 89 years) using 3 different balance tests (BESTest, Mini-BESTest and Brief-BESTest). The sample was stratified in 4 age groups and the mean scores for the Mini-BESTest were 26.3 points ± 1.1 (50 - 59 years), 24.7 points ± 2.2 (60 – 69 years), 21 points ± 3.1 (70 – 79 years), and 19.6 points ±4.2 (80 – 89 years). Reference values for the Mini-BESTest have also been established in Portuguese healthy older adults.[85] The Portuguese study results were lower than scores found in the Brazilian and Canadian studies: 22.4 points ± 6.3 (60 – 69 years), 21.6 points ± 5.9 (70 – 79 years) and 16.2 points ± 6.2 (80 – 89 years).[85]

1.4.4 Composite mobility capacity measure

Standing up from a seated position is one of the most frequently performed functional tasks, is an essential pre-requisite to walking, and is important for independent living and preventing falls.[81,86] The ability to change from a seated to a standing position and vice-versa reveals physical capacities related to leg strength, changes in balance and motor control.[81,86,87] The Sit-to-Stand test is a simple, fast, low cost test that measures the time required to stand up from a seated position a certain number of times or the number of times a person is able to stand from a seated position during a pre-determined time period.[88] There are different ways to do a sit-to-stand test. Some register the time a person takes to complete a specific number of repetitions (e.g.,5 or 10-repetition Sit-to-Stand test), others count the number of complete sit-to-stand repetitions a person completes within a specific time frame (e.g., 30-second Sit-to-Stand test, 3-minute Sit-to-Stand test). Depending on the type of sit-to-stand test evaluators can look at muscle power, or endurance capacities.[89] The 30-second Sit-to-Stand test has been shown to be a valid measure of bilateral leg power in older people and is a relevant tool to use in cohort studies and clinical settings.[88,89]

Bohannon[90] conducted a meta-analysis to determine normative data for the 5-repetition Sit-to-Stand test for older adults greater than 60 years of age. The results were organized in 10-year age ranges and not discriminated for gender. Mean values reported for the age groups are as follows: 11.4s (60 to 69 years), 12.6s (70 to 79 years) and 14.8s (80 to 89 years). Macfarlane et al[91] reported Sit-to-Stand results in 1038 older adults from Hong Kong, China. They found a negative relationship between age and the number of repetitions accomplished in 30s. Mean (± SD) results for women ranged from 12.3 ± 4.2 repetitions (60 to 64 years) to 7.9 ± 2.7 repetitions (≥ 90 years), and for men ranged from 14 ± 4.3 repetitions (60-64 years) to 5.8 ± 2.6 repetitions (≥ 90 years).

1.5 Performance

The International Classification of Functioning, Disability and Health uses the term "performance" to refer to what a person does in daily life conditions.[42] There are many aspects of human behaviour that can be observed related to performance and one of them is mobility performance (e.g., how one gets around in their world). Mobility involves all types of movement from one place to another (e.g., transferring chair to bed, walking indoors and outdoors), and includes using any means of transportation (e.g., scooter, car, bus), to do activities of daily living, to work, and to participate in leisure activities.[35,92] Walking and driving are the two most common forms of mobility among community-dwelling older adults.[92] Mobility is associated with quality of life and health conditions because low levels of mobility are linked to activity restrictions that can result in physical deconditioning and reduced social participation.[35] In our study, we were interested in studying mobility performance, specifically in the form of walking – i.e., walking behaviour in everyday life.

1.6 Walking performance measures

1.6.1 Indirect measures of performance

Information about walking performance can be assessed through direct or indirect measures. Common ways to indirectly measure performance are through questionnaires, detailed diaries and brief logs because they are easy to apply and offer a way to learn about activities performed daily.[93,94] The downside of self-reported measures is that they depend on the person's ability to recall daily activities which might be inaccurate and be influenced by health status, cognitive and psychological factors.[93] While there are a number of physical activity self-report tools that exist, often they evaluate physical activity in a general way, and the total scores are not specific to walking.. There are three main types of physical activity self report tools: global questionnaires (short questionnaires to assess someone's physical activity status), short-term recall questionnaires (to assess the frequency, duration, and intensity of different types of physical activity during a specific time – past week or month), and quantitative history recall questionnaires (long questionnaires that need the respondent to remember the frequency, duration, and intensity of different types of activities performed during the past year or lifetime).[94]

The Community Health Activities Model Program for Seniors (CHAMPS) questionnaire is an example of short-term recall questionnaire that assesses participation and physical activity in older adults.[94] To respond to the CHAMPS, older adults must recall the number of hours they spent performing 40 different social, leisure and physical activities in a typical week during the past 4 weeks. This questionnaire can be used to classify activities according to metabolic equivalent values and estimate moderate to vigorous-intensity physical activity minutes per week.[49,95]

Since the CHAMPS was designed to be used with the older adult population, the questions considered physical activities common to seniors that vary in intensity (lighter to more vigorous activities). Questions 24 – 28 are explicitly related to walking activity. They ask about frequency of jogging/ running, walking/ hiking uphill, walking fast for exercise, walking to do errands, and walking leisurely for exercise.[95] Therefore, this questionnaire can provide information about frequency and intensity of daily walking in older adults.[96]

There are other questionnaires used to estimate walking performance such as the Walking Impairment Questionnaire (WIQ),[97] developed to estimate walking impairment in people with peripheral artery disease, the Walking Estimated-Limitation Calculated by History (WELCH) questionnaire,[67,98] and questionnaires used to validate objective measures of performance (e.g., to register time out of home).[26]

Although indirect measures of physical activity performance are less expensive compared to objective measures, they are also less accurate, and this may be particularly true when they are used in the older adult population. For example, tools that qualify exercise intensity based on reference values established in younger populations will be less accurate if they are applied to older adults.[99] Another reason for reduced accuracy is lack of inclusion of questions about activities common to older adults.[99] Older adults who are less active have difficulty recalling sporadic activities, and inactive older adults tend to over-estimate physical activity intensity.[99] Kowalski and colleagues[99] conducted a systematic review of indirect and direct measures of physical activity in older adults and found weak to moderate correlations between indirect (e.g., self-reported tools such as questionnaires) and direct (e.g., pedometers, accelerometers) measures of physical activity including walking. Direct measures of physical activity were more highly correlated with each other.

1.6.2 Direct measures of performance

Recording walking performance measures objectively requires equipment, such as accelerometers,[78,100] pedometers,[49,101,102] global positioning system (GPS) devices,[50,103,104] and smartphones,[5,50,55] which can be expensive and require some technical support to collect and analyze data.[93] Accelerometers are designed to monitor movement and to obtain precise information about physical activity timing, duration, volume, and intensity over many days in a row with minimum invasiveness, which makes them ideal to comprehensively monitor older adults' walking performance.[25,93,94] Accelerometers are small mobile inertial sensors that can be applied to different parts of the body such as the waist, wrist, ankle, foot, etc. Some of the outcome variables that can be monitored with accelerometers include steps/day, cadence (peak cadence, peak 30-minute cadence, and average cadence), activity counts, estimated energy expenditure and sedentary time.[25,78,93,94,105]

Accelerometers have been shown to be valid in detecting steps accumulated over different periods of time (e.g., each second or each minute).[106,107,108] Webber et al[109] found the threshold of ≥ 40 steps/min using accelerometers with low frequency extension (LFE) files had the highest sensitivity and specificity estimates for identifying continuous outdoor walking in older adults with mobility limitations. Aadland and colleagues[110] studied the reliability of accelerometer measured physical activity estimates and sedentary time in adults (mean age 31.3 years). Findings demonstrated that to reliably measure overall moderate-to-vigorous physical activity in adults, the monitoring needs to happen for 7-10 days, while to monitor light physical activity, 3 – 4 days of wear time is enough.

Accelerometers have limitations that need to be appreciated when considering using them in research. Those limitations are related to the placement of the monitor in relation to the purpose of a study,[93] and to the lack of sensitivity to differentiate sedentary and light-intensity activity.[111] Limitations can also be related to the technical knowledge required to interpret results.[93] The difficulty in detecting light-intensity activity is a common problem when measuring walking activity in older people who walk at slow speeds, and it can lead to a modest underestimation of the total physical activity time.[111] Researchers can use different analysis techniques to minimize underestimating how much older adults walk. For example, when using ActiGraph accelerometers, the manufacturer recommends researchers use the LFE algorithm to detect steps in individuals who walk at gait speeds ≤ 0.8 m/s.[107,112,113]

Different outcome variables have been reported when quantifying walking performance in older adults. Tudor-Locke and colleagues[100] determined normative data for walking performance (using steps/day as the outcome measure) in older adults over 65 years of age using accelerometry data from the NHANES 2005-2006. They demonstrated that as people age, they walk fewer steps/day (e.g., 75th percentile data: women 65 years of age = 6166 steps/day while women 75 years of age = 4583 steps/day).

Measures of cadence (steps/min) can also be used to provide information about walking intensity.[114] For younger people, a mean cadence of 100 steps/min is considered to represent moderate intensity physical activity but this threshold may not be accurate for older people.[105] Age-related data show that other cadence measures also vary across age groups.[115] Tudor-Locke et al[115] reported normative data for mean 1-minute peak-cadence (the minute with the highest cadence during one day of data collection) in people of different ages. They found values were lower for older individuals (i.e., 94.2 steps/min for those 60-69 years of age and 81.5 steps/min for those ≥ 70 years of age). Mean peak 30-min cadence (the highest stepping rates in 30 non-consecutive minutes for one day) for older adults was also lower with age, 65.2 steps/min for people 60-69 years and 52.6 steps/min for people ≥ 70 years.

1.7 Relationships between walking capacity and walking performance measures in older adults

Physical capacity and walking performance tests measure different aspects of mobility.[5] Results from capacity tests demonstrate the highest level of functional mobility of an individual in a controlled environment at a specified moment, while results from performance tests show how a person behaves in daily life.[5] Researchers and clinicians often use standard capacity tests to attempt to understand performance, but the association between capacity and performance is not always consistent or predictable.[5]

Tudor-Locke and colleagues[116] tested a small group of community-dwelling, high-functioning older adults and compared results of walking capacity tests (Short Physical Performance Battery and GAITRite) and walking performance measures (steps/day, peak 1-min cadence, peak-30 min cadence) using pedometers and accelerometers. They found that when high-functioning older adults were asked to walk at usual speed their gait speeds were ≥ 0.8 m/s, and they attained cadence levels ≥100 steps/min during clinical tests, however in daily life conditions they rarely met these thresholds. Peak 1-min cadence values ≥ 100 steps/day were only reached during ≅8 min/day and peak-30 min cadence values were < 80 steps/min. Since these measures were from a group of high functioning older adults, it is expected that less active older adults would have lower results.

Mudge et al[117] tested the relationship between 4 clinical measures of walking capacity (Rivermead Mobility Index (RMI), Rivermead Motor Assessment (RMA), 6MWT and 10-mWT) and accelerometer steps/day in 50 participants after stroke. They found that 6MWT results were more closely associated with average steps/day ($\rho=0.67$ $p<0.01$) compared to the relationship between 10-mWT results, and steps/day ($\rho=0.55$ $p<0.01$). Based on these results they suggested that the 6MWT may be the best walking capacity test to predict walking performance in this population.[117]

Bowden and colleagues[48] examined the relationship between gait speed and steps/day in 59 individuals (ages = 61.9 ± 10.8 (SD) years) with poststroke hemiparesis (≥ 6 months).

Participants completed either the 10mWT or the 4mWT (average = 0.74 ± 0.33 m/s) and wore an accelerometer to register walking performance (steps/day) during waking hours for at least 5 consecutive days. Data were analyzed using Pearson's correlation method, and they found that self-selected walking speed was significantly correlated with indoor and outdoor walking performance (steps/day) ($r=0.687$, $p< .001$).[48]

Giannouli et al[5] studied whether mobility capacity results (stride length, gait speed and cadence) measured during an iTUG (instrumented Timed-Up and Go) test (7m distance) were able to predict walking performance measures (active gait time, steps/day, mean action range and maximum action range). They found that capacity tests explained very small amounts of variance (5% - 21%) in walking performance measures. Stride length ($r= 0.369$ $p\leq 0.01$) and iTUG time ($r = - 0.442$ $p\leq 0.01$) were found to be the strongest predictors of steps/day. Gait speed and cadence (over 7m) did not show significant relationships with walking performance measures.

Lohne-Seiler et al[118] conducted a cross-sectional study investigating the association of musculoskeletal fitness and static balance with walking performance (steps/day) in Norwegian older adults (n=161, mean age=72.7 years). In linear regression analyses, they found an increment of 1000 steps/day was related to higher mean balance scores (One Leg Standing test) ($b = 1.88$, 95 % CI: 0.85 to 2.90 ($p \leq 0.001$), representing a mean increase of 2s on the test. Dohrn et al[119] found that higher levels of walking performance (≥ 5000 steps/day vs. <5000 steps/day) in community dwelling older adults (n=57, mean age = 75.6 years) with osteoporosis were associated with higher gait speeds (GAITRite - OR 1.03 CI: 1.01-1.06 p=0.01) and better balance test results (Figure eight oversteps test, OR 0.88 CI: 0.79-0.98 p=0.016). A study from McInnes and colleagues[10] with 86 community-dwelling older adults found that balance (Single Leg Stance) was significantly associated with number of journeys, dynamic outdoor activity, total distance travelled and steps/day (R^2 = 32 to 43%).

1.8 Modifiers of the relationship between walking capacity and walking performance

The number and variety of factors that may influence the relationship between walking capacity and walking performance is a vast field to investigate. People can be physically capable of walking a long distance but most of the time they do not do this frequently in their daily lives.[5] There is some evidence in the literature that suggests that frailty, pain, and self-efficacy are three specific factors that influence the relationship between walking capacity and performance in older adults.[12,46,120]

Frailty is a complex and multi-level health condition which can present in all ages, but is seen with higher prevalence in older people.[29,31,44,121] Different combinations of impairments caused by chronic diseases, reduced physiological functions, physical disabilities, reduction in cognition and psychological stressors can result in frailty.[29,31,44] A frail person may present with low muscle mass and/or low weight, difficulty in walking (slow and unsteady), and difficulty in managing activities of daily living.

Frailty influences different aspects of daily life because it can affect gait, mobility, balance, strength, and cognition.[15] Binotto et al[44] reviewed 49 publications that investigated relationships between physical frailty and gait speed in older adults. They found that frailty and slow walking speed are related, and that gait speed can be considered a marker of frailty. In a large study,[122] researchers found that 20.8% of 5532 older adults over 65 years of age had slow gait speed (23.8% of these individuals with slow gait speed were pre-frail and 76.7% were frail). The study from Montero-Odasso et al[123] used direct measures of walking capacity (GAITRite) to study the association between gait characteristics and frailty (Cardiovascular Health Study Index Frailty Status) in community-dwelling older adults. Gait speed (usual and fast pace, cm/s) and cadence (steps/min) varied with frailty status ($p<0.001$). For example, mean usual pace gait speeds of non-frail, pre-frail and frail groups were 1.24 ± 0.13, 0.95 ± 0.21 and 0.79 ± 0.19 m/s respectively, and mean cadence values were 118.27 ± 6.68, 106.26 ± 9.05, 101.22 ± 21.07 steps/min respectively. The values for fast-paced gait speed showed larger variation with the same association analysis. However, they did not study gait speed or cadence in real life walking settings, or whether the relationships with frailty status are present in the same way.

Despite low gait speed being considered a marker of frailty,[68,69] Binotto and colleagues[44] found that 43% out of the 49 studies analyzed did not describe the prevalence of low gait speed in their samples. From the studies that included gait speed as a marker of frailty, only 10.2% of the studies described reduced gait speed as a common manifestation in pre-frail (prevalence 9.9% - 86.5%), and frail (prevalence 4.7% - 89%) older adults. In 30.6% of the studies, gait speed outcomes were associated with a number of factors such as disability, frailty, sedentary lifestyle, diseases, falls, muscular weakness, cognitive impairment, body fat, stress, lower life satisfaction, low performance in quantitative parameters of gait and napping duration.

Jansen et al[12] investigated whether frailty status moderates the association between motor capacity and mobility performance in 112 community-dwelling older adults over 65 years of age. Participants were organized in 3 groups: non-frail, pre-frail and frail based on the Fried frailty test. Motor capacity test outcomes were 'normal walking speed' (e.g., daily life walking speed) measured over a 4.57 m distance in the participants' homes, and fast walking speed (e.g., maximum walking speed capacity) measured over a 10m distance in participants' homes. Mobility performance measures were average number of steps per walking bout (with a walking bout defined as a minimum of 3 consecutive steps) and maximal number of steps in one walking bout measured with an unobtrusive, shirt-embedded sensor (PAMSys™, BioSensics LLC, Watertown, MA, USA) during 48-hours of daily life. 'Normal walking speed' (NWS) and maximum number of steps in one bout were found to be related (R^2= .285; $p < .001$). When frailty status was considered in the multiple regression model, it showed a strong and significant moderation effect (ΔR^2= .048; p= .024; pre-frail × NWS: B = 1.08, p = .021; frail × NWS: B = 1.05, p = .010). NWS was positively related to the maximal steps in one walking bout in the pre-frail and frail individuals and negatively related in the non-frail group.

The analyses of fast walking speed (FWS) and the maximum number of steps in one bout in Jansen et al[12] demonstrated no direct effect. However, when frailty status was present in the model a moderation effect was present (B= .76, p= .033). The association between FWS and average number of steps per walking bout was weak (R^2 = .144; p = .149), and frailty status had no moderation effect in this association (ΔR^2 = .013; p = .350). Considering findings related to both NWS and FWS, these results indicate that, in people with some degree of impairment (i.e., frail or pre-frail status), greater capacity allows for greater performance, but the same relationship does not exist in people with high baseline levels of motor capacity.[12]

Frailty is known to be predictive of risk of falls, hospitalization, institutionalization, poor treatment response, and mortality.[29,31,44,121] Blodget et al[124] analyzed the levels of moderate-vigorous physical activity from the NHANES and found that frailty in community-dwelling adults over 50 years of age was associated with lower levels of physical activity, lower levels of self-rated health status and higher levels of health care needs. Theou et al[125] analyzed studies about exercise interventions for frailty management and found that structured physical activity positively affects mobility, balance, body mass index, aerobic capacity, muscle strength and flexibility, and cognitive function. Findings in studies such as these reinforce the idea that levels of frailty and physical activity are related, but it is not clear how much frailty influences the relationship between walking capacity and walking performance in older adults.

1.9 Significance of study

Although walking is the most common physical activity older adults engage in, there are several factors that often influence how much older adults walk indoors and outdoors. Clinicians use capacity tests to measure physical abilities to better understand people's walking capacity and to try to estimate walking performance. However, research has demonstrated that the relationship between what people can do and what people really do in their daily lives is complex and factors such as frailty may play an important role in moderating these relationships in older adults. Since there are many different walking capacity tests, another challenge is to select the best walking capacity test to provide information about specific walking performance outcomes.

Many studies have demonstrated positive correlations between individual measures of walking capacity and walking performance measures,[5,12,25,44,46,50,55,68,119,126] but not many researchers have tried to determine whether a combination of capacity measures improves the association with performance. In addition, studies about relationships between capacity and performance have primarily focused on individuals with specific chronic conditions as opposed to general mobility limitations. Outcomes of these studies can not be generalized to older people who are not part of these populations with chronic conditions.

Chapter 2 – Purpose and research questions

2.1 Purpose

Our main purpose was to determine the association between mobility capacity and walking performance in community-dwelling older adults with outdoors walking limitations. Secondarily we investigated how frailty influences these relationships between mobility capacity and walking performance.

2.2 Research questions

1. Are results from capacity tests (6MWT, 10mWT [comfortable], 30sSTS, and the Mini-BESTest) related to walking performance (peak 30-min cadence per day, time walked in bouts per day, steps per day)?
2. Do combinations of capacity tests explain more variance in performance, compared to individual capacity test results?
3. Does frailty (Cardiovascular Health Study Frailty Index) influence the relationship between mobility capacity and walking performance?

2.3 Hypotheses

1. We hypothesized that the relationships between capacity tests (6MWT, 10mWT, 30sSTS, Mini-BESTest) and walking performance measures would be low to fair. Of the four capacity tests, we hypothesized that 6MWT would be more strongly related to steps per

day and time walked in bouts per day compared to the other capacity tests. We also hypothesized that comfortable 10mWT results would be the most strongly related to peak 30-min cadence values.

2. We hypothesized that combinations of capacity tests (because they consider different aspects of capacity important for community ambulation) would explain greater amounts of variance in walking performance compared to individual measures of capacity.
3. Based on previous literature, we hypothesized that walking capacity measures would be more strongly linked to walking performance in people who were pre-frail/frail (vs. non-frail).

