SEX AND GENDER CONSIDERATIONS IN EXERCISE-BASED TELEREHABILITATION AFTER STROKE

EXPLORING THE INTERSECTION BETWEEN SEX- AND GENDER-BASED CONSIDERATIONS AND EXERCISE-BASED TELEREHABILITATION IN INDIVIDUALS WITH STROKE

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TITLE:	Exploring the intersection between sex- and gender-based considerations and exercise-based telerehabilitation in individuals with stroke
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LAY ABSTRACT (147/150 words)

Stroke affects men and women differently. Unfortunately, women experience poorer recovery of their limbs and also participate less in stroke rehabilitation services due to factors like being a primary caregiver. Virtual rehabilitation programs may enable more women to benefit from stroke rehabilitation by removing barriers such as the need for travel. The goal of this research was to gather and synthesize information on factors that enabled and impeded participation in exercise-based virtual rehabilitation. We also explored the experiences of people with stroke who participated in a 4-week lower limb focused virtual exercise program, and closely explored their unique physical and psychological responses to the program. Overall, we found many positive factors and few impeding factors to participating in telerehabilitation, and that people with stroke think that virtual rehabilitation is an accessibility form of stroke rehabilitation that improves psychological outcomes and lower limb strength, especially in women.

ABSTRACT (300/300 words)

Sex- and gender-based factors disproportionally impact stroke recovery in women, and thus there is an urgent need for rehabilitation scientists to consider innovative forms of delivering stroke rehabilitation to optimize their participation, physical and psychosocial outcomes. Telerehabilitation which involves minimal travel requirements and costs may help overcome barriers related to accessing rehabilitation services. This PhD thesis is comprised of three studies that had an overarching aim of examining the intersection between sex- and gender-based considerations and exercise-based telerehabilitation among individuals with stroke.

The first study was a scoping review of 38 primary research studies exploring facilitators and barriers to participation in exercise-based telerehabilitation in men and women with stroke. We reported many facilitators related to environmental factors including variety of games or exercises, convenience/flexibility of the training schedule, accessibility, strong communication skills possessed by therapists, and self-reported improvements in physical function. Challenges with internet connectivity and wearing and/or adjusting the technological device(s) used were the most commonly reported barriers. Both men and women reported being satisfied with the intervention components and possessed knowledge to participate. The second study aimed to explore participants' experiences with a synchronously-delivered 4-week lower extremity-focused telerehabilitation program. Participants corroborated many of the facilitators identified in our scoping review, in addition to telerehabilitation providing opportunities to extend the continuum of stroke recovery. The third study included multiple case studies of 6 participants involved with the 4-week exercise-based telerehabilitation, whereby we explored sex- and gender-based factors that could potentially explain the responses in performance-based strength and health-related quality of life. We reported that factors such as stroke type and

marital status of female participants could have helped explain their more favourable responses in contrast to males. Overall, this thesis provided preliminary evidence of the use of telerehabilitation as a viable means of delivering stroke rehabilitation to women.

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30s-STS	30-second Sit-To-Stand test
ABC	Activity-Specific Balance Confidence
ADL	Activities of Daily Living
CID	Clinically Important Difference
FCI	Functional Comorbidity Index
IADL	Instrumental Activities of Daily Living
ICF	International Classification of Functioning, Disability and Health Framework
IQR	Interquartile Range
JBI	Joanna Briggs Institute
MDC	Minimal Detectable Change
MMAT	Mixed Methods Appraisal Tool
mRS	Modified Rankin Scale
MMSE	Mini Mental State Examination
MoCA	Montreal Cognitive Assessment
NA	Not Applicable
NR	Not Reported
NIH-SS	National Institutes of Health Stroke Severity Scale
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Review
RCT	Randomized Controlled Trial
RoB 2	Cochrane Collaboration Revised Risk of Bias Assessment
ROBINS-I	Risk of Bias in Non-randomised studies – of Interventions
SAGER	Sex and Gender Equity in Research
SEM	Standard Error of Measurement
SIS-3	Stroke Impact Scale – Version 3
SF-MoCA	Short-Form Montreal Cognitive Assessment
SUS	System Usability Scale
TAM	Technology Acceptance Model
TDF	Theoretical Domains Framework
TRAIL	TeleRehabilitation with Aims to Improve Lower extremity recovery post-stroke
UK	United Kingdom
USA	United States of America
UTAUT	Unified Theory of Acceptance and Use of Technology used to guide

DECLARATION OF ACADEMIC ACHIEVEMENT

Elise Wiley is the first author on all components of this thesis, of which is formatted in a sandwich manner. The candidate led all aspects of the research projects. The grand introduction (Chapter 1) and grand discussion (Chapter 5) were completed by the candidate, with feedback and guidance from Dr. Ada Tang. The contributions of the candidate and co-authors for each study (Chapters 2,3,4) are described below.

Chapter 2:

Wiley, E., Moncion, K., Noguchi, K.S., Huynh, E., Park, S., Fang, H., Brooks, D., MacDermid, J.C., Sakakibara B.M., Tang, A. Facilitators and Barriers to Participation in Exercise-Based Telerehabilitation in Individuals with Stroke: A Scoping Review of Quantitative and Qualitative Studies. Manuscript formatted for submission to *Telemedicine and e-Health*

Contributions

EW and AT were responsible for the conceptualization of this study, with feedback from BMS, DB, and JCM. EW designed and conducted the systematic search with support from a McMaster University librarian. EW, KM, KSN, EH, HF, and SP screened titles and abstracts and full-texts. EW, KM, KSN, EH, HF, and SP extracted data and performed risk of bias quality appraisals. EW conducted the analysis and consolidation of findings, with assistance from HF, KM and KSN. EW and AT drafted the manuscript. All authors provided feedback on the final draft.

Chapter 3:

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and women with stroke across Canada. *Disability and Rehabilitation,*

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Contributions

EW, BMS, and AT were responsible for the conceptualization of this study. EW and SP recruited participants. EW collected data (semi-structured interviews and direct observation). EW led data analysis, with input from SP, BMS, and AT. EW, BMS, and AT drafted the manuscript. RB, MB, JJE, AH, EI, JCM, MML, CP, SP, RT, JY reviewed and provided feedback on the final draft. AT and BMS are the principal investigators (co-PIs) on the study in which this sub-study was conducted on. The co-PIs were responsible for writing the grant preparation and application of the main trial, of which made this study possible.

Chapter 4:

Wiley, E., Sakakibara, B.M., MacDermid, J.C., Brooks, D., Tang, A. How can sex-and gender-based characteristics explain individual responses to a 4-week exercise-based telerehabilitation program within the first year of stroke? Multiple case studies. Manuscript to be submitted to *Disability and Rehabilitation*.

Contributions

EW, AT, and JCM were responsible for the conceptualization of the study, with feedback from BMS and DB. EW led the data acquisition and analysis. EW and AT drafted the manuscript. All authors reviewed and provided feedback on the final draft. AT and BMS are the principal investigators (co-PIs) on the main trial from which this sub-study was conducted. The co-PIs were responsible for securing grant funding to support the main trial.

CHAPTER 1: INTRODUCTION

1.1 Stroke

1.1.1 Epidemiology of stroke

Over 100 million individuals live with stroke across the world, and stroke remains the second-leading cause of death and third leading cause of disability worldwide.[1] The burden of stroke is projected to continue to increase as the global population ages, with incidence expected to double by 2050.[2] The rates of stroke are higher among males than females during midlife, but shift to higher rates in females beginning in the eight decade of life.[3] Of concern, the disability-adjusted life-years due to stroke have increased by 32% since 1990.[2] Thus, a growing proportion of the population are living with the long-term effects of stroke.