Chapter 3 - Methods

3.1 Data source

Data for this secondary data analysis came from the Getting Older adults OUTdoors (GO-OUT) study which was a two-group randomized controlled trial that was conducted in four Canadian cities (Edmonton, Winnipeg, Toronto, and Montreal).[49,104] Data collection for this study took place between 2018-2020. The feasibility of this project was tested by a pilot study conducted by Barclay et al.[104] The purpose of this 2-year study was to compare the .effectiveness of 1) a 10-week outdoor community mobility intervention combined with a one-day educational workshop, to 2) weekly calls with reminders about improving outdoor walking and the same one-day workshop, in people older than 65 years of age with outdoor walking limitations.[49] The study is registered with ClinicalTrials.gov (NCT03292510).

Different strategies for recruitment of participants for the GO-OUT study were used such as advertisements in senior sections of local community newspapers, referral from other participants, public service radio announcements, electronic newsletters, posters and brochures in places like seniors' residences and fitness centres. There were two intake periods, one cohort in 2018 and a second cohort in 2019. As described in the study's protocol,[49] participants had to be older adults (age ≥65 years); living independently in the community; able to walk at least 1 block (~50 metres) continuously on a flat surface without supervision (with or without walking aids); report difficulty walking in the outdoor community environment, and pass a cognitive screen (i.e., score of ≥ 18/22 on the Mini-Mental State Exam-telephone version[127]). Individuals were not eligible to participate in the study if they were physically active and engaged in ≥150 min/week of physical activity indoors or outdoors. Also, people were excluded if they were receiving therapy to improve mobility, and had high risk for falls according to the American Geriatric Society criteria[128] (≥2 falls in the last 12 months, cardiac, respiratory, peripheral vascular or other health conditions that would prevent safe and full participation in the interventions (self-report); postural hypotension, abnormal resting heart rate, severely limited visual acuity). Participants for the second cohort were not asked about weekly duration of physical activity, but they were asked if they felt they had problems walking outdoors. If the answer was yes to any of the examples given (e.g., using curbs, ramps and stairs, walking over uneven ground, lack of motivation or lack of confidence to walk outdoors for exercise), the participant was eligible to be included.

At baseline, demographic data, medication use, car access, and walking ability were collected using questionnaires. Baseline testing included collection of data on height and weight, heart rate, blood pressure, comorbidity, frailty, ambulation self-efficacy, health related quality of life, participation and physical activity, life-space mobility, aerobic capacity, balance, leg strength, gait speed, outdoor walking activity, and neighbourhood walkability. Physical capacity measures included 6MWT, 10mWT (comfortable speed), 30-second Sit-to-Stand test, and the Mini-BESTest. For walking performance outcomes, participants wore accelerometer devices for 7 days. Data were collected at baseline and 3, 5.5, and 12 months later at community or academic centres. Details of all data collection procedures have been published by Salbach et al.[49]

The one-day interactive and educational workshop was designed to educate all participants about the following topics: physical activity recommendations from the Canadian Physical Activity Guidelines for older adults, how to set SMART goals, use of pedometers, Nordic pole walking, foot care, appropriate shoes for walking outdoors, proper walking patterns, falls prevention, monitoring exercise intensity and safety; postural awareness and balance exercises. After the workshop, participants were randomly assigned to one of the 2 groups (weekly reminders group or outdoor walking group (GO-OUT intervention)).

3.2 Strengths of using GO-OUT data for the current research

The GO-OUT study dataset consists of information collected in older adults with walking limitations that includes common physical capacity tests used in clinical practice, and walking performance measures conventionally used in research on daily activity. The study collected accelerometer data that allowed estimation of time (and steps) walked, walking cadence and other performance measures. In addition, information about frailty status of participants was collected, which enabled analyses of how frailty may affect the relationship between physical capacity and walking performance.

3.3 Limitations of using GO-OUT data for the current research

The sample from the GO-OUT study was adequate for the analyses planned, however included only older adults with outdoor mobility limitations, so the results cannot be generalizable to populations with different characteristics. The number of participants identified as frail in the sample was very small when compared to non-frail and pre-frail groups.

3.4 Study population

The study population for this project included baseline data collected by trained evaluators in 2018 and 2019 from participants from all four study sites.

3.4.1 Data inclusion criteria

This study considered the baseline data collected from 206 participants of the GO-OUT study. Details about the protocol for recruitment, selection, randomization, and data collection were described and published by Salbach et al.[49] The Cardiovascular Health Study Frailty Index provided information on level of frailty (non-frail, pre-frail, frail).

3.4.2 Data exclusion and management criteria

For this study, participants with missing data were excluded from the dataset. Missing information included 6MWT (n=5), 10mWT (n=1), CCI (n=1), frailty index (n=5), more than one of the above types of data (n=9) and walking performance measures (n=16). This resulted in the exclusion of 37 participants from the dataset. Results from excluded participants are described in Chapter 6.

3.5 Study measures

3.5.1 Demographic information

Information about sex, age, and comorbidity (Charlson Comorbidity Index) were analyzed for sample description. These variables were used as covariates in the statistical analyses.

3.5.2 Measures of walking capacity

Four direct measures of walking capacity provided information about aerobic capacity, gait speed, balance, and leg strength. The capacity tests were 6MWT,[46,129] 10mWT,[75,130,131,126] Mini-BESTest,[132,133] and 30-second Sit-to-Stand test (30sSTS).[91,134] The protocol includes information about validity and details about how these tests were conducted.[49] For a small number of participants (n=10) from one site, the 6MWT was carried out on a 10m walkway, instead of the standard 30m walkway because of limitations in the distance available for testing.

3.5.3 Measures of walking performance

The walking performance measures provided information about steps/day, peak 30-minute-cadence per day (average steps per minute recorded for the 30 highest, but not necessarily consecutive minutes in a day),[109] and time walked in bouts per day (period of time in which cadence was ≥ 40 steps per minute for a minimum of 5 minutes, permitting 1 minute below the threshold).[109] Data for these outcomes were collected over 8 days using ActiGraph GT3X+ activity monitors.[49]

3.5.4 Frailty

Measures of frailty levels were collected using the Cardiovascular Health Study Frailty Index.[135,136] This index uses self-reported measures (occurrence of unintentional weight loss in the last year, exhaustion, and low level of physical activity), and direct measures of physical capacity (dominant hand grip strength and 10mWT) to characterize frailty levels. There are 3 levels of frailty in this classification model: frail (3-5 indicators present); pre-frail (1–2 indicators present), and not frail (no indicators present).[49,136]

The calculation of frailty levels was done by attributing the values of 0 or 1 (0=not frail or 1=frail) according to the answers/results of each criterion.[136] For the weight loss criterion, frailty was considered present if the participant lost 10 pounds (4.5kg) in a year unintentionally. Self reported exhaustion was evaluated by each participant’s responses to these two statements: a) I felt that everything I did was an effort; b) I could not get going. For each statement, participants were asked: “How often in the last week did you feel this way?” and scores were attributed such that none/ rarely (< 1 day) = 0; some or a little of the time (1-2 days) = 1; moderate amount of time (3-4 days) = 2; most of the time (>4 days) = 3. If score of 2 or 3 was present for either statement, frailty was considered present for this criterion. The third criterion was evaluated using the Cardiovascular Health Study Index (CHSI) to determine the weekly physical activity level of participants. This index includes a formula to determine energy expenditure (kcal) based on physical activity reported. Participants reported the type, frequency, hours and/or minutes per session and location of participation in physical activity during the last two weeks. Frailty was considered present if self reported physical activity represented energy expenditures lower than 383 kcal/week for men and lower than 270 kcal/week for women. For grip strength, evaluation used an algorithm that considered body mass index and sex to determine whether frailty was present or not. Recommended cut off values for men and women as described by Fried et al[136] are included in Table 1.

Table 1- Cut off values to determine presence of frailty status using grip strength criteria

Sex	BMI (kg/m^2)	Grip strength (kg)
Men	≤ 24	≤ 29
	>24 to 26	≤ 30
	>26 to 28	≤ 30
	>28	≤ 32
Women	≤ 23	≤ 17
	>23 to 26	≤ 17.3
	>26 to 29	≤ 18
	>29	≤ 21

Walking time is the fifth criterion and the 10mWT (comfortable speed) baseline result was used along with height information of participants to determine whether participants' results were above or below the cut off values for frailty (Table 2). If walking time was higher than the threshold, a frailty indicator (0=not present, 1=frail) was assigned to the participant.

Table 2 - Cut off values of walking time criteria for frailty indicator

Sex	Height (cm)	Walking time (s)
Men	≤ 173	≥ 7
	> 173	≥ 6
Women	≤ 159	≥ 7
	> 159	≥ 6

3.6 Ethics

The Health Research Ethics Board from the University of Manitoba, along with the respective ethics boards of the McGill University, University of Alberta and University of Toronto approved The Getting Older Adults OUTdoors (GO-OUT) study. This retrospective analysis study was approved by the Health Research Ethics Board at the University of Manitoba (HS 24567 H2021:009, see Appendix 1).

3.7 Data Analysis

Statistical analyses to test our hypotheses were conducted as shown as shown in Table 3.

Table 3 - Statistical analyses plan

Phase One – Descriptive Statistics: data were checked for missing data, normality of distribution, and linear regression assumptions.	
Descriptive statistics	Calculate mean/SD values for: a) covariates (age, sex, Charlson Comorbidity Index). b) capacity tests (6MWT, 10mWT, Mini-BESTest, 30s Sit-to-Stand). c) performance measures (peak 30 min cadence, time walked in bouts, steps/day). d) modifier of performance (frailty).
Phase two – Correlation analyses examined associations between measures of capacity, performance, and covariates.	

<table>
<tr><td colspan="6">Phase three – Multiple linear regression analyses with single capacity measures were conducted to determine the association between individual capacity tests and performance measures, controlled for covariates.</td></tr>
<tr><td colspan="3">Independent Variables (Capacity)</td><td colspan="3">Dependent Variables (Performance)</td></tr>
<tr><td colspan="3">• 6MWT
• 10mWT
• Mini-BESTest
• 30s Sit-to-Stand</td><td colspan="3">• peak 30 min cadence
• time walked in bouts
• steps/day</td></tr>
<tr><td colspan="6">Phase four – Multiple linear regression analyses with combinations of capacity measures were conducted to determine which combination of significant independent variables (capacity tests) were most closely associated with walking performance.</td></tr>
<tr><td colspan="6">Phase five – Hayes' Process was done to test for a moderation effect of frailty on the relationship between capacity and performance measures.</td></tr>
<tr><td colspan="2">Independent Variables</td><td colspan="2">Modifier</td><td colspan="2">Dependent Variables</td></tr>
<tr><td colspan="2">• 6MWT
• 10mWT
• Mini-BESTest
• 30s Sit-to-Stand</td><td colspan="2">• Frailty</td><td colspan="2">• peak 30 min cadence
• time walked in bouts
• steps/day</td></tr>
</table>

Data were first analyzed to identify missing data. All statistical analyses were conducted using IBM SPSS Statistics (version 27.0.0.0, IBM Corp., Armonk, NY). After exclusion of participants with incomplete data, linear regression assumptions were tested (see Chapter 7) to check independence of observations (i.e., independence of residuals) using Durbin-Watson statistic, linearity of relationships, homoscedasticity, multicollinearity, outliers using Cook's distance, and normality of residuals. Except for sex and frailty, all variables were continuous. Sex data were transformed through assigning dummy-variables (0 = male, 1 = female).

Descriptive statistics identified characteristics (means, SD) of our sample for each variable included in the study. These analyses were run for the group as one, and also by frailty groups (non-frail, pre-frail and frail). Post-hoc analyses (Fisher's Least Significant Difference –

LSD) were performed to identify significant differences between groups. Strength and direction of the relationships between all independent variables, covariates and dependent variables were assessed using bivariate Pearson correlation analysis. Correlation strength was qualified according to Portney[137] as ≤ 0.25 little or no relationship, 0.25 to 0.50 low to fair, 0.50 to 0.75 moderate to good, and ≥ 0.75 strong relationship.

In order to identify which capacity measures (independent variables) were associated with walking performance (dependent variable), regression analyses were conducted. Multiple linear regression was used to determine associations between individual capacity measures (6MWT, 10mWT, Mini-BEST, 30sSTS) and individual performance measures (peak 30-minute cadence, time walked in bouts, and steps per day), controlled for covariates (resulting in 12 regression equations – Appendix 2).

Multiple linear regression analysis with more than one capacity measure was done to identify the combinations of capacity tests that explained the most variance in each performance measure, adjusting for covariates. Capacity measures were added to the multiple regression equations in the order of most to least significant (according to p value, i.e., the variable with the smallest p value ≤ 0.05 was entered first, then the next smallest p value etc., if p > 0.05 then the variable was not included in the multiple regression equation).

The multiple regression models with more than one capacity measure demonstrated the amount of variability could be explained by each of the independent variable by generating the coefficients of determination (R^2) of each prediction model. Partial correlation coefficients from multiple regression models were used to represent the degree of association between single performance measures and single capacity measures while controlling for other independent variables (other capacity measures and covariates).

Moderation effect was tested to identify if the relationship between each mobility capacity test and each performance measure changed by the presence of frailty. Moderation testing uses linear regression models where it tests the independent variable, the moderator, and the interaction of both (Field, 2018) (12 equations listed in Appendix 1). The Hayes' PROCESS macro for SPSS (version 3.5)[133] was used to calculate the moderation effect. It was convenient to use the PROCESS tool over using normal regression in SPSS because it automatically centered the predictors, calculated the interaction variable and produced slopes analyses. Due to small size of the frail group (n=8), the sample was dichotomized as non-frail (n=59) and pre-frail/frail (n=109) for the moderation effect analyses.

3.7.1 Sample size justification / Power equation

Because this was a secondary data analysis, power associated with our analyses was checked post-hoc using an on-line post-hoc statistical power calculator for multiple regression.[138] For the multiple linear regression equations using only one capacity measure (see Table 2 in manuscript), the lowest R^2 value we obtained was $R^2 = 0.12$ (for the dependent variable of time walked in bouts and using the independent variable 6MWT, including covariates). Power was determined to be 0.979 for this result, given the number of independent variables was four, the observed R^2 was 0.12, probability level was 0.05 and sample size was n=168. For the multiple linear regression equations that included all capacity measures (see Table 3 in manuscript), the lowest R^2 value we obtained was $R^2 = 0.19$ (for the dependent variable of time walked in bouts and using the independent variables 6MWT, 10mWT, 30sSTS, Mini-BEST, including covariates). Power was determined to be 0.998 for this result, given the number of independent variables was seven, the observed R^2 was 0.19, probability level was 0.05 and sample size was n=168. These results demonstrate that we had more than adequate power for the analyses undertaken.

Chapter 4 – Linking methodology and main research findings

Statistical methodology used for data analyses was checked with a statistician from the Centre of Healthcare Innovation, Winnipeg, MB. Results were analyzed and a manuscript was written describing the main results of this research. I, Sabrina Abreu Schlickmann Gil, am the primary author on the manuscript and I was also primarily responsible for data analysis and initial interpretation of findings. My thesis advisory committee members, Drs Webber, Barclay and Salbach were responsible for the original data collection in the GO-OUT study, for overseeing interpretation of findings, and for providing feedback on writing the manuscript.

The manuscript (Chapter 5) describes the main research findings. Other results not fully explored in the manuscript are described in Chapter 6.

Chapter 5 – Associations between mobility capacity and walking performance in community-dwelling older adults with outdoor walking limitations.

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ABSTRACT

Purpose: To determine relationships between mobility capacity and walking performance, and whether frailty moderates these relationships.

Methods: This was a secondary data analysis of baseline data from 168 older adults, in the GO-OUT study. Capacity tests included 6-minute Walk Test (6MWT), comfortable 10-metre Walk Test (10mWT), 30-second Sit-to-Stand (30sSTS) and Mini-BESTest. Walking performance was captured with 7-day accelerometry as peak 30-minute cadence, time walked in bouts (TWB) and steps/day. Multiple linear regression was used to determine individual and combined associations between capacity and performance measures Frailty was tested as a moderator.

Results: Individual measures of capacity explained relatively small amounts of variance in peak 30-minute cadence (24-28%), TWB (12-17%), and steps/day (18-22%). Performance was best explained by models including multiple capacity measures (peak 30-minute cadence R^2 =37%, with 6MWT and 30sSTS significant, TWB R^2 =19% with 10mWT significant, steps/day R^2=25% with 30sSTS significant, all $p \leq 0.05$). Frailty did not moderate any relationships.

Conclusion: Peak 30-minute cadence is thought to represent the best natural effort in daily life. The 6MWT and 30sSTS are both significantly associated with this performance measure and may be used by physiotherapists to better understand real-world walking performance in their clients.

INTRODUCTION

Regularly engaging in physical activity and exercise assists older adults to maintain or improve aspects of physical capacity and cognitive function which support healthy aging.[1] Community ambulation is one the most common forms of physical activity among older adults, and it challenges physical capacities (e.g., leg strength, balance, walking speed, endurance) that tend to decrease as people age.[2–5] Physiotherapy and other rehabilitation goals frequently focus on activity and participation requirements related to ambulation to maintain independence,[6] social participation,[7,8] and physical health.[9–12].

Research has demonstrated that there are associations between physical capacity (what a person can do in a standardized, controlled environment) and performance (what a person actually does in their everyday environment).[13] However, in older adults with mobility limitations, measures of capacity (e.g., gait speed, stride length, cadence) account for only a small proportion of variance in measures of performance (e.g., steps/day, minutes of walking).[14–17] Some findings suggest that walking capacity is related to performance only when a degree of physiological impairment is present. For example, Jansen et al (2019)[15] demonstrated comfortable gait speed was associated with performance measures (maximal number of steps in a walking bout and average number of steps in a bout) only in pre-frail/frail individuals, whereas higher capacity tended to be associated with lower performance in the non-frail group in community-dwelling older adults.

Typical clinical measures of capacity include evaluation of gait speed,[3,18,19] leg strength,[17,20] balance[21] and walking tolerance.[12,22,23] Some measures of performance that have been reported in the literature are walking time,[12,23–25] cadence,[26–28] steps/day,[6,10,29] number of steps in bouts,[15] and self reported physical activity.[29–31] While many researchers have reported positive correlations between individual walking capacity and walking performance measures,[3,4,9,15–18,29,30,32] few have attempted to determine whether a combination of capacity measures improves predictability of performance. In addition, studies examining relationships between capacity and performance have primarily focused on individuals with specific chronic conditions[9,10,18] as opposed to general mobility limitations.

The purpose of this study was to investigate individual and collective associations between recommended measures of mobility capacity and walking performance in older adults with difficulty walking outdoors. We used baseline data collected in the GO-OUT randomized controlled trial[25] for this analysis which included investigation of associations between individual measures of capacity and performance, and combinations of measures of capacity and performance to provide practical advice to clinicians working with older adults. Specifically, our objectives were to determine: 1) individual associations between 6-Minute Walk Test (6MWT), 10-metre Walk Test (10mWT), 30-second Sit-to-Stand test (30sSTS) and Mini-BESTest with each of the performance measures of peak 30-minute cadence, time walked in bouts (TWB), and steps/day while controlling for age, sex and comorbidity index; 2) whether combinations of capacity measures explain greater variance in walking performance compared to single measures; and 3) whether frailty acts as a moderator in the relationship between walking capacity and walking performance.

METHODS

This study was a secondary data analysis of the Getting Older Adults Outdoors (GO-OUT) study, a randomized controlled trial for community dwelling older adults conducted in four Canadian cities (Edmonton, Winnipeg, Toronto, and Montreal) between 2018 and 2020. Details of the randomized controlled trial inclusion and exclusion criteria are available in the protocol.[25] In brief, community dwelling older adults 65 years of age and older were included if they self-reported having difficulties walking outdoors due to physical impairment, lack of confidence, and/or lack of motivation. Also, participants had to be living independently in the community; able to walk at least 1 block (~50 metres) continuously on a flat surface without supervision (with or without walking aids) and pass a cognitive screen. Participants were excluded if they reported engaging in 150 minutes or more of physical activity per week, were at high risk for falls, and if they were currently receiving rehabilitation assessment or treatment. Before data collection, all participants signed informed consent forms approved by the ethics review boards of University of Alberta, University of Manitoba, University of Toronto, and McGill University.

We used baseline data collected from participants in the GO-OUT study (total sample size at baseline was n= 205). Sex, age, and comorbidity describe demographics of our sample (Table 1) and were used as covariates for the statistical analyses. Comorbidity was evaluated using the Charlson Comorbidity Index questionnaire (CCI) which is scored from 0 to 7 points, where 0 means no comorbidity and 7 indicates a high comorbidity level.[33–35] The CCI evaluates comorbidity level based on the number and severity of pre-defined health conditions associated with mortality. It is a weighted score and is used to predict short and long-term outcomes such as function, hospitalization, and mortality rates.

Capacity Measures - Aerobic capacity, comfortable gait speed, balance, and leg strength were evaluated using the 6-minute-walk-test (6MWT),[4,36] comfortable 10-metre walk test (10mWT),[3,10,16,17] Mini-BESTest,[21,37] and 30-second Sit-to-Stand test (30sSTS),[38] respectively. Procedures for conducting these tests followed specifics as detailed in the protocol paper,[25] however, the 6MWT was carried out on a 10m walkway, instead of the standard 30m walkway for ten participants from one site because of limitations in space available for testing.

Performance measures - The walking performance measures included: 1) Peak 30-minute cadence (average steps per minute recorded for the 30 highest, but not necessarily consecutive, minutes in a day), 2) mean time walking in bouts per day (period of time in which cadence was $\geq$ 40 steps per minute for a minimum of 5 minutes, permitting 1 minute below the threshold),[28] and 3) average steps/day. Data for these outcomes were collected over 8 days, using ActiGraph GT3X+ activity monitors (ActiGraph LLC, Pensacola, FL) as described in the GO-OUT protocol.[25]

Moderator - Frailty levels were determined using the Cardiovascular Health Study Frailty Index,[39] which uses self-reported measures of unintentional weight loss in the last year, exhaustion, and physical activity. In addition, walking speed (10mWT comfortable speed) and dominant hand grip strength are included. The classification model includes 3 levels: frail (3-5 indicators), pre-frail (1–2 indicators), and not frail (no indicators).[25,39]

Data Analysis -. Statistical analyses were conducted using IBM SPSS Statistics (version 27.0.0.0, IBM Corp., Armonk, NY). Thirty-seven participants were excluded from analysis because of missing data. All assumptions for using linear regression were met. Multiple linear regression was used to assess associations between individual measures of capacity (independent variables) and walking performance (dependent variables), adjusted for the covariates of age, sex and CCI. The four measures of capacity were examined together in multiple linear regression models of performance, also adjusted for the covariates of age, sex and CCI. The criteria to add each capacity measure to these multiple regression equations (multi-capacity measure models) was according to p value, i.e., the variable with the smallest p value ≤ 0.05 was entered first, then the next smallest p value etc. (if $p > 0.05$ then the variable was not included). ANOVA R^2 results demonstrated the amount of variance explained by the independent variables, and partial correlation coefficients demonstrated the unique contribution of the independent variable in the model while controlling for other variables. The Hayes' Process[40] macro for SPSS (version 3.5) was used to determine whether frailty moderated the effect between mobility capacity and walking performance in multiple linear regression models with single capacity measures. The number of participants identified as frail in the sample was very small when compared to non-frail and pre-frail groups. For this reason, pre-frail and frail participants were combined for the moderation analyses (i.e., the sample was dichotomised as non-frail (n=59) and pre-frail/frail (n=109)).

RESULTS

The GO-OUT study baseline dataset included 205 participants; however, 37 participants were excluded from this study due to missing data, leaving n = 168 for analysis. Characteristics for non-frail, pre-frail and frail participants are provided in Table 1. Post-hoc testing (Fisher's LSD method) demonstrated that differences between means were significant for most variables in each of the non-frail, pre-frail, and frail categorizations (Table 1). All capacity test results were significantly different for all 3 comparisons between groups ($p < 0.05$). Performance results were higher in the non-frail group compared to pre-frail and frail groups ($p < 0.05$).

Multiple Linear Regression - All twelve multiple linear regression models with only one capacity measure were significant (Table 2). The associations between capacity and performance were low to fair (r = 0.313 – 0.502, $p < 0.01$). Individual measures of capacity explained 24.0 – 28.3% of the variance in peak 30-minute cadence, 12.0 – 17.0% of the variance in TWB and 18.0 – 22.0% of the variance in steps/day, adjusting for age, sex and CCI. The four multiple regression models that included combined measures were also significant (Table 3, $p < 0.05$). The 6MWT (partial correlation = 0.192) and 30sSTS (partial correlation = 0.205) were significantly associated with peak 30-minute cadence, and together accounted for 36.8% of the variance. Nineteen percent of the variance in TWB (partial correlation = 0.196) was explained by the 10mWT. The 30sSTS (partial correlation = 0.175) was significant in the model for steps/day, explaining 25.0% variance.

Moderation Analyses - We investigated whether frailty status moderated the relationships between walking capacity and walking performance. Every model was tested for the moderation effect of frailty and the relationships among the variables remained the same (no change in direction nor in strength). There was no evidence that frailty had a significant moderation effect ($p < 0.05$) in any of the relationships.

DISCUSSION

The main objective was to investigate associations between measures of capacity commonly used in physiotherapy and measures of walking performance in older people with mobility limitations. All individual measures of capacity (6MWT, 10mWT, 30sSTS, and Mini-BESTest) were positively associated with each of the performance measures (peak 30-minute cadence, TWB, and steps/day). In general, the strength of correlations between capability and performance measures was low to fair.[41] All measures of capacity were more highly correlated with peak 30-minute cadence ($0.445 < r > 0.502$) compared to TWB ($0.313 < r > 0.403$) and steps/day ($0.350 < r > 0.403$). No single measure of capacity consistently explained the greatest variance in performance in all of the multiple linear regression models that included single capacity measures.

Capacity test outcomes for participants in our study were similar to those reported in other samples of older adults. Mean values for 6MWT for non-frail (395.17m) and pre-frail (355.31m) participants were close to baseline mean values reported by Holland and colleagues[42] for older people with COPD (359m, mean age 75y). Meanwhile, the mean 6MWT for participants in our study categorized as frail (221.85m) was even lower than the value reported by Kwok and colleagues[43] for frail older people (295m, mean age 73y). Mean values for 10mWT were below reference values measured in other studies[3,4] for similarly aged participants, however individuals in those studies were well functioning and without disabilities. Non-frail and pre-frail 30sSTS results were comparable to those for older adults between 60 to 64 years of age,[38] whereas our frail participants had lower 30sSTS results compared to people over 90 years of age.[38] Mini-BEST results were akin to values measured in the general Canadian older adult population.[2]

Peak 30-minute cadence was more highly correlated with each capacity test compared to TWB and steps/day, and had the greatest variance explained by capacity in the simple and multiple linear regression equations. Peak 30-minute cadence reflects intensity-related walking behaviour during everyday life[44] and is thought to represent an individual's best natural effort over 24 hours.[45] Higher intensity walking may occur in short intervals, or in longer periods of purposeful walking throughout the day. While steps/day records the total steps during walking hours without regard for intensity or continuity, peak 30-minute cadence captures the 30 minutes with highest levels of cadence whether they occurred in short or long bouts during the day. For this reason, peak 30-minute cadence may provide more useful information about walking performance compared to time walked in 5-minute bouts, or steps/day. Peak 30-minute cadence values in our participants were within the 60-75th percentiles based on age specific normative values from NHANES 2005-2006 data.[27]

Capacity measures in our study explained greater variance in performance compared to that reported by Giannouli and colleagues[16] who reported that just 5% to 21% of the variance in daily activity measures detected with a smartphone were explained by capacity measures collected in an instrumented Timed-Up-Go test (time to completion, stride length, stride velocity, and cadence). Jansen and colleagues[15] reported 28% of the variance in their measure of performance (maximal number of steps in one walking bout) was explained by normal walking speed assessed over a distance of 4.57m in participants' homes. On further analysis, this result was driven by the moderation effect of frailty and the association between capacity and performance was not significant for the non-frail group. Interestingly, McInnes and colleagues[46] reported balance (single leg stance) and cognitive capacity (Mini Mental Status Exam) accounted for the 43% of variance in number of steps/day and time in dynamic outdoor activity in an older aged sample. In our study, Mini-BEST results (a comprehensive measure of balance) were not significant in multiple linear regression equations with multiple capacity measures for peak 30-

minute cadence, TWB, nor steps/day. Comparing the results of the models of single capacity measures and the models with multiple capacity measures, we might expect that all capacity measures would remain significant in the models that included the combined measures of capacity. However, for peak 30-minute cadence only two capacity measures remained significant, and for TWB and steps/day only one capacity measure remained significant. The capacity measures that remained significant in the combined models were the ones that explained additional variance beyond that explained by other capacity tests in the models.

Researchers have used many different outcome measures to assess mobility capacity and walking performance, and different combinations to learn about their relationships. Despite the difficulties in making comparisons between studies, some of our data can be examined in the context of other researchers' work. Our participants had higher steps counts per day compared to reported normative values.[6] Older adults often walk more slowly than younger individuals, resulting in steps not captured by the accelerometer. In the GO-OUT study, ActiLife software's low frequency extension (LFE) algorithm was used in an attempt to ensure that steps were detected in the sample of mobility-limited older adults[47,48] however, this may have resulted in some non-step movements being counted as steps.[48] Leg strength has previously shown to be correlated with steps/day,[17] which is similar to our finding that 30sSTS was the capacity test most highly associated with steps/day (partial correlation = 0.175). While studies in people who had stroke[10,24] showed the 6MWT, as the strongest predictor of steps/day, in our study 6MWT did not remain significant as a predictor of steps/day.

We also examined our data to determine whether frailty moderated the relationship between capacity and performance as was previously shown.[15] In our study, frailty did not increase or decrease the variance in performance explained by capacity, whereas Jansen and colleagues[15] only found significant relationships between capacity and performance in people who were pre-frail/frail. These differences may be related to the different measures of performance utilized in the two studies. Jansen et al[15] measured cumulated physical activity time, maximum steps per walking bout (with a walking bout defined as a minimum of 3 steps), and average steps per walking bout detected with a shirt-embedded sensor. The fact that the number of frail participants in our sample was very small (8.3%) may have also influenced our ability to determine whether frailty moderates the relationship between capacity and performance. Further studies with larger samples of pre-frail/frail older adults are necessary to better determine the effects of frailty in these relationships.

Since the greatest percentage of variation in walking performance was explained for the outcome of peak 30-minute cadence, and peak 30-minute cadence is thought to represent an individual's best natural effort over 24 hours,[44] researchers should consider including peak 30-minute cadence when attempting to measure important characteristics of walking in everyday life. In addition, clinicians and researchers should look for smart watch technology that reports variables related to peak 30-minute cadence (e.g., number of minutes per day with walking cadence > 100 steps per day, or above another individually-defined cadence threshold).

Studies have shown positive relationships between physical activity and health,[23,51] and walking is a primary contributor to physical activity among older people.[23,51,52] Walking contributes to maintenance of independence, active social participation and delays some deleterious effects of aging.[53,54] For this reason, it is important for physiotherapists to understand which mobility capacity tests they can rely upon to estimate walking performance in older adults. The 6MWT results provides information about endurance and cardio-vascular capacity, whereas the 30sSTS measures not only bilateral leg strength but also the integrated combination of physical functions (muscle strength, coordination and postural control) required to walk.[20] The tests used in this study represent common assessments, which are inexpensive and simple to perform in a clinical setting. The 6MWT, 10mWT, 30sSTS, and Mini-BEST provide information about how the individual is likely to perform in everyday life. Assessing capacity, which is associated with walking performance, can guide physiotherapy treatment with older adults (e.g., to focus treatment on improving leg strength, endurance, balance). While the capacity tests utilized in this study accounted for 37% of the variance in peak 30-minute cadence, an important measure of walking performance, much is still unexplained and other possible modifiers (e.g., mood, self-efficacy, pain) should continue to be investigated.

Limitations: Our sample included only older adults with mobility limitations, and, as such, results may not be generalizable to other populations. Because this was a secondary data analysis, it was not possible to control quality of data collection. However, the main study personnel were trained and used standardized protocols.[25] Moreover, the capacity measures used have been shown to be highly reliable which supports accuracy of data. Our findings, and those of other researchers, demonstrate that the degree of association between capacity and performance is highly dependent on the specific outcomes measured. As such, it is important for clinicians to carefully consider relevant representations of daily walking performance for their client, and then choose associated capacity tests to assess and monitor the individual's progress.

Key messages

Mobility capacity tests commonly used in clinical settings may provide information about how older people move in their everyday lives. Understanding relationships between capacity and performance can help clinicians target treatments to improve mobility. Clinicians should choose outcome measures known to be associated with real-world performance. The 6MWT and 30sSTS are significantly associated with 30-minute peak cadence, a measure of walking performance that represents best natural effort in daily life.

Manuscript table 1 – Characteristics of Participants

Mean ± SDI	NON-FRAIL	PRE-FRAIL	FRAIL	TOTAL
N = 168	59	95	14	168
Age (years)	72.68 ± 6.40¤	74.63 ± 6.60†	82.14 ± 6.87	74.57 ± 6.96
Sex (F=Female/M=Male)	81% (F) 19% (M)	70.5%(F) 29.5% (M)	51%(F) 49% (M)	73% (F) 27%(M)
Charlson CI	1.24 ± 1.24*¤	1.77 ± 1.32	2.21 ± 1.80	1.62 ± 1.36
Capacity Measures				
6MWT (m)	395.17±80.92*¤	355.31 ±86.04†	221.85 ± 53.97	358.18 ± 93.35
10mWT (m/s)	1.16 ± 0.21*¤	1.06 ± 0.20†	0.74 ± 0.18	1.07 ± 0.23
30sSTS	9.86 ± 3.08*¤	8.13 ± 4.17†	2.86 ± 2.80	8.30 ± 4.13
Mini-BESTest	22.08 ± 3.36*¤	20.56 ± 5.15†	13.86 ± 5.04	20.54 ± 5.04
Performance Measures				
Peak 30-min Cadence/day (steps/min)	74.08 ± 16.52*¤	66.52 ± 14.80†	52.38 ± 13.40	68.00 ± 16.33
Total min walked in bouts/day (min)	32.11 ± 21.49*¤	22.38 ± 20.75	15.91 ± 20.40	25.26 ± 21.53
Steps/day	11030.53 ± 3048.65*¤	9397.50 ± 2928.61	7990.10 ± 3131.8	9853.71 ± 3117.40

* post-hoc test significant between non-frail and pre-frail ($p < 0.05$)
† post-hoc test significant between pre-frail and frail
¤ post-hoc test significant between non-frail and frail
$p \leq 0.05$ for all variables.

Manuscript table 2 – Multiple linear regression results (models including single capacity measures)

Dependent variable		Independent variable (4 models for each dependent variable)			
Peak 30-minute cadence		**6MWT**	**10mWT**	**30sSTS**	**Mini-Best**
	Constant	29.895	51.071	57.873	38.189
	r	.502	.445	.480	.481
	B (95% CI)	.088 (.061, .115)	28.586 (18.305, 38.868)	1.798 (1.217, 2.378)	1.474 (.974, 1.974)
	β (p-value)	.504 (p<.001)	.403 (p<.001)	.454 (p<.001)	.455 (p<.001)
	R^2	.283	.240	.270	.250
	Partial correlation	.452	.395	.432	.415
Time Walked in bouts	**Constant**	7.264	33.197	26.506	12.125
	r	.315	.375	.328	.313
	B (95% CI)	.070 (.030, .109)	33.197 (19.008, 47.385)	1.519 (.684, 2.355)	1.197 (.479, 1.914)
	β	.301	.355	.291	.280

	(p-value)	(p=.001)	(p<.001)	(p<.001)	(p=.001)
	R^2	.120	.170	.130	.120
	Partial correlation	.264	.340	.271	.250
Steps per day	**Constant**	1029.296	3232.118	9705.391	7302.459
	r	.370	.350	.403	.398
	B (95% CI)	10.703 (5.230, 16.176)	3934.778 (1902.786, 5966.770)	271.072 (156.488, 385.655)	210.020 (111.086, 308.953)
	β (p-value)	.321 (p<.000)	.291 (p<.000)	.359 (p<.000)	.340 (p<.000)
	R^2	.185	.184	.220	.200
	Partial correlation	.290	.287	.344	.312

All models included all 3 covariates (age, sex, Charlson comorbidity index).
Beta results should be interpreted as: After adjusting for age, sex and comorbidity index for every one increase in the capacity measure (x), the predicted value of the performance measure (y) increases by the Beta value plus the constant value ($y = \beta x + constant$).
R^2 value indicates the percentage of the variance in the dependent variable that is explained by the independent variables collectively. R-squared quantifies the strength of the relationship between the independent variables in the model and the dependent variable on a 0 – 100% scale.
Significance level: $p \leq 0.05$

Manuscript table 3 – Multiple linear regression results (models including multiple capacity measures)

Dependent variable			Independent variables			
Peak 30-minute cadence			6MWT	10mWT	30sSTS	Mini-Best
	Constant	4.346				
	B (95% CI)		0.044 (0.009,0.079)	7.200 (-5.478, 19.878)	0.898 (0.230, 1.565)	0.552 (-0.028, 1.132)
	β (p-value)		.252 (p=.015)	.101 (p=.264)	.227 (p<0.01)	.170 (p=0.62)
	R^2	0.368				
	Partial correlation		0.192	0.088	0.205	0.147
Time Walked in bouts	Constant	-19.723				
	B (95% CI)		0.004 (-0.048, 0.057)	24.271 (5.350, 43.192)	0.643 (-0.354, 1.639)	0.413 (-0.453, 1.278)
	β (p-value)		0.019 (p=0.872)	0.259 (p=0.012)	0.123 (p=0.205)	0.097 (p=0.348)
	R^2	0.190				

	Partial correlation		.013	.196	.100	.074
Steps per day	**Constant**	3443.720				
	B (95% CI)		2.990 (-4.326, 10.307)	1394.346 (-1234.244, 4022.936)	157.716 (19.293, 296.140)	86.855 (-33.405, 207.115)
	β (p-value)		0.090 (p=0.421)	0.103 (p=0.296)	0.209 (p=0.026)	0.141 (p=0.156)
	R^2	0.254				
	Partial correlation		0.064	0.083	.175	.112

All models included all 3 covariates (age, sex, Charlson comorbidity index).
Beta results should be interpreted as: After adjusting for age, sex and comorbidity index for every one increase in the capacity measure (x), the predicted value of the performance measure (y) increases by the Beta value plus the constant value (y = βx + constant).
R^2 value indicates the percentage of the variance in the dependent variable that is explained by the independent variables collectively. R-squared quantifies the strength of the relationship between the independent variables in the model and the dependent variable on a 0 – 100% scale.
Significance level: $p \leq 0.05$

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Chapter 6 – Linking the manuscript and all other findings

Some of the results from statistical analysis were not explored in the manuscript due to the word count limitation required by the journal we intend to submit our manuscript to. This chapter describes in more detail the results related to statistical assumption testing, and inclusion/exclusion of participants.

6.1 Results of testing assumptions for using linear regression

Our research methods included data analysis using linear and multiple regression models. Before proceeding with analysis, it was necessary to make sure the dataset was appropriate for using linear regression models. To determine if the dataset was appropriate, it was checked according to 8 assumptions (listed below).[139,140] Our dataset was found to be adequate for linear regression analysis, meaning it was valid to use these types of analyses. Below are the assumptions tested and the results.

a) Assumption #1: Dependent variable should be on continuous scale. In our study all dependent variables (peak 30-minute cadence, total minutes walked in bouts, steps per day) were continuous.

b) Assumption #2: Two or more independent variables can be either continuous or categorical. In our study, sex was designated as a categorical (nominal) variable. All the other variables (6MWT, 10mWT, 30sSTS, Mini-BEST, age and Charlson Comorbidity Index) were continuous.

c) Assumption #3: Independence of observations (i.e., independence of residuals**)** - In order to test for independence of observations (residuals), the Durbin-Watson statistic can be generated in SPSS. If the value is between 1.5 - 2.5 then the residuals are independent.[139] The Durbin-Watson statistic showed no autocorrelation. Durbin-Watson for peak 30-minute cadence = 1.834, for total minutes walked in bouts = 1.806, and for steps per day = 2.113.