1.1.2 Continuum of stroke care

In Canada, stroke care commonly includes four levels: 1) hyperacute stroke management; 2) acute stroke management; 3) stroke rehabilitation; and 4) community reintegration.[4] Hyperacute and acute stroke management are focused on neurological evaluation of the patient and thrombolytic therapy,[5] typically taking place within the first week of stroke onset.[6] The transition to inpatient stroke rehabilitation involves comprehensive care from a multidisciplinary team of healthcare providers (e.g., physical therapist, occupational therapists, speech-language pathologists),[7] with focus on early and safe mobilization (e.g., transfers, sitting up).[8] Patients also receive information about their disease and physical condition, and how to manage their health in the long-term.[9] The duration of inpatient rehabilitation is approximately one month in Canada,[10] after which they may receive outpatient stroke rehabilitation in a private clinic or hospital setting, and return home the same day.[11] The decision of pursuing outpatient rehabilitation setting is often based on patients' functional needs, participation-related goals, and availability of

social support from family.[12] Importantly, after 12 weeks, community-based physical therapy services may not be publicly funded,[13] and thus posing as an economical barrier to accessing care for many Canadians in the chronic stages of stroke (i.e., >6 months[6]). The final stage of the continuum of stroke care involves community reintegration, whereby the individual resumes or adapts their family and community life, engage in roles and responsibilities, and contribute to society.[14]

1.2 Unmet rehabilitation needs after stroke

As rehabilitation scientists, it is important to acknowledge that physical and psychological unmet rehabilitation needs have immense implications on community reintegration after stroke.[15] Large population-based data suggests that inpatient rehabilitation in the subacute stage involving at least one hour of daily physiotherapy, occupational therapy and speech-language pathology is associated with improved functional independence (i.e., mobility, communication, continence, transfers, cognition, and self-care).[16] However, many individuals with stroke do not receive the recommended amount of inpatient therapy[16] or information about ongoing rehabilitation services, and are discharged to the community with unmet rehabilitation needs.[17] A systematic review of 19 studies found that individuals with sub-acute and chronic stroke most commonly report long-term psychosocial challenges related to emotion, depression, anxiety, as well as cognitive challenges, pain, fatigue, speech, swallowing, and physical impairments.[18] Moreover, approximately 40-50% of individuals with chronic stroke have residual upper[19] or lower extremity impairment.[20]

1.2.1 Unmet rehabilitation needs related to lower-extremity function after stroke

Muscle strength of the lower limb is reduced by 34-62% in individuals with stroke compared to adults without stroke.[21] Stroke-induced sarcopenia is common, whereby cerebral

damage involving motor denervation and loss of local neurons can lead to muscle wasting.[22] Moreover, up to 80% of individuals of stroke experience motor impairments,[23] with spasticity (i.e., velocity-dependent increase in muscle tone and stretch reflex hypersensitivity) being a primary impairment that affects gait, balance, increases the risk of falls[24] and affects the ability to perform activities of daily living (ADLs).[25] In contrast, better balance at discharge from inpatient rehabilitation has been shown to be a protective factor for ADL deterioration.[26] Importantly, psychological consequences can also transpire from post-stroke lower-extremity impairment, of which most commonly includes fear of falling and thus leading to activity avoidance.[27,28] An increased risk of loss of independence may occur from the deconditioning that ensue from the reductions in participation.[29]

1.2.2 Exercise to address unmet rehabilitation needs

Exercise-based interventions may help address unmet lower extremity rehabilitation needs of individuals with stroke. Systematic review evidence (n=10 studies, 355 participants) suggests that progressive, task specific training and aerobic exercise are effective at improving strength and functional mobility among individuals with post-stroke hemiparesis.[30] Moreover, a recent Cochrane review reported that aerobic-based exercise interventions (e.g., aquatic, walking, cycle ergometer, circuit training) are effective at improving maximum (n=17 studies, 782 participants) and preferred (n=12 studies, 588 participants) walking speed, functional mobility (n=16 studies, 882 participants), and balance (n=7 studies, 471 participants).[31] The evidence for resistance training and mixed training on improving these outcomes were uncertain.

Taken together, there is well-documented evidence of the effectiveness of exercise interventions for improving lower extremity recovery needs after stroke. Notably, the interventions included in these reviews were in-person programs, and barriers to access (high

costs, lack awareness of where to access rehabilitation centres and exercise programs, limited transportation particularly in rural areas[32]) may further exacerbate unmet rehabilitation needs[33] and sedentary behaviours.[34] Thus, innovative forms of service delivery for stroke rehabilitation are greatly needed to improve access and health outcomes in the community reintegration stage after stroke.

1.3 Telerehabilitation as a means to deliver stroke rehabilitation services

Telerehabilitation may present as a promising service delivery modality that can address some of the barriers to accessing in-person stroke rehabilitation services and prolong the continuum of stroke recovery.[34] Telerehabilitation is most commonly defined as the delivery of rehabilitation services via information and communication technologies.[35] To date, telerehabilitation has been used to deliver an array of stroke recovery interventions related to functional, motor, cognitive recovery and stroke risk factor self-management programs.[36] Importantly, this thesis focuses mainly on physical rehabilitation after stroke.

It is also important to differentiate between the formats of delivery of telerehabilitation, which include asynchronous, synchronous and/or a combination of both.[37] Asynchronously-delivered telerehabilitation are remotely monitored computer-based interventions that can be adapted by a therapist offline, whereas synchronously-delivered telerehabilitation involves connecting a therapist and participant in real-time.[37]

The onset of the COVID-19 pandemic in 2020 prompted a rapid shift to use of telerehabilitation into routine stroke practice as an alternative to in-person care[38] to minimize the risk of virus transmission,[39] that also has helped extend rehabilitation opportunities beyond the shorter lengths of stay in hospital.[39,40] The pandemic sparked the update of the 2022 Canadian Stroke Best Practice Recommendations which provide evidence-based recommendations and

expert opinion clinical considerations on access, eligibility, consent, privacy, technological considerations, training of healthcare providers and individuals with stroke and their families, and assessments using virtual platforms.[41] The recommendations emphasize that the COVID-19 pandemic was a catalyst towards the widespread adoption of virtual stroke rehabilitation in Canada and should now integrated as a regular component of stroke rehabilitation, even as rehabilitation services return to prepandemic practices.[41] Thus, telerehabilitation has been postulated to continue to be an option of service delivery for stroke rehabilitation, it is important to understand its acceptability and effectiveness for remotely-delivered exercise-based interventions.

1.3.1 Effectiveness of telerehabilitation to address unmet rehabilitation needs

A Cochrane Systematic review by Laver et al., 2020 provides a recent summary of evidence on the effectiveness of telerehabilitation on psychological and physiological outcomes after stroke. The review reported equivalent effects of telerehabilitation and in-person rehabilitation on independence in ADLs (n=2 studies; 75 participants) upper extremity function (n=3 studies; 170 participants), and balance (n=3 studies;106 participants). The studies included in these meta-analyses focused on lower,[42,43] upper[44–46] or combination of lower and upper extremity[47] rehabilitation. Furthermore, equivalent outcomes of telerehabilitation compared to usual care or no rehabilitation were found on outcomes of independence in ADLs (n=2 studies, 661 participants), mobility (n=1 study, 144 participants),[48] health-related quality of life (n=3 studies, 569 participants), upper extremity function (n=2 studies, 54 participants;), and depression (n=6 studies, 1145 participants). Studies included in the meta-analysis on upper extremity function included a combination of upper and lower extremity exercises.[49,50]

Importantly, however, these findings are limited by the small number of trials and low quality of evidence.[51]

In contrast to exercise-based interventions, studies examining health-related quality of life[48,52,53] and depression most commonly involved telephone or psychosocial-based interventions (i.e., counseling, coaching)[48,52–55] delivered by a clinician. It is also worth noting that out of the 12 studies included in the meta-analysis, only four[42,44,45,47] included a synchronous component. Many asynchronously-delivered interventions involved upper extremity-focused virtual reality,[56,57] robotic or exergame style[58–60] with periodical remote monitoring by a therapist. Thus, evidence on the effectiveness of telerehabilitation is mostly based on asynchronously-delivered interventions.

1.3.2 Acceptability of telerehabilitation for the delivery of stroke rehabilitation

A previous systematic review of 11 randomized controlled trials reported high acceptability (i.e., the extent to which people receiving a healthcare intervention consider it to be appropriate, based on physical, cognitive and emotional responses[61]) of telerehabilitation among individuals with stroke, with user satisfaction with videoconferencing software rated higher than telephone calls.[62] Satisfaction is a key determinant of acceptability, and is commonly measured through understanding participants' experiences with the intervention.[61] Satisfaction between telerehabilitation and in-person rehabilitation were comparable for upper limb therapy and balance training,[62] and participants were satisfied with telerehabilitation programs when therapists were trained for effective delivery and when some social interaction was incorporated.[63] Telerehabilitation was also proposed to be a cost-effective alternative to in-person stroke services in terms of time and resources spared.[62] These findings were supported by another systematic review of eight mixed method and exploratory single-group studies, reporting

high satisfaction, usability, and attendance in physiotherapy-based telerehabilitation.[64] Qualitative studies have also reported on the acceptability of telerehabilitation, whereby perceived improvements in physical and psychological impairments,[56,58,65] ability to track progress,[56,57] affordability,[65] and external support from the therapist and family members,[56,57] and accessibility[56,65,66] especially to individuals in remote areas of Canada[66,67,68] are primary facilitators to participation. Given the encouraging facilitating factors, telerehabilitation may be used to extend the continuum of stroke recovery for Canadian adults who are approaching or currently in the community reintegration stage of recovery.

Arguably, there are barriers to participation in telerehabilitation including challenges with technological setup and interface,[56,58–60,65] lack of physical touch from the therapist,[65,66] unstable internet connectivity,[56–58] and inadequate spacing[56] and distractions (e.g., pets)[69] in the physical environment.

1.4 Sex and gender in stroke rehabilitation research and recovery

To date, there has been no research examining the acceptability of exercise-based telerehabilitation in groups who disproportionally experience barriers to accessing and adhering to stroke rehabilitation services, such as women. Women are disproportionally impacted by the effects of stroke. A systematic review of 23 studies (n=19,957 participants) reported that older females with stroke consistently experienced greater walking, ADL and IADL disability for up to 10 years.[70] Our recent study[71] corroborates poorer functional capacity in females, namely in gait speed and overall functional capacity, as assessed by the Short Physical Performance Battery. We also found that linear declines in Short Physical Performance Battery scores over 3 years of follow-up were not different between males and females, though consistently 1.2-points lower in females.[71] Thus, sex-based differences in lower extremity function are evident after stroke, and

may suggest that there are unmet rehabilitation needs in females with stroke and need for interventions to address these impairments.

1.4.1 Definitions of Sex and Gender

It is essential to define and distinguish between the terms sex and gender as these terms, while interrelated, are not interchangeable.[72] Sex refers to biological attributes in humans and animals, which are associated with physical and physiological characteristics including chromosomes, gene expression, hormone levels, and anatomy.[73] Based on these biological constructs, an individual is characterized as being a male, female, or intersex.[74,75] Sex-based factors are the primary drivers for longevity and health in humans and animals due to changes in biological processes occurring throughout the lifespan.[76]

Gender refers to the socially constructed roles, behaviours, expressions and identities of boys, girl, men, women and gender diverse people.[73] Gender is fluid and encompasses five different constructs: gender roles, gender identity, gender relations, institutionalized gender,[74] and gender expression.[77] Gender roles are often to subject to stereotypes, as they represent the behavioural norms applied to men and women in society, which influence an individual's everyday actions, expectations, and experiences.[74] For example, primary caregiving and household responsibilities have historically been associated with women, while primary earner status was associated with men.[78] Gender identity refers to how an individual sees themselves and is seen by others.[74] Gender relations refers to how an individual interacts with others and how they are treated by people in society, based on their gender.[74] Institutionalized gender refers to the distribution of power between men and women in political, educational, and social institutions, respectively.[74] Finally, gender expression refers to the traits, thoughts and beliefs an

individual possesses regarding their gender self-concept, whereby gender expression is most commonly expressed on a continuous spectrum of masculinity to femininity.[77]

In this thesis, terminology of males and females are used to refer to factors related to biological sex (e.g., age, comorbidities), while terms men and women are used to reflect gender-based considerations (e.g., marital status, caregiving roles).[70,72]

1.4.2 Sex- and gender-based differences in stroke recovery

Studies have alluded to both sex- and gender-based factors contributing to poorer stroke recovery outcomes observed in women. Age is a biological factor contributing to poorer clinical presentations and outcomes in females with stroke.[77] Aging males experience mutations in DNA sequencing earlier in the lifespan and this contributes to shorter lifespans in males compared to females.[76] As a result of longer lifespans, females are more likely to be older when they experience stroke, lending to a 3.5 increased likelihood of institutionalization compared to males.[79] Furthermore, older females tend to have higher number of cardiovascular comorbidities, such as hypertension and atrial fibrillation,[80,81] which in combination with stroke can significantly reduce quality of life.[82] The increases in cardiovascular disease risk is associated with progressive age-related reductions in estrogen, a cardioprotective hormone that stimulates angiogenesis and vasodilation, enhances mitochondrial function, regulates arterial stiffness by helping maintaining an equal balance of collagen and elastin in an artery,[83] and reduces oxidative stress.[84] Greater levels of disability among females with stroke have also been attributed to poorer pre-stroke physical function, of which are also linked to estrogen-related impairments.[85] Specifically, reductions in estrogen also results in losses in muscle mass due to altered ATPase function of myosin,[85] which in turn predisposes females to musculoskeletal comorbidities like osteoporosis, even prior to stroke onset.[86]

Older age at stroke onset can also intersect with gender-based factors that lead to poorer post-stroke outcomes in females. Men are more likely to be married at the time of their stroke in contrast to women, who are more likely to be widowed and living alone.[79] Lack of social support from family members is associated with poorer stroke outcomes including depression in women,[87] and can also be related to the increased to loss of independence[79] and reduced access to rehabilitation services.[88] Collectively, the intersection between older age, greater pre-stroke disability, higher prevalence of atrial fibrillation (i.e., sex-based factors) and limited external support can contribute to poorer recovery outcomes among women.[89]

1.4.3 Gender-based barriers to participation in stroke rehabilitation in women

Women with stroke experience barriers to accessing and participating in stroke rehabilitation programs,[90] although it is important to acknowledge that gender-based analyses are limited in the stroke population. Primary caregiving to children and/or older parents and housework are gender roles typically associated with women,[74] often prioritized over seeking support to address unmet rehabilitation needs.[88,90] Women are also likely to identify barriers to participation in rehabilitation services[98–100] such as limited support,[91] transportation, costs, and time. Innovative forms of stroke rehabilitation service delivery can optimize participation and outcomes among women and for those with limited access to rehabilitation (e.g., rural[92] and resource-constrained settings[93]), but the specific examination of sex- and gender-based factors are needed.