Table 4 – Model Summary - Peak 30-minute cadence

Model Summary[b]					
Model	R	R-squared	Adjusted R-Squared	Std. Error of the Estimate	Durbin-Watson
1	.607[a]	.368	.341	13.26484	1.834

a. Predictors: (Constant), Mini-BEST, Sex, Charlson CI, Age, 10mWTcomfort, 30sSTS, 6MWT
b. Dependent Variable: Peak30-minute cadence

Table 5 – Model Summary - Time walked in bouts

Model Summary[b]					
Model	R	R-squared	Adjusted R-Squared	Std. Error of the Estimate	Durbin-Watson
1	.436[a]	.190	.155	19.79601	1.806

a. Predictors: (Constant), Mini-BEST, Sex, Charlson CI, Age, 10mWT comfort, 30sSTS, 6MWT
b. Dependent Variable: Total min walked in bouts/day

Table 6 – Model Summary - Steps/day

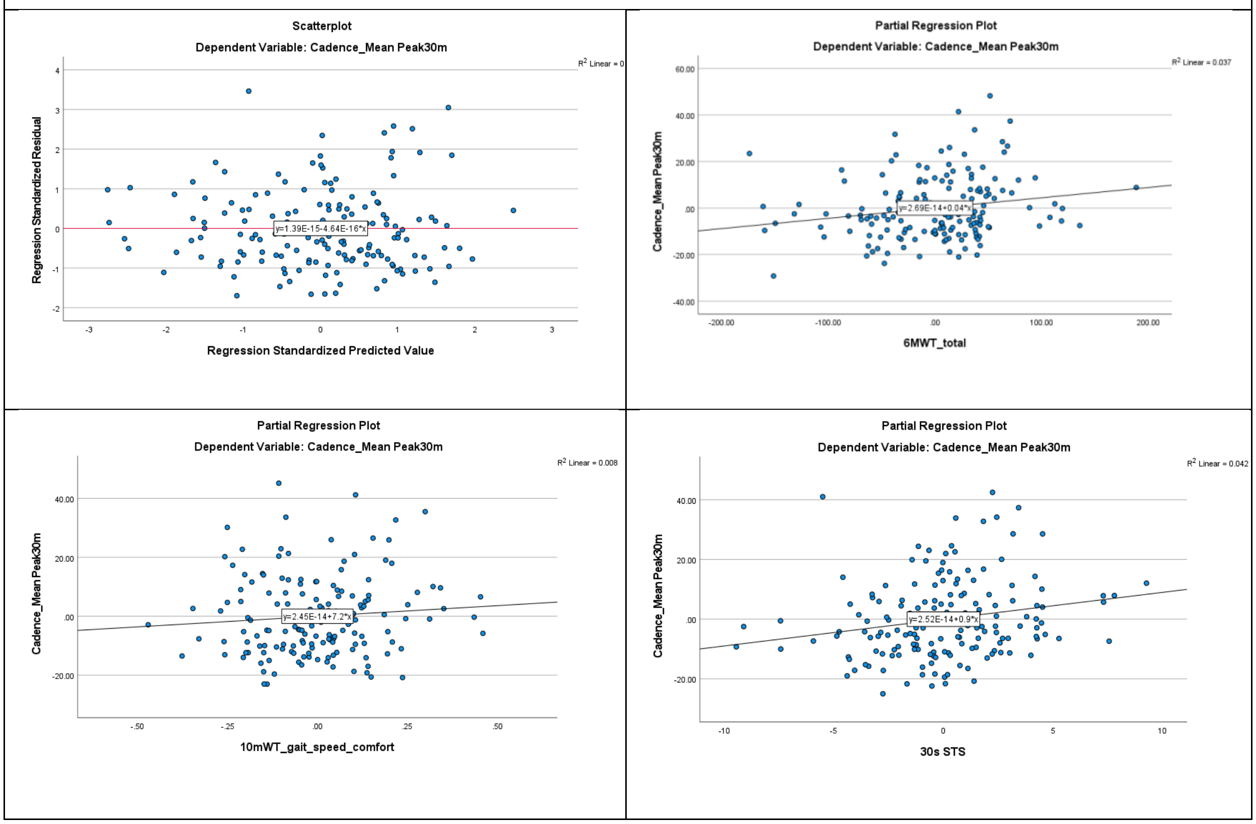
Model Summary[b]					
Model	R	R-squared	Adjusted R-Squared	Std. Error of the Estimate	Durbin-Watson
1	.504[a]	.254	.222	2750.18363	2.113

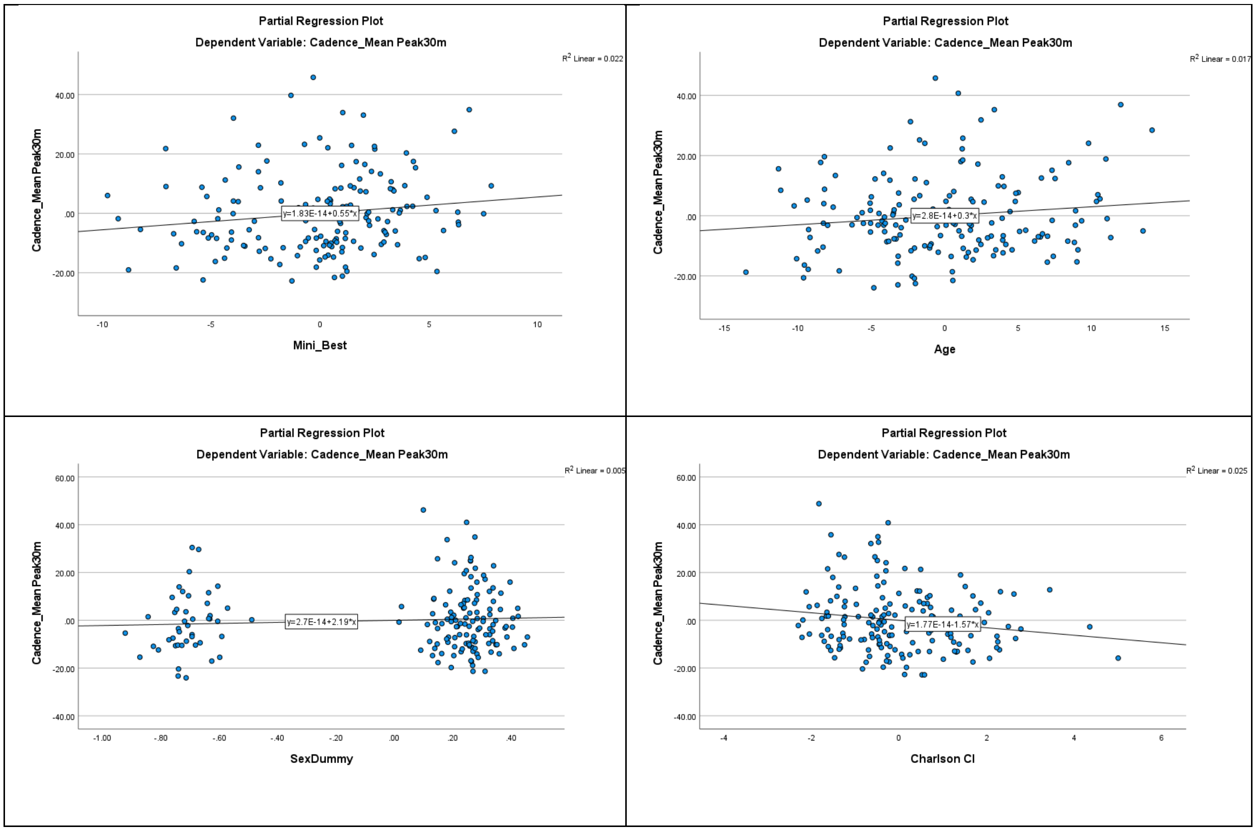
a. Predictors: (Constant), Mini-BEST, Sex, Charlson CI, Age, 10mWT comfort, 30sSTS, 6MWT
b. Dependent Variable: Steps/day

d) Assumption #4: Additivity and linearity assumption show the relationship between the dependent variable and the independent variables are linearly related, and in a model with several independent variables, the combined effect is best demonstrated through adding their effects together.[139] Scatterplot graphs show the distribution of the residuals and should be analyzed visually. If the graph shows a clear curve in the residuals, the assumption of linearity is not met. Graphs below show the scatterplots for our data of regression standardized residuals versus regression standardized predicted values (first graph on top left) and partial regression plots (scatterplots of residuals of the dependent variable and each independent variable regressed separately from the other independent variables). These graphs demonstrated an arbitrary arrangement of dots and no specific curvilinear relationships (fitted lines were added to help visualize the direction of the relationships).

Figure 1 – Scatterplots for linearity assumption testing – Peak 30-minute cadence

Peak 30-minute cadence





Partial Regression Plot
Dependent Variable: Cadence_Mean Peak30m
R² Linear = 0.022
y=1.83E-14+0.55*x
Cadence_Mean Peak30m
Mini_Best
Partial Regression Plot
Dependent Variable: Cadence_Mean Peak30m
R² Linear = 0.017
y=2.8E-14+0.3*x
Cadence_Mean Peak30m
Age
Partial Regression Plot
Dependent Variable: Cadence_Mean Peak30m
R² Linear = 0.005
y=2.7E-14+2.19*x
Cadence_Mean Peak30m
SexDummy
Partial Regression Plot
Dependent Variable: Cadence_Mean Peak30m
R² Linear = 0.025
y=1.77E-14-1.57*x
Cadence_Mean Peak30m
Charlson CI

Figure 2 – Scatterplots for linearity assumption testing – Time walked in bouts

Time walked in bouts

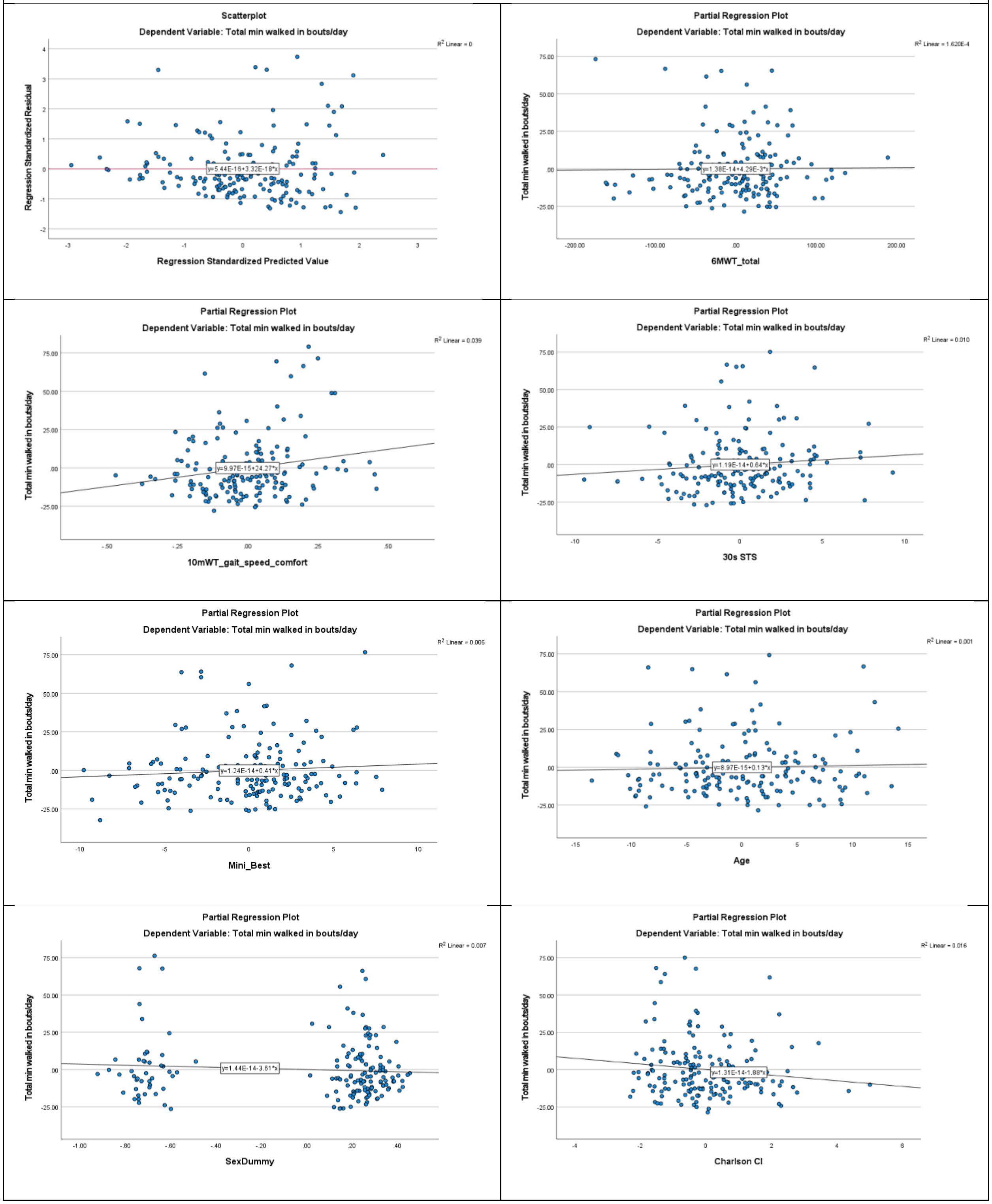
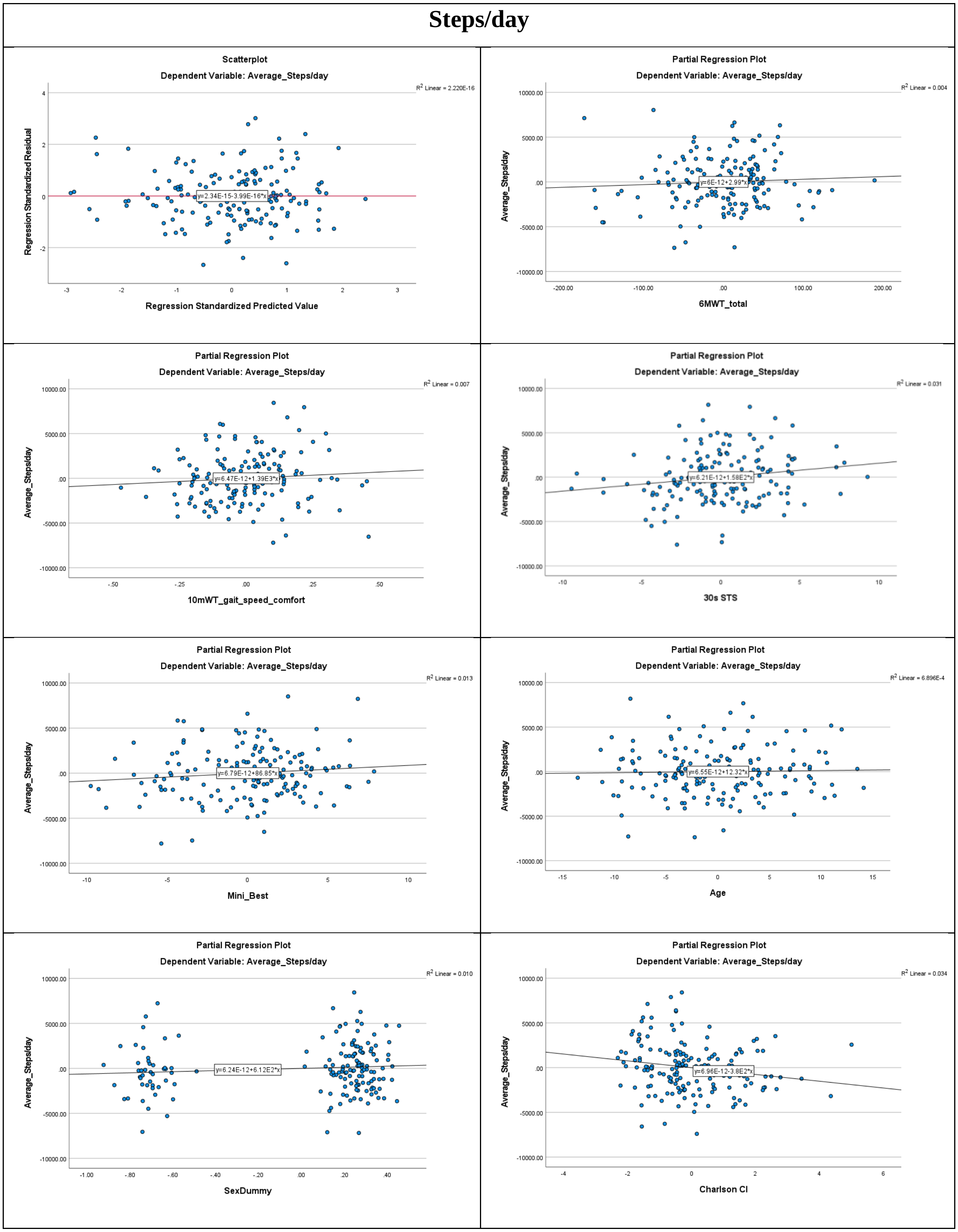


Figure 3 – Scatterplots for linearity assumption testing – Steps/day



e) Assumption #5: In order to check for homoscedasticity, the standardized residuals are plotted against the standardized predicted values. If a plot demonstrates homoscedasticity, the variance of the dots along the line of best fit will remain similar throughout the line.[139,140] As displayed below, plots of our data did not have an obvious pattern, points were equally distributed above and below zero on the X-axis, and to the left and to the right of the Y-axis for all three dependent variables.

Figure 4 – Scatterplots for homoscedasticity assumption testing – Peak 30-minute cadence

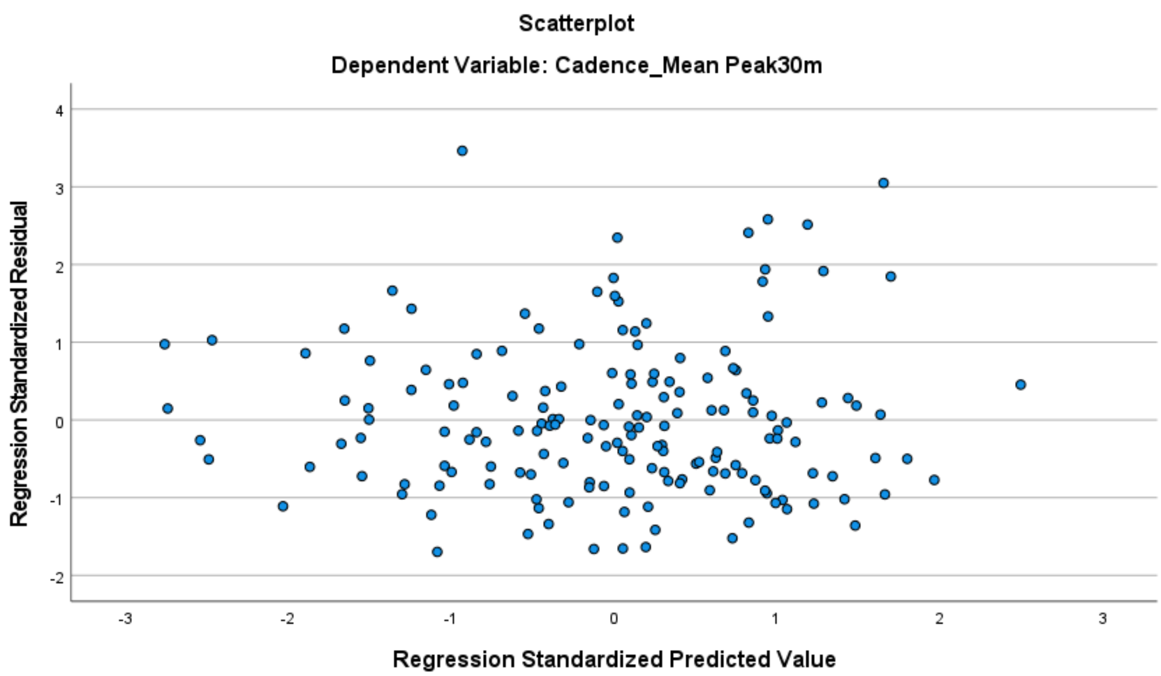


Figure 5 – Scatterplots for homoscedasticity assumption testing – Time walked in bouts