1.4.4 Incorporating sex- and gender-based considerations in research

By incorporating sex-and gender-based considerations, researchers can to expand relevance and application of research findings, reduce the risk of harm by providing equal care for both sexes and all genders and not assuming that study results apply to everyone, and

enhance the opportunities to improve health outcomes and strengthen our understanding of health determinants for all members of society.[94]

International guidelines for reporting Sex and Gender Equity in Research (SAGER) were published in 2016 to help inform and enhance reporting of sex-and gender-based considerations in each stage of scientific research (i.e., research question, hypotheses, study design, analyses, implications of findings, and limitations).[72] Furthermore, the guidelines provide guidance on the use of proper sex and gender terminology, to avoid the interchangeable use of these distinct constructs.[72] Recently developed and validated sex and gender assessment tools including the Stanford Gender Related-Variables for Health Research[95] and GENESIS-PRAXY[78] questionnaires can be used to properly capture of sex and gender constructs and in turn facilitate reporting. These questionnaires involve asking the individual their sex assigned at birth (male, female) and how they currently self-identify (man, woman, gender fluid/non-binary prefer to self-describe, prefer not to answer),[74] as gender identity may differ from biological sex. Overall, the incorporation of sex and gender considerations in research can help improve study rigour,[94] and international reporting guidelines[72] and sex and gender assessment tools[78,95] are available to help researchers effectively incorporate sex and gender considerations into research.

Importantly, sex and gender considerations are critical in the context of stroke recovery and rehabilitation and there is an urgent need to minimize the sex-and gender-related barriers faced by women with stroke. Given that exercise-based telerehabilitation has equivalent outcomes on ADL, upper- and lower-extremity function as in-person based services,[51] it may be used to address unmet rehabilitation needs, while also reducing barriers that women have reported relating to accessing stroke care.[90]

1.5 Gaps in the literature

Although the potential of telerehabilitation is encouraging, no studies to date have explicitly incorporated sex- and gender-based facilitators and barriers to participation to exercise-based telerehabilitation, and responses in functional and health-related quality of life outcomes. More specifically, previous syntheses of the literature[62,64,96] reporting on the facilitators and barriers to participation in telerehabilitation included only quantitative study designs. To thoroughly understand the facilitators and barriers to exercise-based telerehabilitation, it is integral to be inclusive of all types of methodologies including qualitative, quantitative, and mixed method studies.

Additionally, many themes arising in previous qualitative studies involved remotely monitored programs (i.e., asynchronous format of delivery) with limited emphasis on real-time therapist-instructed and guided programs for lower extremity recovery after stroke. Moreover, only one qualitative study[56] involving upper-extremity-focused telerehabilitation reported on experiences in individuals in the sub-acute stages of stroke. It is not known whether these themes translate to other formats of delivery and across transition points at earlier stages of stroke recovery.

Thus, there is a need to explore participants' experiences of synchronously-delivered lower-extremity focused exercise-based telerehabilitation and an opportunity to explore the viability of telerehabilitation within the first year of stroke where individuals are transitioning from the stroke rehabilitation to community reintegration phase of the continuum of recovery.[4] Lastly, to provide a foundation for the evaluation of sex- and gender-based differences in the effectiveness of exercise-based telerehabilitation, initial steps should be taken to explore how

personal characteristics are associated with participation behaviours and functional and health-related quality of life outcomes trajectories.

1.6 Overall Thesis Aim

The overall aim of this PhD thesis was to examine the intersection between sex- and gender-based considerations and exercise-based telerehabilitation among individuals with stroke through the exploration of facilitators and barriers to participation, and experiences and long-term responses to a synchronously-delivered telerehabilitation lower extremity-focused telerehabilitation program.

This thesis is comprised of three distinct, yet interrelated studies that address the overall aim. The studies included in this thesis are written in manuscript style (Chapters 2,3,4), and the titles and objectives of each study are provided below. Due to the nature of study methodologies used, hypothesis testing was not applicable in the three studies.

1.6.1 Study 1: Facilitators and Barriers to Participation in Exercise-Based Telerehabilitation in Individuals with Stroke: A Scoping Review of Quantitative and Qualitative Studies

In Chapter 2, I conducted a scoping review of quantitative and qualitative studies to identify and describe the facilitators and barriers to participation in exercise-based telerehabilitation programs among men and women with stroke. My secondary objective was to explore whether gender-related facilitators or barriers exist to participation in telerehabilitation.

1.6.2 Study 2: Exploring the experiences of an exercise-based telerehabilitation program among Canadian community-dwelling adults with stroke

In Chapter 3, I conducted a qualitative study using a thematic analysis approach to develop a deeper understanding of the complex interactions of experiences in relation to telerehabilitation post-stroke.

1.6.3 Study 3: Sex-and gender-based characteristics influence responses to a 4-week exercise-based stroke telerehabilitation program: A multiple case study

In Chapter 4, I conducted case studies that aimed to describe and explore potential sex-and gender-based characteristics that may be potentially associated with the clinical responses of six participants to a 4-week telerehabilitation program for lower extremity recovery after stroke. My secondary objective was to explore adherence, adverse events, and program satisfaction.

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CHAPTER 2: Facilitators and Barriers to Participation in Exercise-Based Telerehabilitation in Individuals with Stroke: A Scoping Review of Quantitative and Qualitative Studies

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2.1 Abstract

Background: Barriers including travel time and costs exist to participation in stroke rehabilitation programs, particularly for women. Telerehabilitation may minimize some of the reported barriers to stroke rehabilitation. This scoping review aimed to identify and describe the facilitators and barriers to participation in exercise-based telerehabilitation after stroke. Our secondary aim was to explore whether gender-related facilitators or barriers exist to participation.

Methods: Six electronic databases were searched for studies exploring facilitators and barriers to participation in exercise-based telerehabilitation in community-dwelling adults with stroke. A list of key constructs were developed and provided a definition, and each construct were mapped onto one or more domains of the Theoretical Domains Framework (TDF).

Results: Thirty-eight studies were identified (n=882 participants). Ease of use (TDF domain: "skills"), comfort with technology ("knowledge" and "skills"), self-perceived improvements in physical function ("reinforcement"), enjoyment ("emotion" and "reinforcement"), accessibility, acceptable audio and video features, convenience/flexibility of the training schedule and variety of games ("environmental"), therapist communication skills ("environmental & "social influences"), positive feedback/encouragement from family and friends ("social influences") and the self-perceived usefulness of telerehabilitation ("intentions" and "reinforcement") were the most commonly reported facilitators. Barriers included challenges with internet speed and connectivity and adjusting and/or wearing the device(s) ("environmental"). Both men and women reported facilitators related to skills and knowledge to participate in telerehabilitation.

Discussion: We found that many facilitators and few barriers exist to participation in exercise-based telerehabilitation interventions for individuals with stroke, whereby the environmental context and resources domain of the TDF was represented by the most constructs.

2.2 Introduction

Stroke rehabilitation is a recommended part of best practices in care.[1] Stroke rehabilitation programs aim to remediate physical and psychosocial impairments of stroke and promote successful community reintegration.[2] Social support from peers, friends and family, and feedback and validation from therapists are facilitators to participation in stroke rehabilitation,[3] but barriers include lack of personalization and shorter lengths of therapy,[3] and lack of time, costs and transportation requirements.[4] Notably, women living in rural areas face barriers to participation in stroke rehabilitation,[5] and often possess a belief that stroke is a not a major health concern.[6]

Telerehabilitation, which involves the delivery of rehabilitation services remotely via information and communication technologies,[7] may address several barriers associated with rehabilitation and in doing so enhance access and options for stroke rehabilitation.[8] Telerehabilitation has been used to deliver an array of interventions related to functional, motor, cognitive recovery and stroke risk factor self-management programs.[9] Systematic reviews of randomized controlled trials (RCTs) have started to examine effects of exercise-based telerehabilitation on outcomes of physical functioning including activities of daily living, balance, satisfaction with care, upper limb function, quality of life and depression, whereby findings indicated that it may be as effective as in-person rehabilitation.[10,11] Although these findings are encouraging, a systematic review of RCTs (n=11 studies) encompassing a variety of intervention focuses (e.g., counselling support, cognitive and psychosocial behavioral) alluded to technological-related challenges such as high equipment costs and internet connectivity concerns as barriers to participation.[8] Given the heterogeneity of interventions included the previous review, there is a need to specifically focus on synthesizing the facilitators and barriers with

engaging in exercise-based telerehabilitation programs among individuals with stroke to understand how participation in stroke rehabilitation services can be optimized, and in turn promote community reintegration. Moreover, given how different barriers to participation in stroke rehabilitation programs exist between men and women,[6,12] it is important to discern whether gender-related factors ease or impede participation in virtual rehabilitation settings.