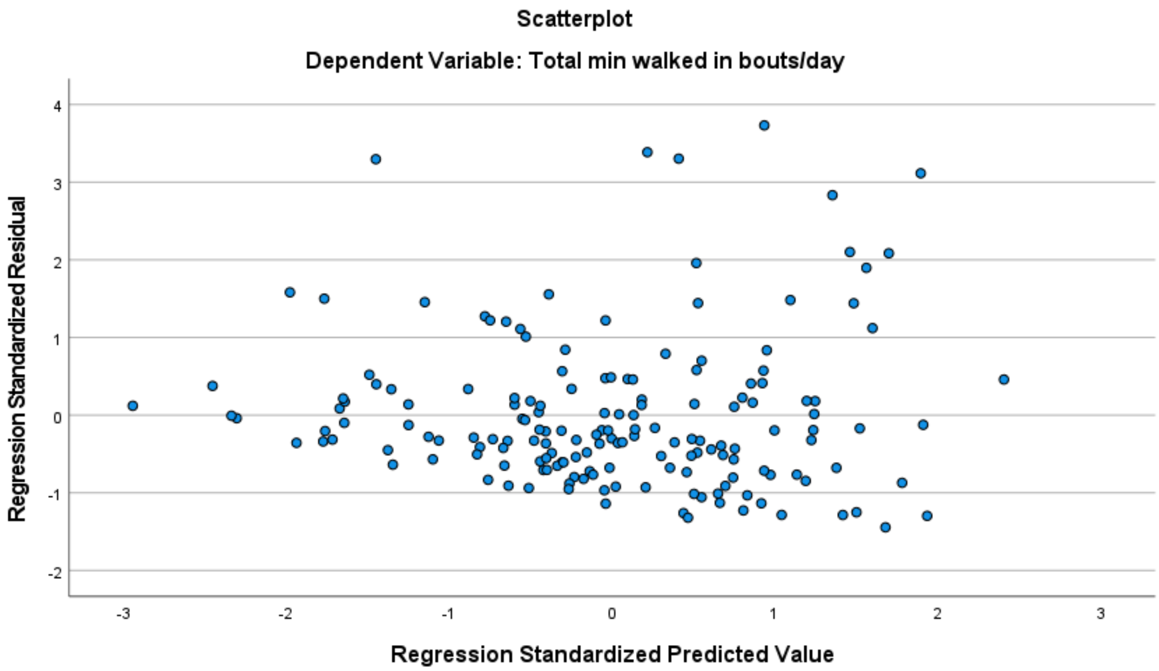
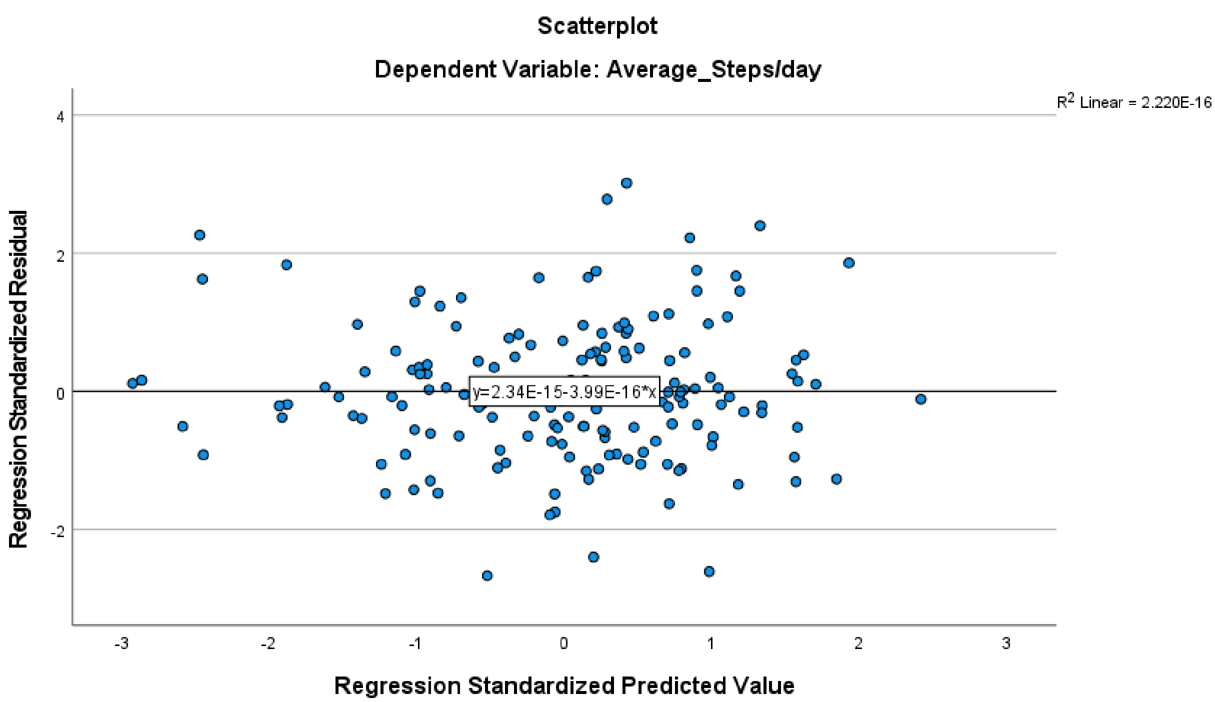


Figure 6 – Scatterplots for homoscedasticity assumption testing – Steps/day



f) Assumption #6**:** Multicollinearity – none of the independent and dependent variables should be highly correlated (i.e., correlations should be < 0.8).[139] Tolerance values should be > 0.2 and VIF values less than 10.[139,140] In our analysis Pearson correlation values ranged (table 7) from -0.279 to 0.502. All tolerance values were > 0.2 and all VIF were less than 10 for each of the dependent variables.

Table 7 – Pearson Correlation analyses

	Cadence	**Time walked in bouts**	**Steps per day**
Age	-.233**	-.173*	-.232**
Sex	.087	-.50	.111
CCI¤	-.230**	-.168*	-.252**
6MWT	.502**	.315**	.370**
10mWT	.445**	.375**	.350**
30sSTS	.480**	.328**	.403**
Mini-BESTest	.481**	.313**	.398**
Frailty†	-275**	-.235**	-.279**

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 8 – Tolerance and VIF results - Peak 30-minute cadence

Coefficients[a]							
	Unstandardized Coefficients		**Standardized Coefficients**			**Collinearity Statistics**	
Model	**B**	**Std Error**	**Beta**	**T**	**Sig.**	**Tolerance**	**VIF**
(Constant)	4.346	17.185		.253	.801		
Age	.299	.179	.127	1.670	.097	.679	1.473
Sex	2.189	2.354	.060	.930	.354	.964	1.038
CCI	-1.567	.776	-.131	-2.020	.045	.944	1.059
6MWT	.044	.018	.252	2.470	.015	.379	2.640
10mWT	7.200	6.420	.101	1.122	.264	.482	2.073
30sSTS	.898	.338	.227	2.656	.009	.541	1.848
Mini-BEST	.552	.294	.170	1.879	.062	.480	2.083
a. Dependent Variable: Peak 30-minute cadence							

Table 9 – Tolerance and VIF results - Time walked in bouts

Coefficients[a]							
	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model	B	Std Error	Beta	T	Sig.	Tolerance	VIF
(Constant)	-19.723	25.646		-.769	.443		
Age	.125	.267	.040	.463	.640	.679	1.473
Sex	-3.612	3.513	-.074	-1.028	.305	.964	1.038
CCI	-1.884	1.158	-.119	-1.627	.106	.944	1.059
6MWT	.004	.027	.019	.161	.872	.379	2.640
10mWT	24.271	9.581	.259	2.533	.012	.482	2.073
30sSTS	.643	.505	.123	1.274	.205	.541	1.848
Mini-BEST	.413	.438	.097	.941	.348	.480	2.083
a. Dependent Variable: Time walked in bouts							

Table 10 – Tolerance and VIF results - Steps/day

Coefficients							
	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model	B	Std Error	Beta	T	Sig.	Tolerance	VIF
(Constant)	3443.720	3562.964		.967	.335		
Age	12.325	37.091	.028	.332	.740	.679	1.473
Sex	612.478	488.074	.087	1.225	.211	.964	1.038
CCI	-379.619	160.863	-.166	-2.360	.019	.944	1.059
6MWT	2.990	3.705	.090	.807	.421	.379	2.640
10mWT	1394.346	1330.998	.103	1.048	.296	.379	2.640
30sSTS	157.716	70.091	.209	2.250	.026	.541	1.848
Mini-BEST	86.855	60.894	.141	1.426	.156	.480	2.083
a. Dependent Variable: Steps per day							

g) Assumption #7: Cook's distance identifies outlier cases that could alter the ability of a model to predict all cases. This can be generated using SPSS Statistics. Values should be less than 1.[139] The table below states the range values of Cook's distance. Our results had no cases reaching the limit value.

Table 11 – Cook's distance values

	Peak 30-minute cadence		Time walked in bouts		Steps/day	
	Min	Max	Min	Max	Min	Max
6MWT	.000	.093	.000	.176	.000	.112
10mWT	.000	.076	.000	.179	.000	.107
30sSTS	.000	.113	.000	.148	.000	.084
Mini-BEST	.000	.070	.000	.161	.000	.073

h) Assumption #8**:** Normality of the residuals – In this assumption the regression residuals need to be normally distributed. To meet this assumption, the points on the normal P-P plot should fall close to the diagonal reference line.[139] As demonstrated below the normal P-P plots showed a tendency of normality for each of the dependent variables. Also, when analyzing the histograms, residuals were fairly normally distributed (bell shaped curve).

Figure 7 – Normal P-P Plot - Peak 30-minute cadence

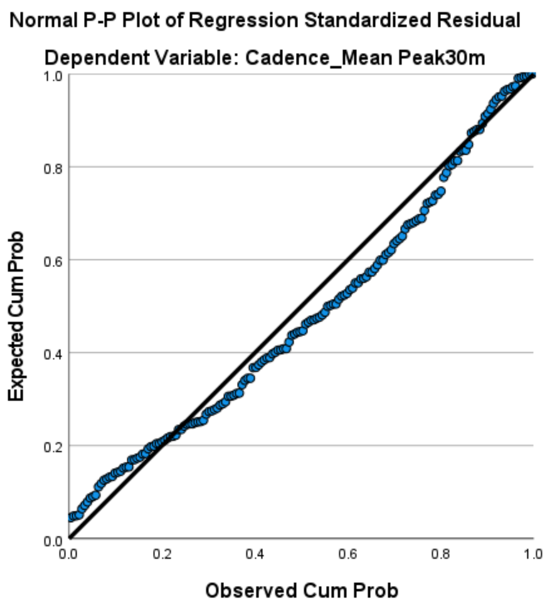


Figure 8 – Histogram - Peak 30-minute cadence

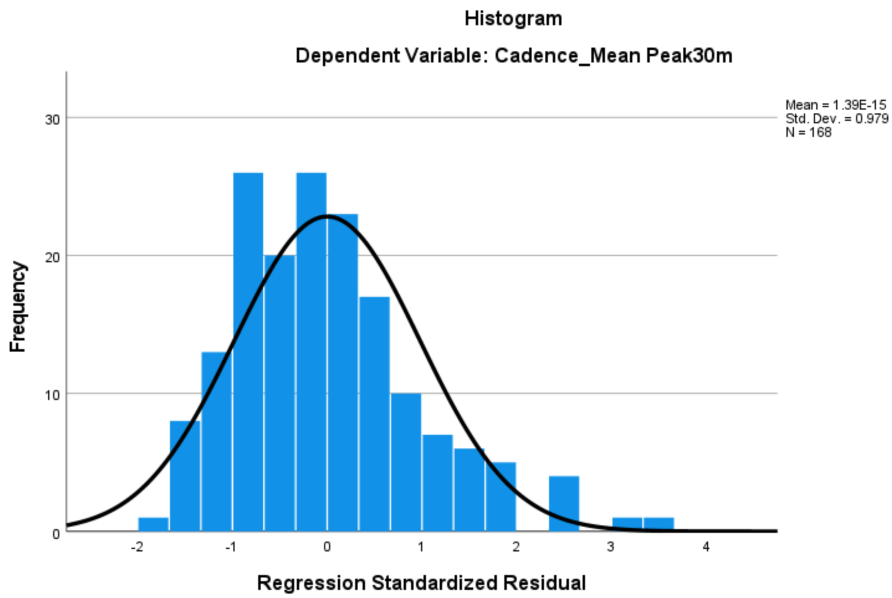


Figure 9 – Normal P-P Plot – Time walked in bouts

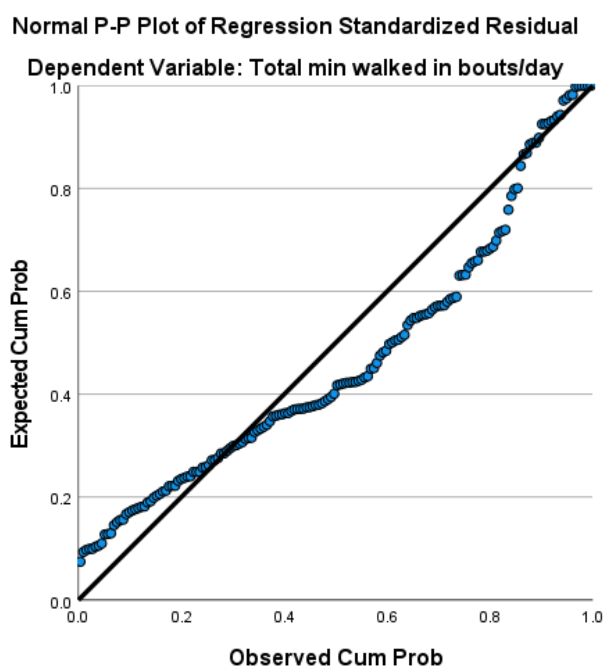


Figure 10 – Histogram – Time walked in bouts

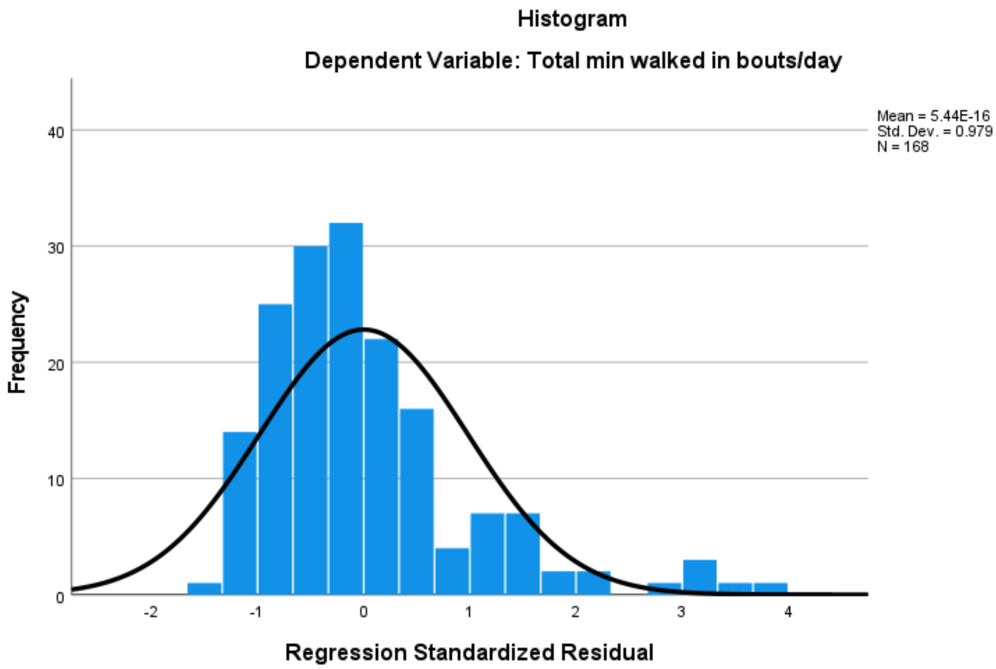


Figure 11 – Normal P-P Plot - Steps/ day

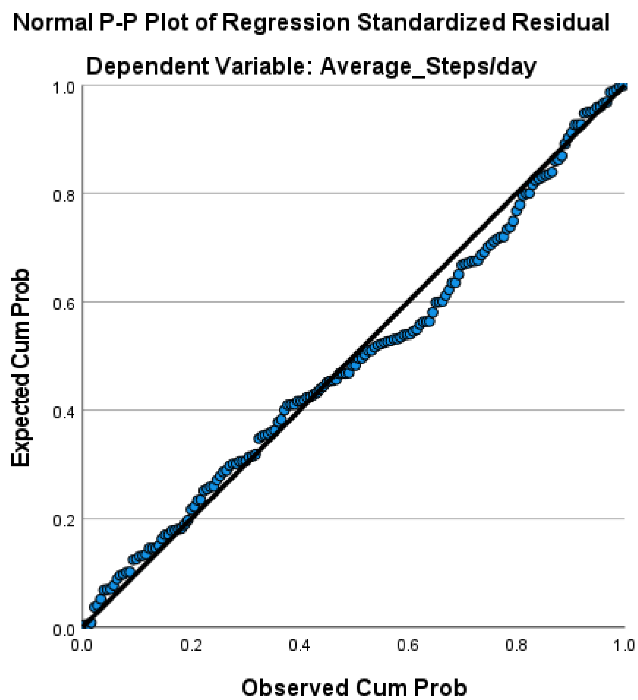
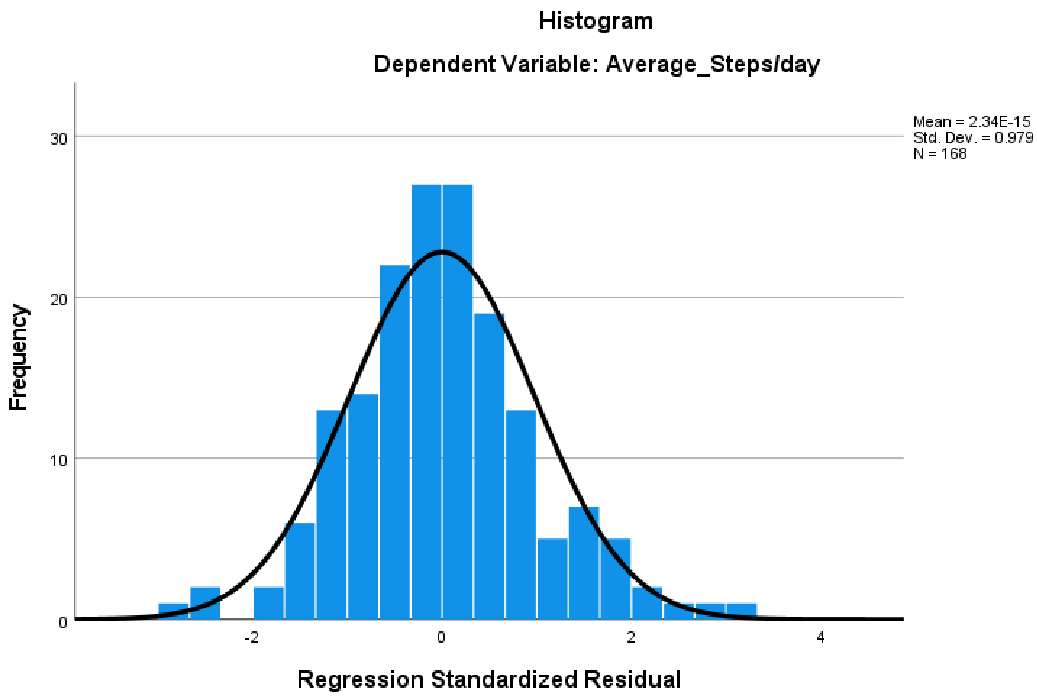


Figure 12 – Histogram – Steps/day



6.2 Inclusion/ exclusion of participants

The original dataset contained information from the 205 participants enrolled in the GO-OUT study. We determined the following exclusion criteria for our secondary data analysis: participants with missing or invalid values were excluded, no substitutions were made. A total of 37 participants were excluded for the following reasons: missing performance data (n=17), missing 6MWT (n=5), missing 10mWT (n=1), missing CCI (n=1), missing frailty index (n=5), missing more than one of the above types of data (n=9). The complete list of excluded participants and the reasons for exclusion are listed in Table 11.

Ten participants from one of the sites had their 6MWT carried out on a 10m walkway, instead of the standard 30m walkway because of limitations in the distance available for testing.

Data from these participants were not excluded based on the comparison between R^2 results of linear regression done using the full sample (n=168) and a sample excluding the 10 participants (n=158). The differences between values of R^2 values from multiple linear regressions (models with single capacity measures) with 6MWT as independent variable for both samples were 0.022 for peak 30-minute cadence, 0.008 for time walked in bouts, and 0.002 for steps/day. Since the differences were very small, data from these participants were kept in the sample.

Table 12 – List of excluded participants

Red-cap ID	Exclusion reason
10-11	No performance data
10-45	No performance data
10-49	No performance data
10-52	No performance data
10-56	No performance data
10-60	10mWT data error (not usable)
11-14	No frailty index as missing PAQ (per below activity threshold rules). *
11-20	No frailty index as missing PAQ (per below activity threshold rules). *
11-22	No CCI and no performance data
11-23	No CCI
11-24	Missing 6MWT
11-31	Missing 6MWT
11-34	Missing Mini-BEST, and no frailty index as missing weight, height, grip strength
11-35	No frailty index as missing weight, height, grip strength and missing PAQ (per below activity threshold rules) *
11-36	Missing 6MWT

11-37	No CCI, no frailty index as missing PAQ (per below activity threshold rules) * and no performance data
11-39	Missing 6MWT, and no frailty index as missing PAQ, weight, height, and grip strength.
11-41	Missing 6MWT
12-2	No performance data
12-24	Missing 6MWT
12-28	Missing 6MWT, and no frailty index as missing weight
12-29	No performance data
12-42	No performance data
12-44	No frailty index as missing weight
12-45	No performance data
12-46	No performance data
12-47	No performance data
12-57	No performance data
13-10	No performance data
13-13	No performance data
13-29	No CCI and no performance data
13-36	No performance data
13-38	No 30sSTS, no performance data, no frailty index as missing PAQ (per below activity threshold rules) *
13-48	No frailty index as missing weight loss indicator
13-54	No frailty index as missing PAQ (per below activity threshold rules) *, and no performance data.
13-60	No performance data
13-65	No performance data

*PAQ inclusion/exclusion rules for missing items: If participant missing some items on the PAQ, but the sum of physical activity data available is above frailty criteria, participant included. If participant missing some items and the sum of physical activity data available is below frailty criteria, participant excluded.

6.3 Moderation analyses outputs

The interpretation of results from Hayes PROCESS macro for moderation effect analysis is as follows: If the variable created to demonstrate the moderation effect (Int_1) is not significant, then the moderation effect does not exist between the independent variable (capacity measure) and the moderator (frailty). In our results (Tables 13-24, Figures 13 – 24), the effect of moderation was not significant in any of the models.[139]

Table 13 – Frailty moderation analyses Hayes' Process macro – 6MWT x Peak 30-minute cadence

Model Summary						
R	**R^2**	**MSE**	**F**	**df1**	**df2**	**P**
.5434	.2953	195.0628	11.2450	6.0000	161.0000	.0000
Coefficients						
	Beta coeff	St. Error	t	p	LLCI	ULCI
constant	29.1606	18.1584	1.6059	.1103	-6.6988	65.0200
6MWT	.0939	.0235	4.0013	.0001	.0475	.1402
Frailty	1.6915	10.4525	.1618	.8716	-18.9503	22.3333
Int_1*	-.0146	.0268	-.5425	**.5882**	-.0675	.0384
Age	.1279	.1824	.7015	.4840	-.2322	.4881

Sex	.9140	2.4706	.3699	.7119	-3.9650	5.7930
CCI	-1.7896	.8195	-2.1838	.0304	-3.4079	-.1713
* Int_1: interaction variable Product terms key: Int_1: 6MWT x Frailty Test(s) of highest order unconditional interaction(s): R2-chng F df1 df2 p X*W .0013 .2943 1.0000 161.0000 .5882						

Figure 13 – Frailty moderation effect result graph – 6MWT x Peak 30-minute cadence

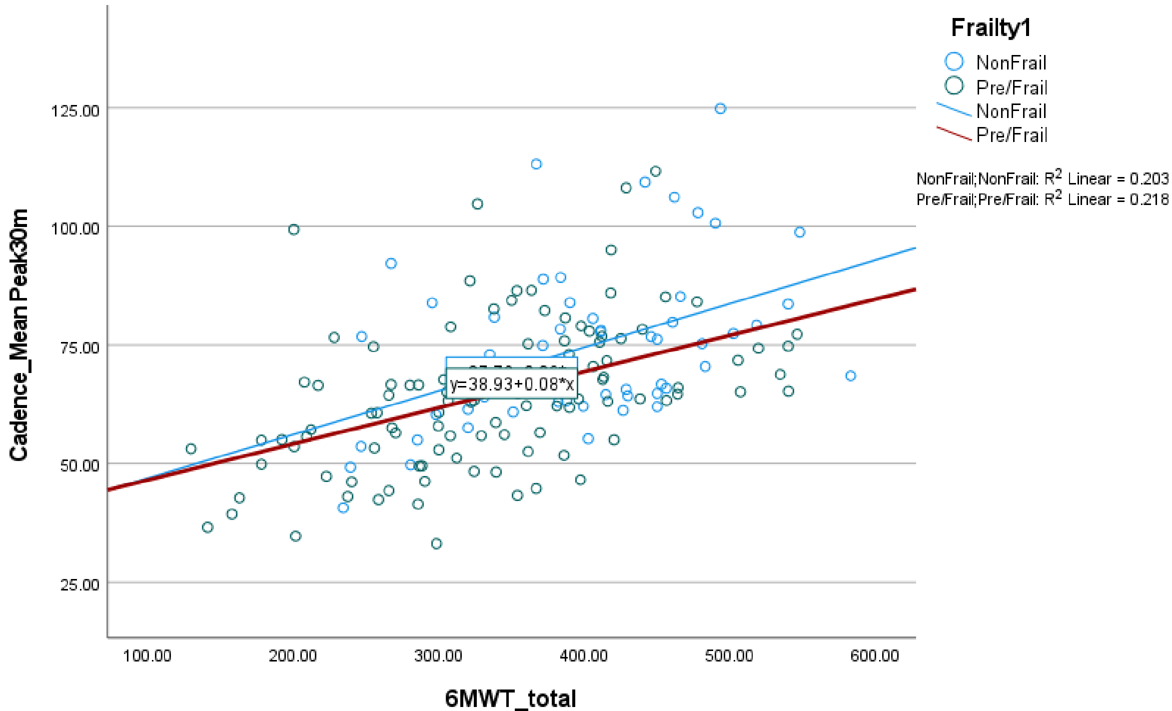


Table 14 – Frailty moderation Hayes' Process macro – 10mWT x Peak 30-minute cadence

Model Summary						
R	**R^2**	**MSE**	**F**	**df1**	**df2**	**p**
5152	.2654	203.3468	9.6937	6.0000	161.0000	.0000
Coefficients						
	Beta coeff	**St. Error**	**t**	**p**	**LLCI**	**ULCI**
constant	38.7801	17.8723	2.1699	.0315	3.4858	74.0744
10mWT	39.4468	8.9435	4.4107	.0000	21.7850	57.1086
Frailty	17.2724	12.1700	1.4193	.1578	-6.7611	41.3059
Int_1*	-19.0673	10.6925	-1.7832	**.0764**	-40.1829	2.0483
Age	-.1245	.1714	-.7265	.4686	-.4630	.2140
Sex	.9669	2.5233	.3832	.7021	-4.0162	5.9500
CCI	-1.8749	.8366	-2.2411	.0264	-3.5271	-.2228

* Int_1: interaction variable
Product terms key:
Int_1: 10mWT x Frailty
Test(s) of highest order unconditional interaction(s):

	R2-chng	F	df1	df2	p
X*W	.0145	3.1800	1.0000	161.0000	.0764

Figure 14 – Frailty moderation effect result graph – 10mWT x Peak 30-minute cadence

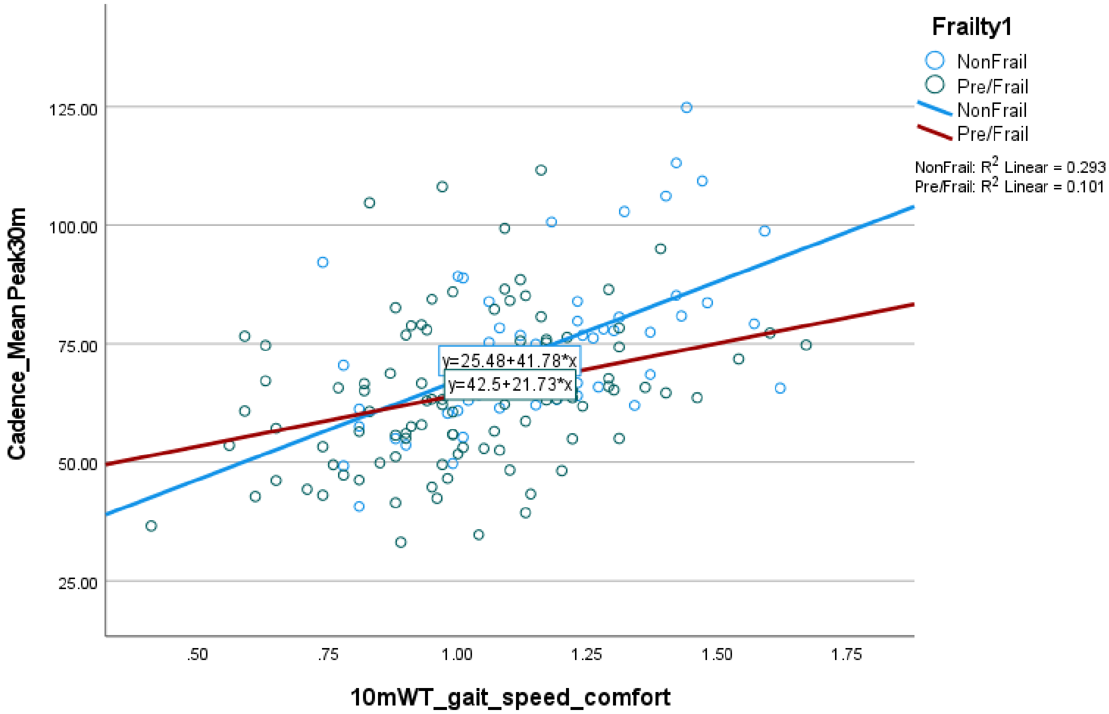


Table 15 – Frailty moderation analyses Hayes' Process – 30sSTS x Peak 30-minute cadence

Model Summary						
R	**R2**	**MSE**	**F**	**df1**	**df2**	**p**
.5336	.2847	197.9943	10.6812	6.0000	161.0000	.0000
Coefficients						
	Beta coeff	**St. Error**	**t**	**p**	**LLCI**	**ULCI**
constant	52.8805	15.3198	3.4518	.0007	22.6268	83.1343
30sSTS	2.3609	.6144	3.8426	.0002	1.1476	3.5742
Frailty	3.9710	6.7590	.5875	.5577	-9.3767	17.3187
Int_1*	-.8413	.6761	-1.2443	**.2152**	-2.1765	.4939
Age	-.0349	.1728	-.2017	.8404	-.3761	.3064

Sex	2.8982	2.5056	1.1567	.2491	-2.0499	7.8464
CCI	-1.5501	.8282	-1.8716	.0631	-3.1857	.0855
* Int_1: interaction variable Product terms key: Int_1: 30sSTS x Frailty Test(s) of highest order unconditional interaction(s): R2-chng F df1 df2 p X*W .0069 1.5483 1.0000 161.0000 .2152						

Figure 15 – Frailty moderation effect result graph – 30sSTS x Peak 30-minute cadence

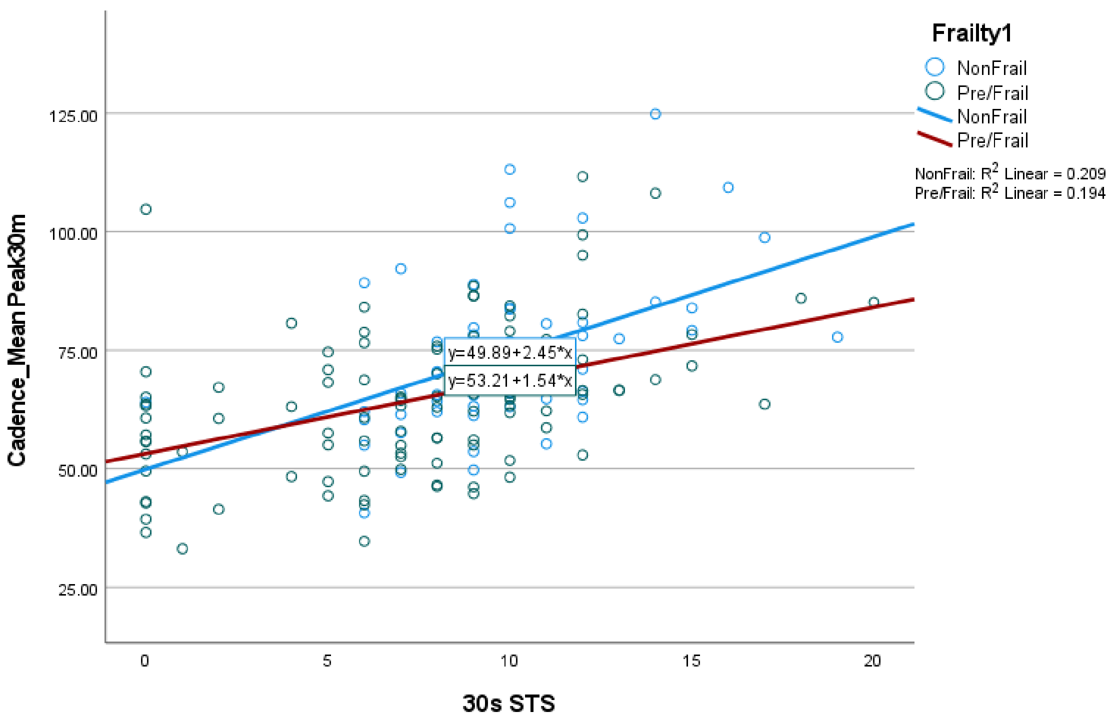


Table 16 – Frailty moderation analyses Hayes' Process macro – Mini-Best x Peak 30-minute cadence

Model Summary						
R	**R^2**	**MSE**	**F**	**df1**	**df2**	**p**
.5297	.2805	199.1533	10.4629	6.0000	161.0000	.0000
Coefficients						
	Beta coeff	**St. Error**	**t**	**p**	**LLCI**	**ULCI**
constant	27.1444	20.0340	1.3549	.1773	-12.4189	66.7078
Mini Best	1.9850	.5634	3.5233	.0006	.8724	3.0976
Frailty	9.8832	13.3324	.7413	.4596	-16.4457	36.2121
Int_1	-.6947	.6035	-1.1512	**.2514**	-1.8865	.4971
Age	.0527	.1801	.2925	.7703	-.3030	.4084
Sex	1.2484	2.4961	.5001	.6177	-3.6809	6.1777
CCI	-1.4150	.8366	-1.6914	.0927	-3.0672	.2371

Product terms key:
Int_1: Mini Best x Frailty
Test(s) of highest order unconditional interaction(s):

	R2-chng	F	df1	df2	p
X*W	.0059	1.3251	1.0000	161.0000	.2514

Figure 16 – Frailty moderation effect result graph – Mini-Best x Peak 30-minute cadence

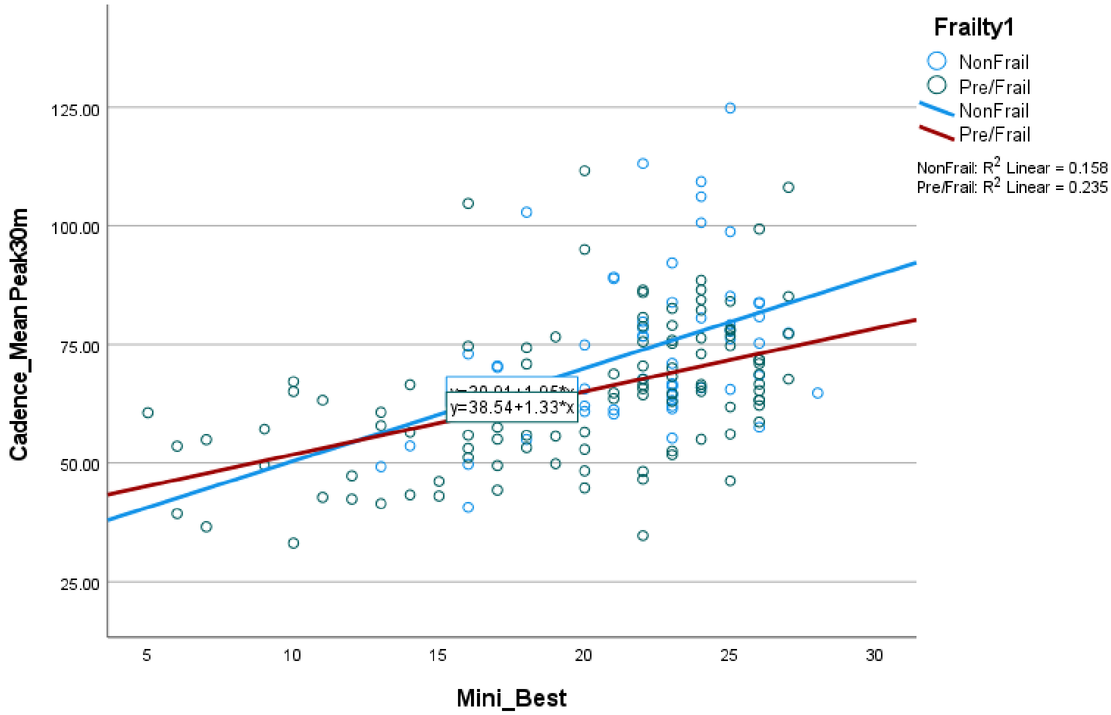


Table 17 – Frailty moderation analyses Hayes' Process macro – 6MWT x Time walked in bouts

Model Summary						
R	**R^2**	**MSE**	**F**	**df1**	**df2**	**P**
.3850	.1482	409.7520	4.6684	6.0000	161.0000	.0002
Coefficients						
	Beta coeff	**St. Error**	**t**	**p**	**LLCI**	**ULCI**
constant	1.6453	26.3179	.0625	.9502	-50.3275	53.6181
6MWT	.0911	.0340	2.6802	.0081	.0240	.1583
Frailty	9.3379	15.1494	.6164	.5385	-20.5793	39.2550
Int_1	-.0422	.0389	-1.0849	**.2796**	-.1190	.0346
Age	.0097	.2643	.0366	.9709	-.5123	.5317

Sex	-4.8687	3.5808	-1.3597	.1758	-11.9402	2.2027
CCI	-1.8419	1.1877	-1.5508	.1229	-4.1874	.5037
* Int_1: interaction variable Product terms key: Int_1: 6MWT x Frailty Test(s) of highest order unconditional interaction(s): R2-chng F df1 df2 p X*W .0062 1.1770 1.0000 161.0000 .2796						

Figure 17 – Frailty moderation effect result graph – 6MWT x Time walked in bouts

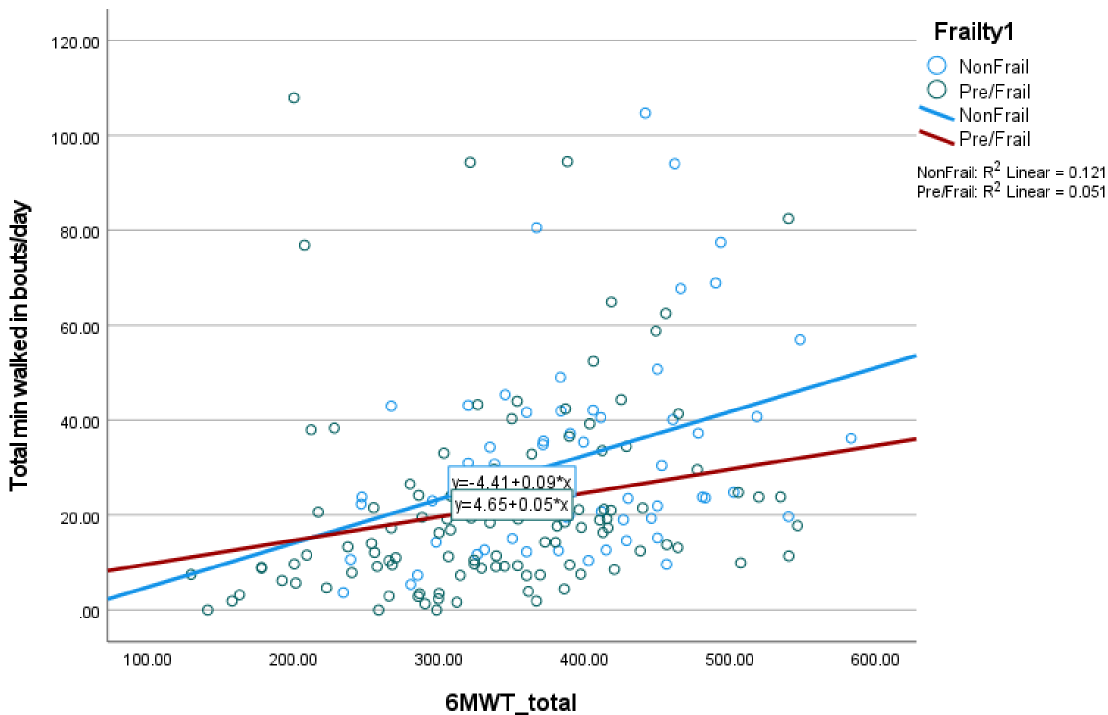


Table 18 – Frailty moderation analyses Hayes' Process macro – 10mWT x Time walked in bouts