The primary aim of this scoping review was to identify and describe the facilitators and barriers to participation in exercise-based telerehabilitation programs among individuals with stroke. Our secondary aim was to explore whether gender-related facilitators or barriers exist to participation in telerehabilitation.

2.3 Methods

The protocol for our scoping review was registered on Open Science Framework (osf.io/f4wga). Scoping reviews provide for a rigorous means of synthesizing the extent of knowledge in an emerging field,[13,14] and thus is deemed appropriate to explore the facilitators and barriers to participation in a continually evolving platform for delivering stroke rehabilitation. This scoping review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Review (See Appendix 2.1 for checklist), and the 5-stage methodological framework developed by Arksey & O'Malley (identifying the research question, searching for relevant studies, selecting studies, charting the data, collating, summarizing, and reporting the results).[13,14]

Eligibility Criteria

Population: Community-dwelling adults (≥18 years of age) post-stroke. No restrictions placed on time since stroke, number of strokes recorded or type of stroke, but the participants

could not be living in long-term care settings. Studies combining other neurological conditions were not included, unless authors provided stroke-specific data.

Types of Sources: Any quantitative or qualitative study design (e.g., mixed methods, non- and randomized controlled trials, single group experimental, qualitative studies) were eligible for inclusion. Studies that aimed to systematically summarize and/or analyze the state of the literature (e.g., scoping reviews, systematic reviews with meta-analyses, etc.), conference posters or abstracts, editorials and thesis documents were excluded. We also excluded grey literature including commentaries and government documents due to the substantial heterogeneity that would be introduced to the analysis process, as well as challenges with critically appraising the material.[15]

Concept: Reported any form of facilitators or barriers through semi-structured interviews, satisfaction surveys, participant experience questionnaires, etc. Randomized controlled trials or feasibility studies with no *a priori* outcomes related to facilitators or barriers to participation in a telerehabilitation intervention (i.e., clearly articulated in the research question and/or objective or in any sections of the abstract). Qualitative studies that sought the perspective of a caregiver, therapist or service provider were excluded.

Context: Involved the delivery of an exercise-based telerehabilitation program/ intervention focused on improving physical function (at least one FITT parameter and rehabilitation focus defined). Telerehabilitation could be delivered synchronously by connecting the patient and therapist in real time via any device, asynchronously monitored and adapted offline by a therapist, or a combination of both.[9] Protocols with initial in-home setups of technology by study staff or in-person assessments (e.g., administration of questionnaires) were acceptable. Interventions that involved in-person components such as structured home visits

and/or clinic-based conventional/usual care as part of the protocol for all participants, or hybrid community-based programs (i.e., some participants and/or therapists remote and some on site), app-based interventions that did not involve any patient monitoring from a healthcare professional, telehealth consultation interventions (e.g., patient consultation with neurologist), and interventions that did not include an exercise component (e.g., lifestyle coaching, education, stroke risk factor self-management only, speech language pathology interventions) were excluded. Home-based programs without any form of monitoring or therapist-initiated check-ins were excluded.

Language: Primary research studies published in the English language only.

Guiding Theoretical Framework

The Theoretical Domains Framework (TDF)[16,17] is commonly used to identify facilitators and barriers influencing health-related behaviours. We defined barriers as factors that obstructed, hindered or impeded the ability to participate in the telerehabilitation program, and facilitators were any factors that enabled or eased individuals' abilities to participate.[18] The facilitators and barriers identified were mapped onto one or more of the 14 domains of the TDF. Each of the 14 domains of the TDF represents determinants of adherence to a behaviour.[16,17] This approach using theory-driven analyses can ultimately be used to provide basis for further intervention refinement and development of telerehabilitation interventions.

We also sought to explore whether the identified facilitators and barriers encompassed any gender-related factors. Gender refers to the social, environmental, cultural, and behavioural factors and choices that impact a person, and is comprised of 4 different constructs (gender roles, identity, relations, and institutionalized gender).[19] Gender-related considerations that could inform researchers and clinicians of key behavioural factors that may facilitate or impede the

implementation of exercise-based telerehabilitation programs in practice and research were reported.

Information Sources

A systematic search of the literature was conducted using 6 electronic databases (MEDLINE, EMBASE, Web of Science, CINAHL, PsycINFO, and AMED Allied and Complementary Medicine) from inception to February 22, 2023, and updated on May 16, 2024. The search strategy was developed in consultation with an institutional librarian from McMaster University and included key search terms related to "telerehabilitation", "facilitators", "barriers" and "stroke". A sample of our search strategy from MEDLINE can be found in Appendix 2.2. We also searched the reference lists of the studies included in our review and other relevant reviews. Records identified from the search were de-duplicated and uploaded to Covidence (Veritas Health Innovation Ltd, Melbourne, Victoria, Australia), an online data management software.

Identification of Studies

Independent pairs of reviewers screened titles and abstracts for eligibility (EW & KM, KSN, SP, EH, or HF). To ensure consistency and thorough understanding of the eligibility criteria, the independent pairs piloted 100 records, whereby the primary author (EW) screened all records and the second reviewers screened 20 records each. After the piloting stage, reviewers discussed and compared results and resolved any discrepancies. Once titles and abstracts screening were complete and conflicts resolved, pairs of independent reviewers (EW & KM, KSN, SP, EH, or HF) completed full-text screening. Twenty-five full-texts articles were piloted and assessed for eligibility (5 articles per second reviewer). Reasons for exclusion of sources at the full-text stage were recorded and reported. At both the title and abstract and full-text stages,

discrepancies between reviewers were discussed and resolved with an independent author with expertise in the area of research and not involved with the review process (AT).

Data Extraction

Independent pairs of reviewers extracted (EW & KM, KSN, SP, EH, or HF) data from eligible studies using an online data extraction sheet on Covidence developed by the primary author, piloted by all authors, and refined if needed. For all studies, specific details about the lead author, year of study, country, type of telerehabilitation (i.e. synchronous, asynchronous or combination), focus of telerehabilitation program (e.g., lower extremity verses upper extremity exercises), study sample size, and participant characteristics (e.g., age, sex, gender- and stroke-related characteristics) were extracted. With regards to concept data, EW & KM, KSN, or SP extracted qualitative data that included the research question, type of qualitative methodological approach and analysis, the identified themes and/or participant feedback from open-ended questions within the study, and any other key findings that informed our analyses (e.g., illustrative quotes).[20,21] For quantitative research studies, EW & SP, EH, or HF extracted relevant data on study outcomes, which included the research question and satisfaction or feasibility survey responses. Due to pragmatic reasons, we did not extract or analyze outcomes that were related to changes in pre-post self-reported or performance-based assessments.

Data reporting and analysis

Data were analyzed both quantitatively and qualitatively.[22] The qualitative summary table included all studies that incorporated qualitative methodology (e.g., semi-structured interviews, focus groups or open-ended questions conducted in case reports, case series and mixed methods studies). The type of qualitative method, data collection and analysis methods and context of the telerehabilitation interventions were reported.