Model Summary						
R	**R^2**	**MSE**	**F**	**df1**	**df2**	**P**
.4343	.1887	390.2869	6.2395	6.0000	161.0000	.0000
Coefficients						
	Beta coeff	**St. Error**	**t**	**p**	**LLCI**	**ULCI**
constant	-8.7574	24.7601	-.3537	.7240	-57.6539	40.1391
10mWT	43.9421	12.3903	3.5465	.0005	19.4736	68.4106
Frailty	16.8090	16.8603	.9970	.3203	-16.4869	50.1049
Int_1	-20.0811	14.8133	-1.3556	**.1771**	-49.3345	9.1723
Age	-.0534	.2374	-.2248	.8224	-.5223	.4155
Sex	-4.9426	3.4958	-1.4139	.1593	-11.8461	1.9610
CCI	-1.8866	1.1590	-1.6278	.1055	-4.1755	.4022

Product terms key:
Int_1: 10mWT x Frailty
Test(s) of highest order unconditional interaction(s):

	R2-chng	F	df1	df2	p
X*W	.0093	1.8377	1.0000	161.0000	.1771

Figure 18 – Frailty moderation effect result graph – 10mWT x Time walked in bouts

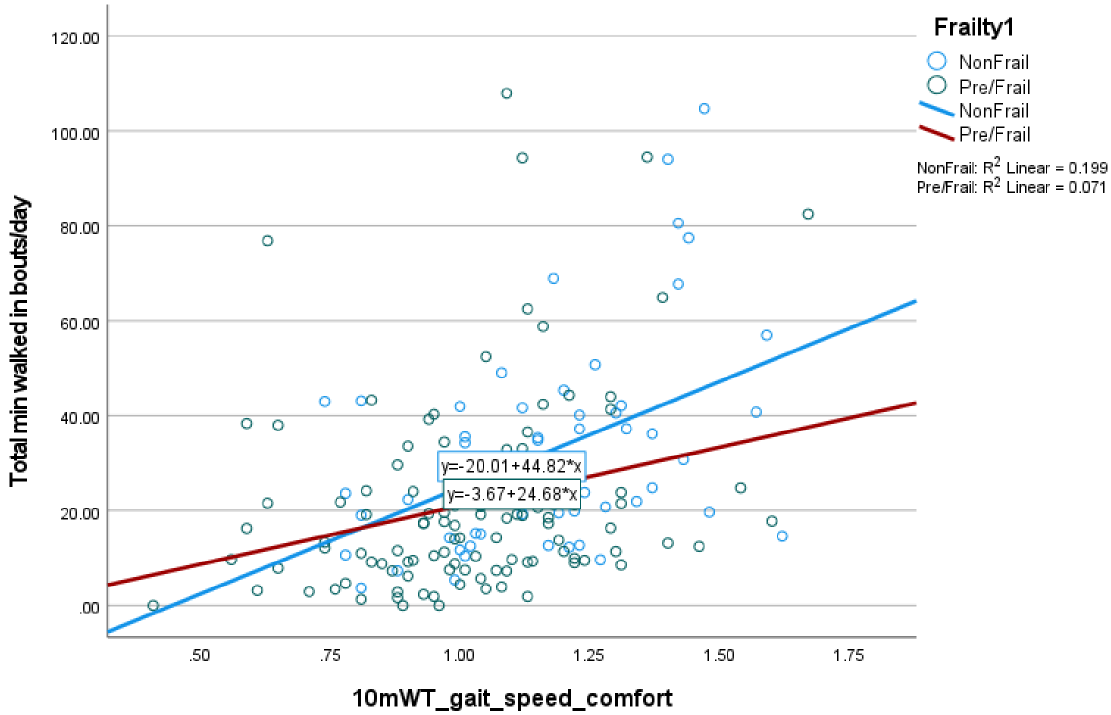


Table 19 – Frailty moderation analyses Hayes' Process macro – 30sSTS x Time walked in bouts

Model Summary						
R	**R^2**	**MSE**	**F**	**df1**	**df2**	**P**
.4012	.1610	403.6003	5.1485	6.0000	161.0000	.0001
Coefficients						
	Beta coeff	**St. Error**	**t**	**p**	**LLCI**	**ULCI**
constant	15.5940	21.8728	.7129	.4769	-27.6006	58.7885
30sSTS	2.7141	.8772	3.0940	.0023	.9818	4.4464
Frailty	9.5942	9.6501	.9942	.3216	-9.4628	28.6513
Int_1	-1.7272	.9653	-1.7892	**.0755**	-3.6335	.1792
Age	-.0763	.2467	-.3093	.7575	-.5635	.4109

Sex	-3.3550	3.5774	-.9378	.3497	-10.4196	3.7097
CCI	-1.5976	1.1825	-1.3510	.1786	-3.9328	.7377

Product terms key:
Int_1: 30sSTS x Frailty
Test(s) of highest order unconditional interaction(s):

	R2-chng	F	df1	df2	p
X*W	.0167	3.2012	1.0000	161.0000	.0755

Figure 19 – Frailty moderation effect result graph – 30sSTS x Time walked in bouts

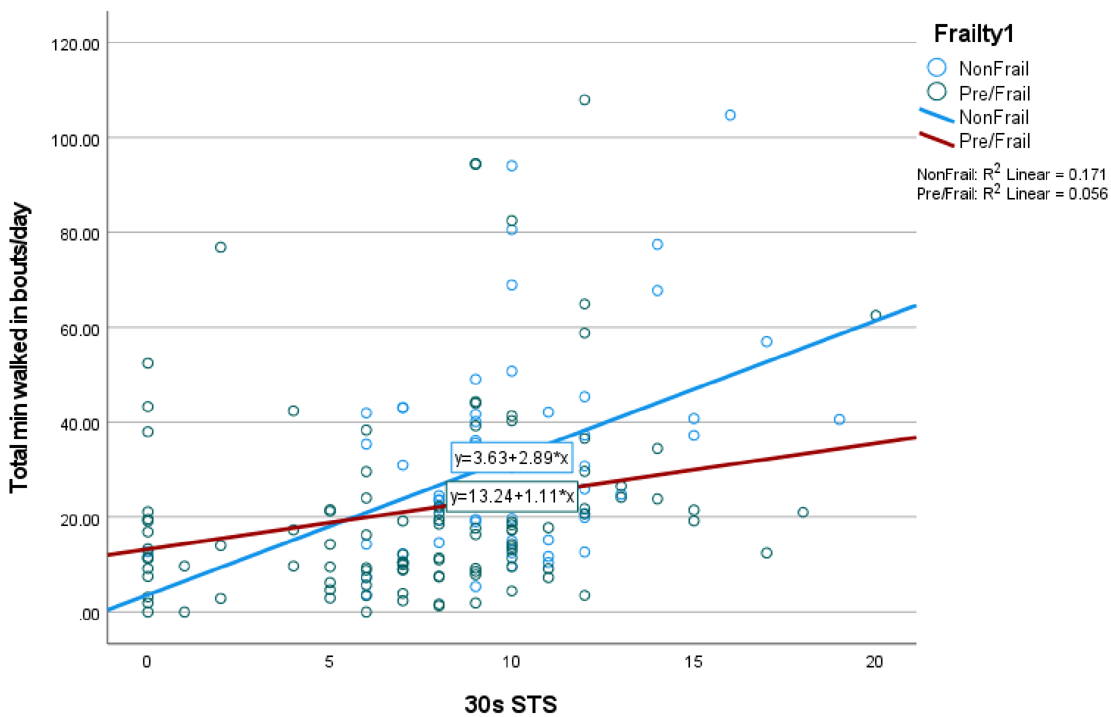


Table 20 – Frailty moderation analyses Hayes' Process macro – Mini-BEST x Time walked in bouts

Model Summary						
R	**R^2**	**MSE**	**F**	**df1**	**df2**	**p**
.3958	.1566	405.6992	4.9831	6.0000	161.0000	.0001
Coefficients						
	Beta coeff	**St. Error**	**t**	**p**	**LLCI**	**ULCI**
constant	-12.2942	28.5941	-.4300	.6678	-68.7621	44.1738
Mini Best	2.3184	.8041	2.8832	.0045	.7304	3.9063
Frailty	24.2055	19.0290	1.2720	.2052	-13.3731	61.7841
Int_1	-1.4634	.8613	-1.6990	**.0913**	-3.1644	.2376
Age	-.0130	.2571	-.0505	.9598	-.5206	.4947
Sex	-4.6944	3.5626	-1.3177	.1895	-11.7300	2.3411
CCI	-1.6396	1.1941	-1.3731	.1716	-3.9977	.7185

Product terms key:
Int_1: Mini-Best x Frailty
Test(s) of highest order unconditional interaction(s):

	R2-chng	F	df1	df2	p
X*W	.0151	2.8865	1.0000	161.0000	.0913

Figure 20 – Frailty moderation effect result graph – Mini-BEST x Time walked in bouts

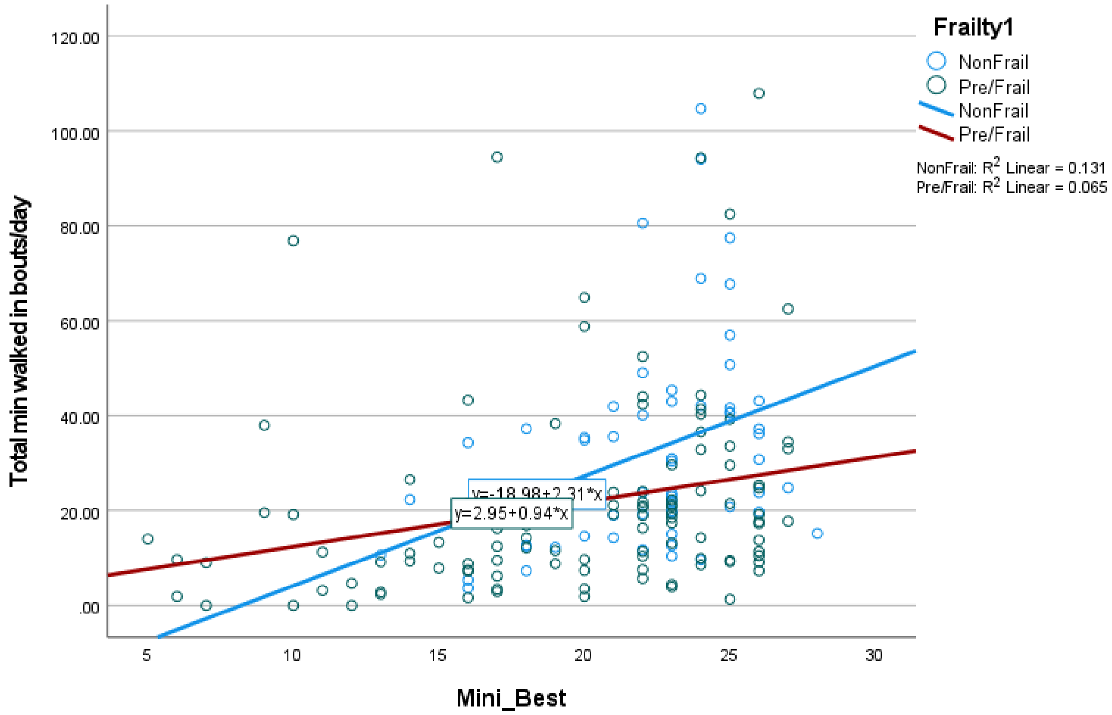


Table 21 – Frailty moderation analyses Hayes' Process macro – 6MWT x Steps/day

Model Summary						
R	**R^2**	**MSE**	**F**	**df1**	**df2**	**p**
.4552	.2072	7991851.17	7.0116	6.0000	161.0000	.0000
Coefficients						
	Beta coeff	**St. Error**	**t**	**p**	**LLCI**	**ULCI**
constant	7320.6481	3675.4790	1.9918	.0481	62.2769	14579.0192
6MWT	12.7619	4.7478	2.6880	.0079	3.3859	22.1378
Frailty	781.8464	2115.7203	.3695	.7122	-3396.2983	4959.9911
Int_1	-4.5617	5.4314	-.8399	**.4022**	-15.2876	6.1642
Age	-15.5817	36.9151	-.4221	.6735	-88.4820	57.3186
Sex	360.4354	500.0867	.7207	.4721	-627.1407	1348.0114

CCI	-399.2477	165.8733	-2.4069	.0172	-726.8158	-71.6796

Product terms key:
Int_1: 6MWT x Frailty
Test(s) of highest order unconditional interaction(s):

	R2-chng	F	df1	df2	p
X*W	.0035	.7054	1.0000	161.0000	.4022

Figure 21 – Frailty moderation effect result graph – 6MWT x Steps/day

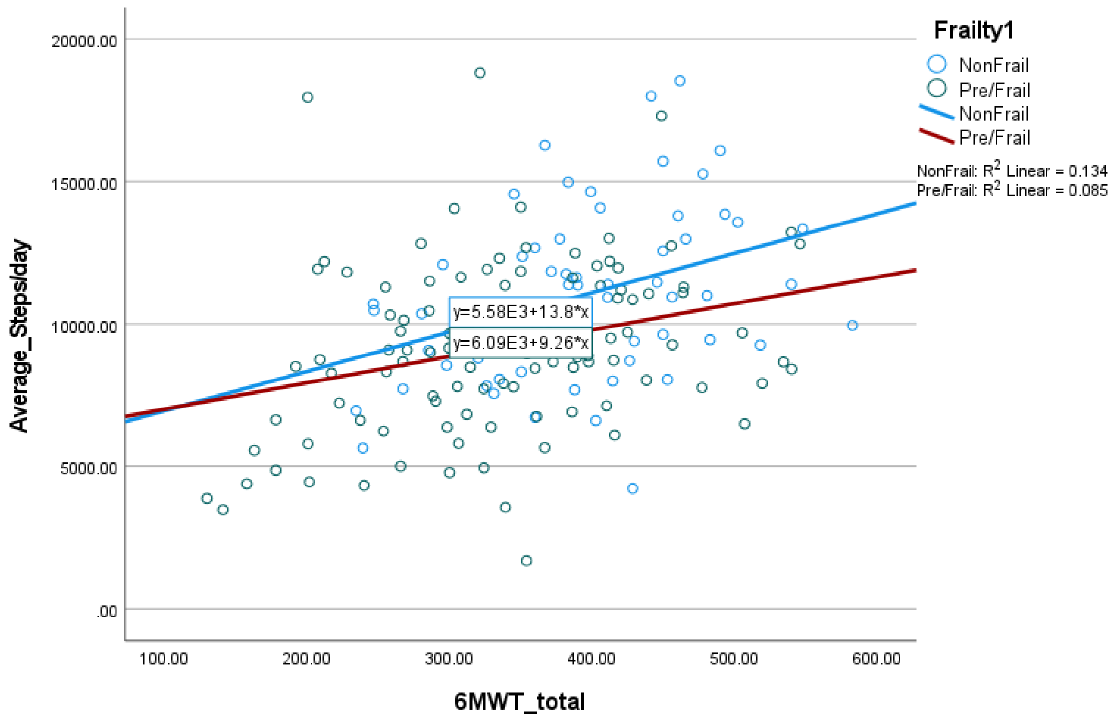


Table 22 – Frailty moderation analyses Hayes' Process macro – 10mWT x Steps/day

Model Summary						
R	**R^2**	**MSE**	**F**	**df1**	**df2**	**P**
.4554	.2074	7989750.57	7.0205	6.0000	161.0000	.0000
Coefficients						
	Beta coeff	**St. Error**	**t**	**p**	**LLCI**	**ULCI**
constant	8139.8933	3542.6418	2.2977	.0229	1143.8504	15135.9362
10mWT	5105.0398	1772.7893	2.8797	.0045	1604.1184	8605.9611
Frailty	1777.5354	2412.3463	.7368	.4623	-2986.3891	6541.4598
Int_1	-2417.1522	2119.4644	-1.1405	**.2558**	-6602.6908	1768.3863
Age	-39.0172	33.9728	-1.1485	.2525	-106.1070	28.0726
Sex	362.0659	500.1720	.7239	.4702	-625.6786	1349.8104
CCI	-408.6754	165.8310	-2.4644	.0148	-736.1600	-81.1909
Product terms key: Int_1: 10mWT x Frailty Test(s) of highest order unconditional interaction(s): R2-chng F df1 df2 p X*W .0064 1.3006 1.0000 161.0000 .2558						

Figure 22 – Frailty moderation effect result graph – 10mWT x Steps/day

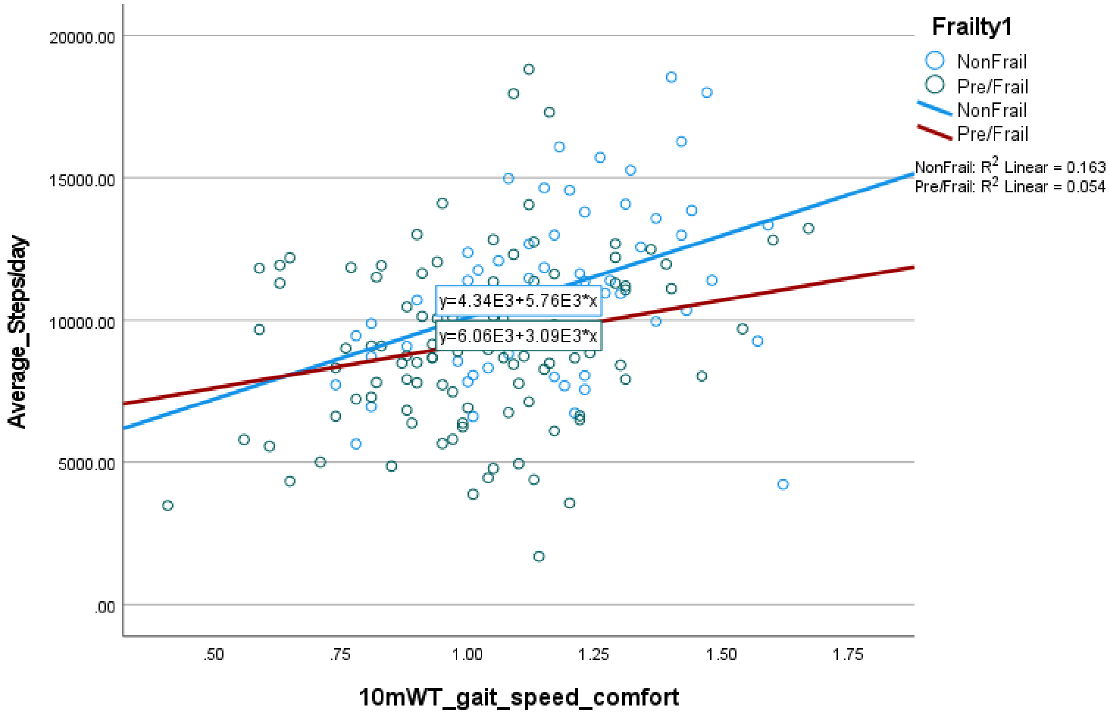


Table 23 – Frailty moderation analyses Hayes' Process macro – 30sSTS x Steps/day

Model Summary						
R	**R^2**	**MSE**	**F**	**df1**	**df2**	**p**
.4836	.2339	7722528.66	8.1919	6.0000	161.0000	.0000
Coefficients						
	Beta coeff	**St. Error**	**t**	**p**	**LLCI**	**ULCI**
constant	9216.3452	3025.5744	3.0461	.0027	3241.4119	15191.2786
30sSTS	334.9623	121.3403	2.7605	.0064	95.3383	574.5862
Frailty	166.4655	1334.8580	.1247	.9009	-2469.6250	2802.5559
Int_1	-109.5549	133.5307	-.8204	**.4132**	-373.2526	154.1427
Age	-21.5286	34.1236	-.6309	.5290	-88.9162	45.8590
Sex	640.0017	494.8447	1.2933	.1977	-337.2223	1617.2258
CCI	-360.4972	163.5740	-2.2039	.0290	-683.5247	-37.4698

Product terms key: Int_1: 30sSTS x Frailty Test(s) of highest order unconditional interaction(s): R2-chng F df1 df2 p X*W .0032 .6731 1.0000 161.0000 .4132

Figure 23 – Frailty moderation effect result graph – 30sSTS x Steps/day

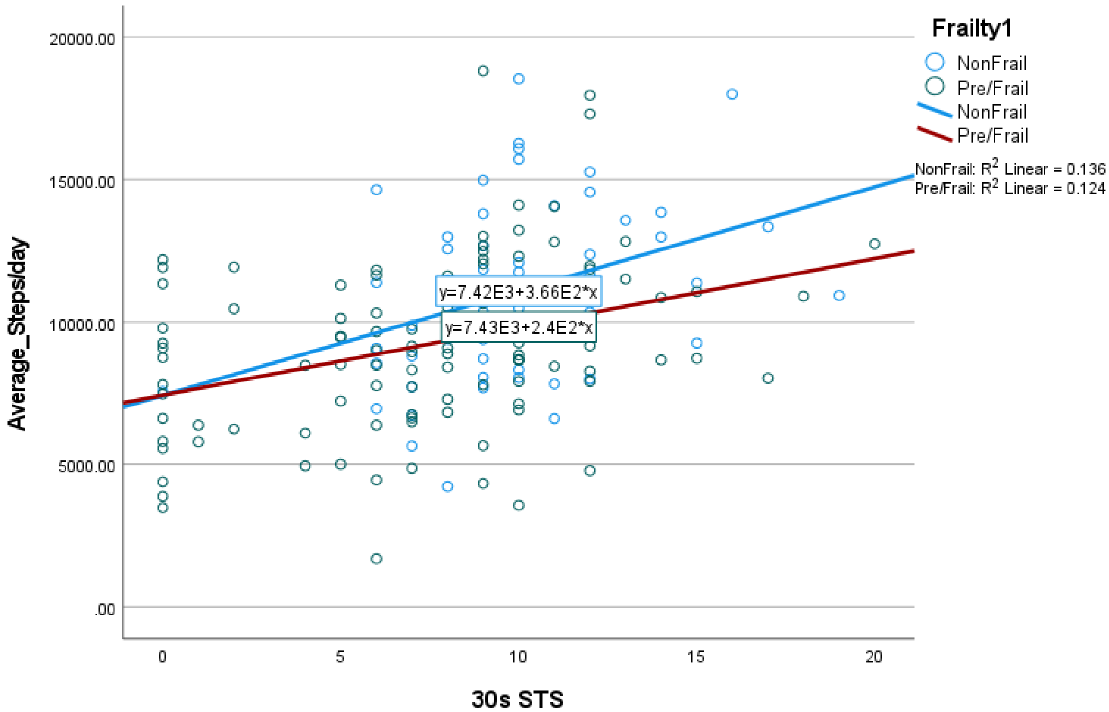


Table 24 – Frailty moderation analyses Hayes' Process macro – Mini-BEST x Steps/day

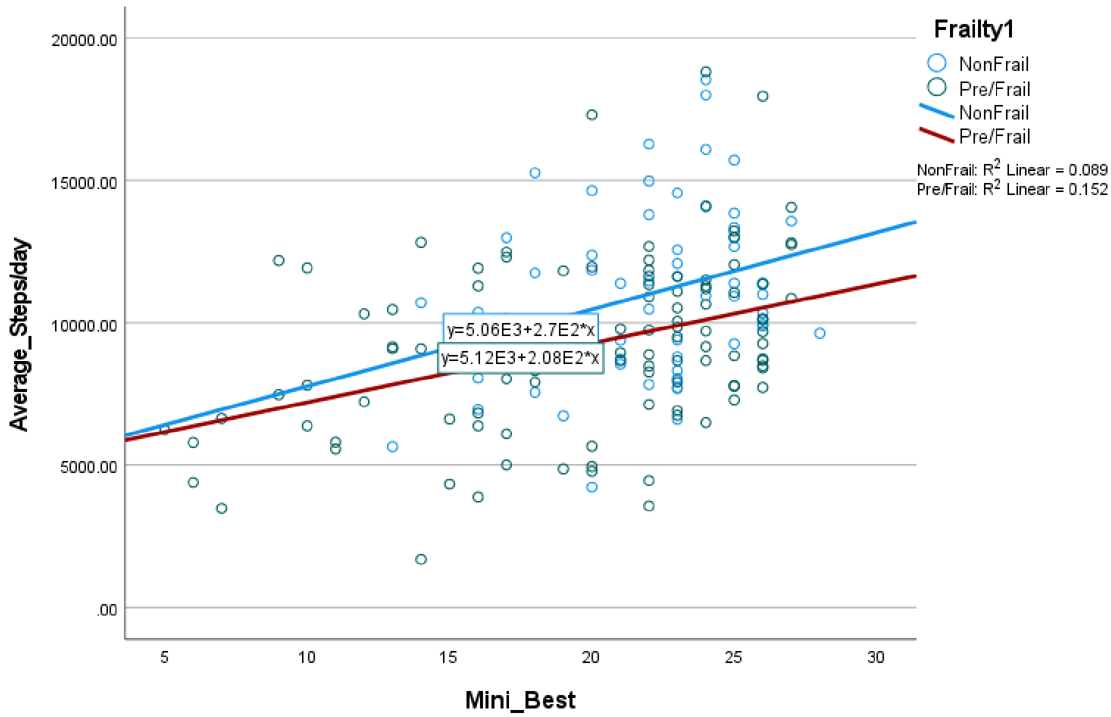
Model Summary						
R	**R^2**	**MSE**	**F**	**df1**	**df2**	**P**
.4725	.2232	7829840.35	7.7119	6.0000	161.0000	.0000
Coefficients						
	Beta coeff	**St. Error**	**t**	**p**	**LLCI**	**ULCI**
constant	6226.4098	3972.3822	1.5674	.1190	-1618.2887	14071.1082
Mini-Best	261.0910	111.7088	2.3372	.0207	40.4874	481.6946

Frailty	630.7510	2643.5645	.2386	.8117	-4589.7855	5851.2876
Int_1	-77.9410	119.6605	-.6514	**.5157**	-314.2478	158.3658
Age	-11.8883	35.7121	-.3329	.7396	-82.4129	58.6362
Sex	399.4989	494.9316	.8072	.4208	-577.8967	1376.8945
CCI	-341.8780	165.8862	-2.0609	.0409	-669.4715	-14.2844

Product terms key:
Int_1: Mini-Best x Frailty
Test(s) of highest order unconditional interaction(s):

	R2-chng	F	df1	df2	p
X*W	.0020	.4243	1.0000	161.0000	.5157

Figure 24 – Frailty moderation effect result graph – Mini-BEST x Steps/day



Chapter 7 – Discussion

The main purpose of this study was to determine the individual and collective associations between mobility capacity tests and walking performance measures in community-dwelling older adults with outdoors walking limitations. Secondarily we explored how frailty influences these relationships between mobility capacity and walking performance.

The first hypothesis for this thesis was that the magnitude of association between capacity tests (6MWT, comfortable 10mWT, 30-second Sit-to-Stand, Mini-BESTest) and walking performance measures would be low to fair ($0.25 \leq r \leq 0.50$).[137] This statement was confirmed by the Pearson correlation coefficients (Table 10) that were within the expected range of association. Further, we hypothesized that of the four capacity tests 6MWT would be more strongly related to steps per day and time walked in bouts per day compared to the other capacity tests. We also hypothesized that comfortable 10mWT results would be the most strongly related to peak 30-min cadence values. These hypotheses were not confirmed by our results. The highest correlation result was found between the capacity measure of 6MWT and the performance measure of peak 30-minute cadence (0.502). Time walked in bouts (a second measure of performance) was most highly correlated to 10mWT (0.375), whereas steps per day (our third measure of performance) was most highly correlated with 30-second STS (0.403). Multiple linear regressions (single capacity measure models) results (Manuscript Table 2) demonstrated that 6MWT explained 28% of variance in peak 30-minute cadence with a partial correlation result of 0.45, followed by 30-second STS (27%), Mini-BESTest (25%), and 10mWT (24%). For time walked in bouts per day, 10mWT explained 17% of the variance, followed by 30-second STS (13%), 6MWT (12%) and Mini-BESTest (12%). Steps per day had higher variance explained by 30-second STS (22%) followed by Mini-BESTest (20%), 6MWT (18.5%) and Mini-BESTest (18.4%).

Our second hypothesis was that combinations of capacity tests would explain greater amounts of variance in walking performance compared to individual measures of capacity. Multiple regression results with multiple measures of capacity (Manuscript Table 3) confirmed our second hypothesis as the variance explained was higher for all models when compared to the regression models with only one measure of capacity. The results demonstrated that 30-second

Sit-to-Stand was significantly associated with two (out of 3) performance measures: peak 30-minute cadence (along with 6MWT), and steps/day. It is possible Sit-to-Stand results were significantly associated with more than one walking performance measure because this capacity test requires functional coordination of capacities essential to walking (muscle strength, coordination and postural control),[87,89,141] while 6MWT assesses mainly aerobic capacity, 10mWT assesses walking speed and Mini-BESTest is dedicated to assessing balance-related capacity. Walking performance requires a number of skills such as the ability to start and to stop walking, change walking speed, to turn and sit. Without adequate coordination a person can have difficulty in selecting the appropriate speed, distance, direction of movement, timing and muscle tension required to walk. Lack of postural control while walking makes the movement become uncoordinated, unstable, and dangerous due to risk of falls. Coordination and postural control along with muscle strength are necessary to overcome different challenges presented in indoor and outdoor environments, such as avoiding obstacles, going around people, walking up and down sidewalks, stopping walking unexpectedly, etc.[37]

Several studies have demonstrated that gait speed is important and can be considered a functional vital sign,[68] and "marker of frailty".[44] So, based on these studies and the results found by Jansen et al,[12] our rationale for hypothesis 3 was that the presence of frailty would explain greater variance in the relationship between capacity and performance compared to results in non-frail participants. Jansen and colleagues' study used gait speed as the capacity measure, and cumulated physical activity time, average steps per walking bout and maximal number of steps in one walking bout as their measures of performance. They did not find a significant relationship between capacity and performance unless frailty was considered as a moderator. However, our research found significant individual relationships between walking speed and all four capacity measures. We did not detect a significant influence of frailty in the relationships between capacity and performance, based on the specific outcomes utilized in this study. This discrepancy in results may have been due to the limited size of our sample of frail individuals and/or the different specific outcome measures used to measure capacity and performance. It is possible that in samples with a greater number of frail people this moderation interaction effect of frailty may be observed. Likely there are other aspects that also contribute to these relationships, and therefore, further studies on this subject are needed.

Although the moderation effect was not shown with our data, we did demonstrate that capacity tests explained the most variance in the performance variable of peak 30-minute cadence. Peak 30-minute cadence is referred to as a measure of walking performance that represents best natural effort in daily life as it captures the 30 minutes with the highest cadence values of the day (whether they happened in shot or long bouts during the day). It is a performance measure that reflects intensity of walking, which may include short intervals or longer periods of walking throughout the day. However not many studies have used peak 30-minute cadence as a measure of performance. Of the three performance measures, peak 30-minute cadence had the highest variance explained by a combination of capacity tests results (30-second Sit-to-Stand and 6MWT).

Our sample was composed only of older adults with outdoor mobility limitations; therefore, result cannot be generalized to other populations. This study and other researchers' work show that the use of specific outcomes measures has a great impact in the intensity of association between capacity and performance measures. Thus, clinicians should consider including tests such as 30sSTS and 6MWT to assess and later reevaluate their clients to plan treatments, authorize hospital discharges, and monitor progress.

The GO-OUT study collected physical capacity data using low-cost, easy-to-apply tests that are used in the clinical practice of physiotherapists and other health professionals. Participants were older people between 63 and 93 years of age with outdoor walking limitations. These mobility limitations are a common problem for older adults and are not yet well studied, so it is relevant to learn about walking performance in this population. Also, participants in the GO-OUT study were from four distinct Canadian cities, and the walking conditions they need to deal with while walking outdoors would be very different. The opportunity to use data collected by the GO-OUT study was important to carry out an analysis that could bring practical results for professionals who serve the older adult population with mobility limitations.

The associations found between mobility capacity and walking performance confirm that associations exist, but they are not as direct as one might think they would be. There is still a large proportion of variance left unexplained in the models of walking performance that needs to be investigated. Self-efficacy, mood, pain, and cognition are some examples of factors that should be investigated to verify their influence in relationships between walking capacity and walking performance. When assessing walking capacity, 6MWT, 10-mWT, 30-second Sit-to-Stand and Mini-BESTest can provide valuable information about walking performance. Nevertheless, if physiotherapists need to choose only a couple of tests due to time constraints, clinicians should use the 6MWT and 30-second Sit-to-Stand to assess walking performance in older adults with outdoor mobility limitations.

Appendix 1 - Health Research Ethics Board Certificates

Research Ethics Bannatyne
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HEALTH RESEARCH ETHICS BOARD (HREB)
CERTIFICATE OF FINAL APPROVAL FOR NEW STUDIES
Delegated Review

PRINCIPAL INVESTIGATOR:	INSTITUTION/DEPARTMENT:	ETHICS #:
Sabrina Abreu Schlickmann Gil	University of Manitoba/College of Medical Rehabilitation Sciences	HS24587 (H2021:009)
APPROVAL DATE: January 17, 2021	**EXPIRY DATE:** January 17, 2022	
STUDENT PRINCIPAL INVESTIGATOR SUPERVISOR (if applicable): Dr. Sandra Webber		

PROTOCOL NUMBER:	PROJECT OR PROTOCOL TITLE:
NA	Can mobility capacity tests predict walking performance in older adults?[Linked to Hs21345 (H2017:408)]
SPONSORING AGENCIES AND/OR COORDINATING GROUPS: Non funded - linked study funded by CIHR	

Submission Date of Investigator Documents:	HREB Receipt Date of Documents:
December 15, 2020	December 17, 2020

THE FOLLOWING ARE APPROVED FOR USE:

Document Name	Version (if applicable)	Date
Protocol:		
University of Manitoba Bannatyne Campus Research Ethics Board Submission Form for Retrospective Chart or Records Review		December 15, 2020
Consent and Assent Form(s):		
Other:		
Data Capture Sheet		15/12/2020

CERTIFICATION

The above-named research study/project has been reviewed in a ***delegated manner*** by the University of Manitoba (UM) Health Research Board (HREB) and was found to be acceptable on ethical grounds for research involving human participants. The study/project and documents listed above was granted final approval by the Chair or Acting Chair, UM HREB.

HREB ATTESTATION

The University of Manitoba (UM) Research Board (HREB) is organized and operates according to Health Canada/ICH Good Clinical Practices, Tri-Council Policy Statement 2, and the applicable laws and regulations of Manitoba. In respect to clinical trials, the HREB complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations of Canada and carries out its functions in a manner consistent with Good Clinical Practices.

A unit of the office of the Vice-President (Research and International) umanitoba.ca/research

- 1 -

QUALITY ASSURANCE
The University of Manitoba Research Quality Management Office may request to review research documentation from this research study/project to demonstrate compliance with this approved protocol and the University of Manitoba Policy on the Ethics of Research Involving Humans.

CONFLICT OF INTEREST
Any Principal or Co-Investigators of this study who are members of the UMHREB did not participate in the review or voting of this study.

CONDITIONS OF APPROVAL:

1. The study is acceptable on scientific and ethical grounds for the ethics of human use only. ***For logistics of performing the study, approval must be sought from the relevant institution(s).***
2. This research study/project is to be conducted by the local principal investigator listed on this certificate of approval.
3. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to the research study/project, and for ensuring that the authorized research is carried out according to governing law.
4. **This approval is valid until the expiry date noted on this certificate of approval.** **A Bannatyne Campus Annual Study Status Report** must be submitted to the HREB within 15-30 days of this expiry date.
5. Any changes of the protocol (including recruitment procedures, etc.), informed consent form(s) or documents must be reported to the HREB for consideration in advance of implementation of such changes on the **Bannatyne Campus Research Amendment Form.**
6. Adverse events and unanticipated problems must be reported to the HREB as per Bannatyne Campus Research Boards Standard Operating procedures.
7. The UM HREB must be notified regarding discontinuation or study/project closure on the **Bannatyne Campus Final Study Status Report**.

Please quote the above Human Ethics Number on all correspondence.
Inquiries should be directed to the REB Secretary **Telephone:** (204) 789-3255/ **Fax:** (204) 789-3414

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HEALTH RESEARCH ETHICS BOARD (HREB)

CERTIFICATE OF ANNUAL APPROVAL

PRINCIPAL INVESTIGATOR:	INSTITUTION/DEPARTMENT:	ETHICS #:
Sabrina Abreu Schlickmann Gil	University of Manitoba/College of Medical Rehabilitation Sciences	HS24567 (H2021:009)
HREB MEETING DATE (if applicable): NA	**APPROVAL DATE:** January 3, 2022	**EXPIRY DATE:** **January 17, 2023**
STUDENT PRINCIPAL INVESTIGATOR SUPERVISOR (if applicable): Dr. Snadra Webber		

PROTOCOL NUMBER:	PROJECT OR PROTOCOL TITLE:
NA	Can mobility capacity tests predict walking performance in older adults?[Linked to Hs21345 (H2017:408)]
SPONSORING AGENCIES AND/OR COORDINATING GROUPS: Non funded - linked study funded by CIHR	

Submission Date of Investigator Documents:	HREB Receipt Date of Documents:
November 15, 2021	November 18, 2021

REVIEW CATEGORY OF ANNUAL REVIEW: **Full Board Review** ☐ **Delegated Review** ☒

THE FOLLOWING AMENDMENT(S) and DOCUMENTS ARE APPROVED FOR USE:

Document Name (if applicable)	Version (if applicable)	Date

Annual approval

Annual approval implies that the most recent ***HREB approved*** *versions of the protocol, Investigator Brochures, advertisements, letters of initial contact or questionnaires, and recruitment methods, etc. are approved.*

Consent and Assent Form(s):

CERTIFICATION

The University of Manitoba (UM) Health Research Board (HREB) has reviewed the annual study status report for the research study/project named on this ***Certificate of Annual Approval*** as per the category of review listed above and was found to be acceptable on ethical grounds for research involving human participants. Annual approval was granted by the Chair or Acting Chair, UM HREB, per the response to the conditions of approval outlined during the initial review (full board or delegated) of the annual study status report.

HREB ATTESTATION

The University of Manitoba (UM) Health Research Board (HREB) is organized and operates according to Health Canada/ICH Good Clinical Practices, Tri-Council Policy Statement 2, and the applicable laws and regulations of Manitoba. In respect to clinical trials, the HREB complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations of Canada and carries out its functions in a manner consistent with Good Clinical Practices.

QUALITY ASSURANCE
The University of Manitoba Research Quality Management Office may request to review research documentation from this research study/project to demonstrate compliance with this approved protocol and the University of Manitoba Policy on the Ethics of Research Involving Humans.

CONFLICT OF INTEREST
Any Principal or Co-Investigators of this study who are members of the UMHREB did not participate in the review or voting of this study.

CONDITIONS OF APPROVAL:

1. The study is acceptable on scientific and ethical grounds for the ethics of human use only. ***For logistics of performing the study, approval must be sought from the relevant institution(s).***
2. This research study/project is to be conducted by the local principal investigator listed on this certificate of approval.
3. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to the research study/project, and for ensuring that the authorized research is carried out according to governing law.
4. **This approval is valid until the expiry date noted on this certificate of annual approval.** A **Bannatyne Campus Annual Study Status Report** must be submitted to the REB within 15-30 days of this expiry date.
5. Any changes of the protocol (including recruitment procedures, etc.), informed consent form(s) or documents must be reported to the HREB for consideration in advance of implementation of such changes on the **Bannatyne Campus Research Amendment Form.**
6. Adverse events and unanticipated problems must be reported to the REB as per Bannatyne Campus Research Boards Standard Operating procedures.
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Appendix 2 - List of linear regression models

MODEL 1A	6MWT + age + sex + CCI = Peak 30-minute cadence
MODEL 1B	10mWT + age + sex + CCI = Peak 30-minute cadence
MODEL 1C	30sSTS + age + sex + CCI = Peak 30-minute cadence
MODEL 1D	Mini-BESTest + age + sex + CCI = Peak 30-minute cadence
MODEL 2A	6MWT + age + sex + CCI = Time Walked in Bouts
MODEL 2B	10mWT + age + sex + CCI = Time Walked in Bouts
MODEL 2C	30sSTS + age + sex + CCI = Time Walked in Bouts
MODEL 2D	Mini-BESTest + age + sex + CCI = Time Walked in Bouts
MODEL 3A	6MWT + age + sex + CCI = Steps per Day
MODEL 3B	10mWT + age + sex + CCI = Steps per Day
MODEL 3C	30sSTS + age + sex + CCI = Steps per Day
MODEL 3D	Mini-BESTest + age + sex + CCI = Steps per Day
MODEL 4A	6MWT + 10mWT + 30sSTS + Mini-BESTest + age + sex + CCI = Peak 30-minute cadence
MODEL 5A	6MWT + 10mWT + 30sSTS + Mini-BESTest + age + sex + CCI = Time walked in bouts
MODEL 6A	6MWT + 10mWT + 30sSTS + Mini-BESTest + AGE + age + sex = Steps per Day

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