The qualitative analyses involved two independent pairs of authors (EW & KM or KSN). Using Microsoft Excel, the independent pairs of reviewers developed a list of key themes (i.e., constructs) based on original findings of each study. Next, the primary author organized the potential constructs into one draft document. Each construct was provided a definition that was guided by previous literature. The analysis was conducted iteratively, where existing constructs were re-defined or new constructs were added based on emerging findings throughout the process. The document was refined by the authors until arriving at a key set of general constructs that sufficiently explained all inferred facilitators and barriers to participation in telerehabilitation.[20] The authors were informed to acknowledge their positionalities (i.e., research background, experiences, etc.) throughout the analysis process. Senior authors (BMS, DB, JCM, AT) with expertise in telerehabilitation interventions and behaviour change theories were consulted to review the final constructs. The reviewers re-evaluated their analyses if deemed necessary by the senior authors. Finally, the identified facilitators and barriers were then presented under the appropriate construct.

The final stages of the qualitative analysis involved mapping the identified analytical constructs onto one or more of the 14 domains of the TDF based on established definitions of the domains.[16,17,23] The primary author developed a table of operationalized definitions for each domain, guided by established definitions by Atkins[16] & Cane[17] and reflective of the research question of interest (See Appendix 2.3). Each of the reviewers (EW & KM, or KSN) conducted their own mapping, then subsequently met to discuss similarities and differences until arriving at a final decision of the appropriate classification onto one or more domains of the TDF. The number of constructs represented by a TDF domain were presented as frequencies and

percentages and narrative summaries of the facilitators or barriers were provided for each construct.

The included quantitative studies either administered satisfaction surveys or the System Usability Scale ([SUS]; aims to assess the practicality of technological device/platform),[24] of which included specific questions/items that were assessed through Likert Scales. For each study, items within the questionnaire items for telerehabilitation participation were categorized as facilitators if mean or median responses indicated positive experiences (“agree” to “strongly agree”), or barriers if mean or median responses ranged from "strongly disagree" to "somewhat disagree" for positive experiences or "agree" to "strongly agree" for negative experiences. Mean or median scores reflecting neutral/mixed values were qualitatively described in the results section and were not included in the count of facilitators and barriers. An example of a scoring table used is provided in Appendix 2.4. In circumstances where the satisfaction data was presented in a manner that would not be suitable to analyze (i.e., presented as total percentage of satisfaction from the SUS questionnaire), we contacted the corresponding authors to access raw mean or median scores of the different satisfaction constructs. An Excel spreadsheet facilitated the analytic process where similar items/questions (e.g. Did the therapist respond to your questions?; Did the therapist address your concerns?) were classified into a single construct (role of the therapist) and subsequently mapped to a TDF domain (environmental context & resources) by two independent reviewers (EW & SP, EH, or HF). Each set of independent reviewers confirmed that the identified constructs adequately represented the items/questions within and between questionnaires/surveys. New constructs were iteratively added, if needed. Relevant quantitative data within case report and series, and mixed method studies were included in our analyses.

The independent mapping process followed the same steps as the qualitative analysis. Identified TDF domains were narratively summarized and the number of specific facilitators or barriers within each construct were also reported. For RCTs, outcome data was only mapped onto the TDF for the telerehabilitation intervention group, as we were not interested in the facilitators and barriers of the individuals participating in the control groups (unless they also involved exercise-based telerehabilitation interventions). We still, however, presented control group data in our summary of findings table (Table 2.1).

Finally, for qualitative data, any inferred gender-related facilitators or barriers were extracted (e.g., hesitancy to seek support/ lack of support), while disaggregated data for men and women were analyzed for quantitative analyses. The primary author narratively summarized the gender-related considerations.

Quality Appraisal

The included studies encompassed multiple study designs. The Cochrane Collaboration Risk revised risk of bias assessment (RoB 2) tool was used for RCTs.[25] The RoB 2 tool provides an indication of bias in 6 domains including: the randomization process, deviations from the indented protocol, missing outcome data, measurement of the outcome, selection of the reporting results and overall risk of bias.[25] Low, some concern, and high risk of bias were determined for each study.[25]

To assess to quality of included qualitative, case report, and case series studies, the JBI Critical Appraisal Checklist for Qualitative Research, Case Report and Case Series were used, respectively.[26] Each included a 10-item checklist that appraises trustworthiness and relevance of study findings.[26] ("Yes", "No", "Unclear", "Not applicable") and each study is provided an overall quality appraisal classification ("Include", "Exclude", "Seek further information").

The quality of non-randomized experimental (e.g., single group pre-post feasibility/pilot studies) quantitative studies were assessed using the National Institutes of Health Quality Assessment Tool for Before-After Studies with no Control Group.[27] The questions are designed to assess for internal validity and consider the risk for selection bias, measurement bias, or confounding factor, study power and the strength of causality between interventions and outcomes.[27] Based on responses to the questions ("Yes", "No", or "Other" selected as responses), overall quality ratings of "Good", "Fair" or "Poor" (if poor, elaborate and state why) were determined for each study.[27]

For studies combining both quantitative and qualitative methodologies, the Mixed Methods Appraisal Tool (MMAT) was used to assess the quality of mixed methods studies.[28] This tool inquires about rationale for using a mixed method design, integration and interpretation of qualitative and quantitative components, inconsistencies with qualitative and quantitative reporting, and adhering to quality criteria for of the traditional methods.[28] Individual responses to each criterion ("Yes", "No", "Can't tell") are considered in the interpretation of included studies.[28]

Finally, the Risk of Bias in Non-randomised studies – of Interventions (ROBINS-I) was used to assess the quality of non-randomised interventional studies. The ROBINS-I tool provides an indication of bias in 8 domains: bias due to confounding, selection of participants, classification of interventions, deviations from intended interventions, missing outcomes, measurement of outcomes, selection of the reported results, and overall bias. Low, moderate, serious, or critical risk of overall risk of bias was determined, based on responses to each item.[29] Quality appraisal was conducted by two independent pairs of authors for both quantitative (EW & SP, EH, or HF) and qualitative studies (EW & KM, or KSN).

2.4 Results

The search yielded a total of 9570 records. Upon removal of duplicates, 6337 titles and abstracts were screened for eligibility. Thirty-eight studies were included, of which 36 were included in the analysis portion of our study (two corresponding authors did not reply to our request for relevant data). Figure 2.1 presents the PRIMSA flow diagram. Given the breadth of research methodologies employed, the quality appraisals are presented in Appendix 2.5.

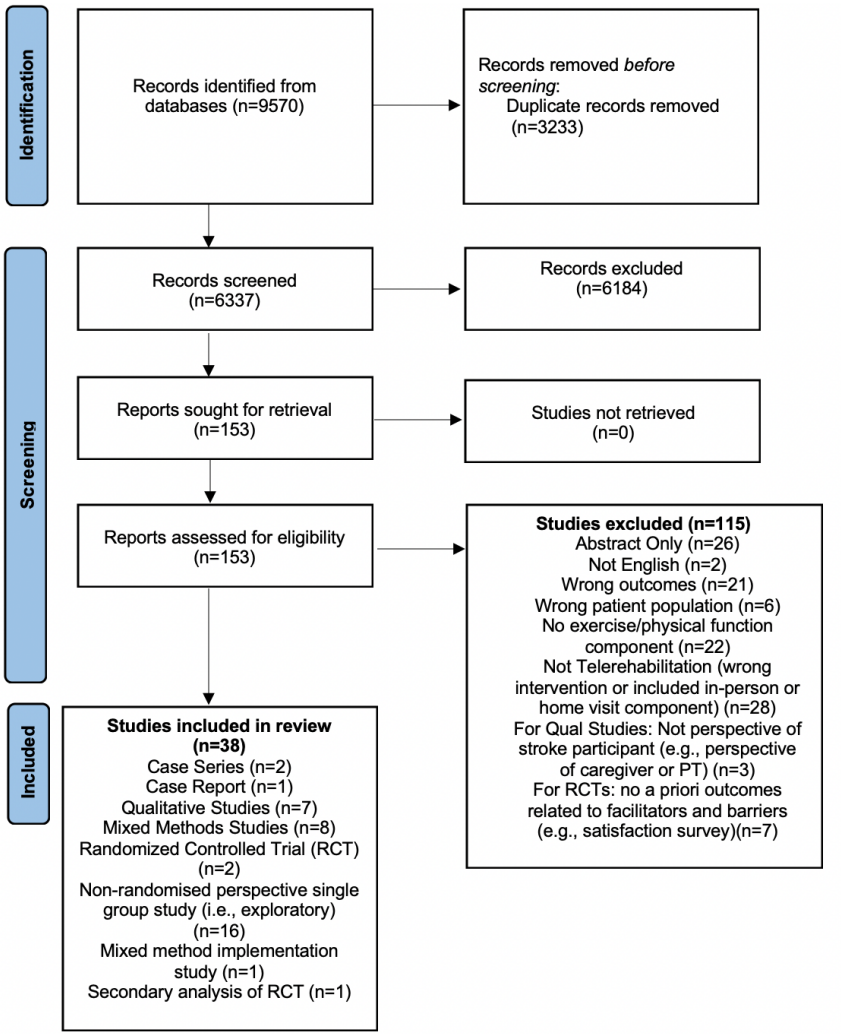

Figure 2.1. PRISMA flow diagram.

Study designs

Study designs included in this review included: multiple case series (n=2),[31,53] case report (n=1),[30] qualitative studies (n=7),[38,39,45,49,61,65,66] mixed methods (n=8),[41,46,48,51,57,62–64] randomized controlled trials (n=2),[32,56] single group non-randomized experimental (n=16),[33–37,42–44,47,50,52,54,55,58–60] secondary analysis of a randomized controlled trial, (n=1)[40] and mixed method implementation study design (n=1).[67]

For studies included in the qualitative analysis, semi-structured interviews were the most common form of data collection (n=15),[30,31,38,39,41,45,46,48,49,57,61–63,65,66] followed by open-ended questions on a feedback form or satisfaction survey (n=4).[51,53,64,67] One study did not report whether open-ended questions were included in their study-specific questionnaire,[50] while three additional surveys with open-ended questions[43,44,55] did not specify an approach to analyzing and reporting qualitative comments and thus only their quantitative data were included in our study.

Participants and Study Characteristics

Detailed study characteristics are provided in Table 2.1. The 38 included studies encompassed a combined sample of 882 participants, with quantitative study samples ranging from 6[43] to 188[34] participants and qualitative and mixed method studies ranging from 5[49] to 40.[64] Proportion of females ranged from 0%[39,45,46] to 67%[31,50] of study samples. Age (mean ± SD) of participants included in studies ranged from 54.0 ± 17.0[44] to 73.6 ± 9.9 years old,[60] and time since stroke onset ranged from 7.4 ± 0.9 days[49] to 13.8 ± 6.0 years.[52]

The multiple case series[31,53] each included 3 participants. Studies were conducted in Canada (n=10),[30–32,43,49,50,55,62,66,67] United States of America (n=12),[37–41,44–48,53,57] Italy (n=5),[33–35,42,56] Australia (n=2),[51,60] China (n=1),[63] Netherlands (n=2),[58,61] Germany (n=1),[36] United Kingdom (n=1),[54] Philippines (n=1),[52] Ghana (n=1),[59] Brazil (n=1),[64] and Singapore (n=1).[65]

Gender-based Considerations

Eleven[31,32,39,41,50,51,55,58,59,61,66] studies (29.0%) alluded to gender-based considerations in their participant demographic tables. Marital status and living arrangement were most commonly reported, with the majority of participants being married and living with their spouse or other family members.[31,32,39,41,51,55,58,61,66] Other gender-based variables included income[59] and employment status (most participants were not currently employed).[39,41,50,55,58,66] These data were not disaggregated by men and women, and as such we were not able to explore whether there were gender-based differences.

Intervention Characteristics

For ease of reporting, intervention characteristics for studies incorporating a qualitative component (mixed method, open-ended feedback forms, case series and case report studies) are provided in Table 2.2 (denoted as "qualitative" in following overview of intervention characteristics), and for purely quantitative studies in Table 2.3 (denoted as "quantitative" in overview of intervention characteristics). Eleven interventions (n=7 qualitative;[39,41,48,57,61,63,64] n=4 quantitative[37,52,58,60]) were delivered asynchronously, 19 were a combination of a synchronous and asynchronous intervention (n=8 qualitative;[30,31,38,45,46,53,62,65] n=11 quantitative[32–34,36,40,42,44,47,54,56,59]), and 8 (n=4 qualitative;[49,51,66,67] n=4 quantitative[35,43,50,55]) were delivered synchronously via videoconferencing. The most common rehabilitation focus was upper extremity function (n=10 qualitative;[30,31,38,45,46,48,61–63,67] n=8 quantitative[32,34,40,44,47,54,56,58]). Twelve studies (n=5 qualitative;[39,51,57,64,65] n=7 quantitative[33,35,36,42,50,52,59]) delivered a combination of upper and lower extremity rehabilitation, 5 were focused on lower extremity rehabilitation (n=2 qualitative;[53,66] n=3 quantitative[43,55,60]), one quantitative study delivered a combination of upper extremity and cognitive training,[37] one qualitative study delivered a multi-disciplinary intervention of exercise, cognitive, diet and speech training,[49] and one study[41] did

not report the rehabilitation focus. Two qualitative[38,66] and 5 quantitative studies[36,40,44,47,55] incorporated educational and/or self-management components. For studies with a qualitative component, interventions ranged from ~2[63] to 22 weeks[64] (mode: 8 weeks) in duration, while those for quantitative studies ranged from 2[52] to 12 weeks[33–36,42,50,59] (mode: 12 weeks).

Facilitators and Barriers to Participation in Telerehabilitation among Individuals with Stroke

Table 2.4 summarizes the facilitators and barriers influencing participation in telerehabilitation interventions for individuals with stroke, with defined constructs and corresponding TDF domains. Facilitators and barriers reported by ≥7 studies (i.e. ~20% of studies of which adequately reflects consensus among studies, based on the broad range of study-specific facilitators and barriers reported) in any given construct are presented in the following section.

Knowledge and Skills

The "skills" domain of the TDF was represented by 2 different overarching constructs: ease of use of the telerehabilitation system/platform and abilities/capacity to participate in telerehabilitation (also mapped onto "knowledge" domain). The ease of use of telerehabilitation was noted as a facilitator in 19 studies (n=8 qualitative;[30,38,39,41,45,49,61,63] n=11 quantitative data[32,33,42,46,47,50–53,56,60]); only two studies lacked a clear consensus regarding ease of use,[31,37] which included qualitative reports of a lack of intuitiveness and user-friendliness of the technology.[31] Within the abilities/capacity construct, eight studies reported that participants were comfortable with using the technology.[30,46,52,55,58,59,60,67] One study reported mixed perceptions regarding computer literacy skills, including ability to troubleshoot or execute simple consumer-level computer skills such as emailing.[48]

Reinforcement

The "reinforcement" domain of the TDF was represented in 6 constructs (includes constructs combined with "environmental context and resources" [n=2], "emotion" [n=3] "intention" [n=1] domains) (See Table 2.4). The most commonly reported construct was perceptions of changes in physical outcomes from participating in a telerehabilitation program and involved facilitators related to improvements in upper- (n=7 qualitative;[30,38,45,46,61,63,67] n=2 quantitative data[44,50]) and lower extremity function (e.g., mobility, strength, balance) (n=3 qualitative;[39,63,66] n=4 quantitative data[50,52,53,64]); no reductions in function were reported.

Positively, there were no salient barriers reported in terms of affective (emotional) factors influencing participation in telerehabilitation. Eight studies (n=5 qualitative;[38,45,51,53,61] n=3 quantitative data[40,46,60]) reported enjoyment with the telerehabilitation program as a facilitator. Two studies (1 qualitative;[48] 1 quantitative[53] data) reported mixed findings related to having fun[48] and being bored[53] with the games in the telerehabilitation program.

Environmental Context and Resources

The "environmental context and resources" domain of the TDF was represented across 10 constructs (includes constructs combined with "social influences" [n=1], "reinforcement" [n=2] and "emotion" [n=1] domains) (See Table 4). Technological considerations most commonly encompassed barriers, where participation was impeded by challenges reported with internet speed and connectivity (n=5 qualitative;[30,31,51,64,65] n=2 quantitative data[42,52]) and with adjusting and/or wearing the device(s) (n=7 qualitative study data[39,45,51,53,61,62,63]). One study[44] reported neutral scores pertaining to experiences with the hand-held devices (e.g., accelerometer & wrist split) used during the intervention. Conversely, technological platforms with acceptable audio and sound features facilitated participation (n= 1 qualitative;[66] n=6 quantitative data[50,51,52,55,59,67]).

Telerehabilitation intervention characteristics that most commonly facilitated participation included the variety of games or exercises (n=5 qualitative[38,45,57,61,62]; n=2 quantitative data[50,51]) and the convenience/flexibility of the training schedule (n=7 qualitative;[38,39,41,45,61,63,65] n=1 quantitative data[50]) (e.g., ability to exercise on own time, control over training through being able to divide sessions into multiple shorter bouts, training schedule helped establish a routine). There were no intervention characteristics reported that impeded participation in ≥7 studies, however two studies reported mixed perceptions related to the challenge level (i.e., appropriate level of difficulty).[48,53]

Accessibility offered by telerehabilitation was reported as a facilitator, namely through limited reliance on transportation (n=6 qualitative;[31,49,51,61,65,66] n=2 quantitative data[50,52]). Fourteen studies with quantitative data[35,37,41,43,44,46,47,50,51,55,56,58,59,64] reported overall satisfaction with telerehabilitation. Findings from one quantitative study[51] were neutral, with half of participants preferring to attend a central venue such as a community centre or physiotherapy clinic if transportation were available, rather than home-based exercise. One qualitative study also reported neutral findings on preferences of service delivery format, noting that those preferring in-person rehabilitation were generally older with severe disability,[65] while neutral findings of one quantitative study reported the telerehabilitation experience being just as good as in-person rehabilitation.[55] Finally, participants in one study strongly disagreed that virtual rehabilitation could replace an in-person program that had been previously delivered prior to the onset of the COVID-19 pandemic.[64]

With regards to the role of therapist and/or staff, strong communication skills was the most common facilitating factor (n=7 qualitative;[30,31,38,51,53,66,67] n=9 quantitative[36,41,42,47,50,55,56,59,64] data), including clear instructions and/or explanations,[42,47,55,56]

active listening,[47,50,55,56,64] friendliness[36,59] and respect,[47,55,56,59] correcting and sharing feedback on exercises,[30,31,38,50,64,66] encouragement,[30,31,38,51,53,66,67] and answering questions[47,56,59] in a timely manner.[41] One quantitative study reported neutral scores with respect to therapists providing advice on how to avoid future problems.[56] One qualitative study reported that participants initially expressed worry about therapist support in a virtual environment that was alleviated with all participants feeling psychologically and physically supported during the intervention.[49]

Social Influences

The "social influences" domain of the TDF was primarily represented by the construct of social support from friends and/or family, where receiving support with technology, positive feedback and/or encouragement was the most commonly reported facilitator (n=7 qualitative data[30,31,38,41,61,65,66]). Two studies reported mixed findings with participants' perceiving the need for family support to use the technology.[51,63] Strong communications skills of the therapist outlined above were also mapped onto the "social influences" domain.

Intentions

The "intentions" domain of the TDF was represented by the two constructs: psychological factors (also mapped onto "reinforcement") and sustained use of telerehabilitation (also mapped onto "behavioural regulation"). Self-perceived usefulness of technology-based interventions for rehabilitation was a facilitator (n=1 qualitative;[63] n=6 quantitative data[32,33,42,46,58,60]). Moreover, 10 studies (n=4 qualitative;[38,46,61,63] n=6 quantitative data[44,50,51,53,55,59]) reported positive behavioural intention regarding the continued use of telerehabilitation in the future, if offered.

Optimism

"Optimism" was represented by recommended use of telerehabilitation for others, with 9 quantitative studies[37,40,44,47,50–52,55,56] reporting positive perceptions.

Other TDF Domains

"Beliefs about capabilities", "memory, attention and decision processes", "goals" and "social identity and roles" domains were represented by few constructs (see Table 2.4), and none under "beliefs about consequences".

Gender-based considerations

Only one quantitative study[40] reported disaggregated data for men and women, although no differences were found in facilitative constructs related to skills and knowledge (e.g., lack of challenge and confusion), aspects of telerehabilitation intervention influencing physical health (e.g., limited fatigue caused by intervention), and telerehabilitation intervention characteristics (e.g., satisfaction with devices and intervention components and appropriate length of sessions). One qualitative study[57] reported that one woman with severe cognitive impairment experienced difficulties playing the games involved with the telerehabilitation program, and did not seek support from a caregiver. Two studies (case series[31] and pilot RCT[32]) each reported that a woman experienced technological challenges, necessitating family support with setting up and using the technology, whereas a qualitative study[66] reported that a woman hesitated to seek technological support from her daughter, out of fear of distracting her from her new job. Related to the "intentions" and "behavioural regulation" domains of the TDF, two women reported a new intention to use their affected arms to perform ADLs, however the man did not corroborate this.[31]

2.5 Discussion

Using the TDF as a framework, we found that many facilitators and few barriers exist to participation in exercise-based telerehabilitation interventions among individuals with stroke. The "environmental context and resources" domain was represented by the most constructs, while the least commonly reported domains were "beliefs about consequences", "memory, attention and decision processes", "social identity and roles", and "goals" related to participation in telerehabilitation. In one study, both men and women reported facilitators related to the intervention characteristics (e.g., satisfaction with program material) and skills and knowledge to participate in telerehabilitation.[40] There were however some differences between genders in perceived intentions to use the affected limb in ADLs,[31] social support[31,32,66] and level of cognitive impairment.[57]

Barriers related to the "environmental context and resources" domain included challenges with internet speed and connectivity,[30,31,42,51,52,65] and wearing and/or adjusting the technological device(s) used in the telerehabilitation program.[39,45,51,53,61,62,63] These barriers have been corroborated in previous research. A RCT (n=52 participants) examining the effectiveness of a lower extremity telerehabilitation intervention post-stroke found that internet-related challenges influenced the implementation of the program, despite structured home visits from the research team.[68] The implementation of thorough troubleshooting protocols, engaging a family member and/or having access to the therapist and/or staff member to troubleshoot could minimize the time spent on resolving the technical challenge.[49,62,66] Challenges with adjusting and/or wearing the device(s) (e.g., foot piece,[53] sensor,[45] robotic,[39,61] inertial mouse attached to exercise object,[62] or wristwatch[63] devices) reinforce the importance of incorporating user experience feedback to ensure device-related concerns are addressed prior to use in research and clinical settings.[69]

Positively however, despite some technological barriers, both men and women with stroke possess skills and knowledge required to facilitate participation in telerehabilitation, as evidenced by a high ease of use with technology.[30,32,33,38,39,41,42,45–47,49–53,56,60,61,63] According to the Technology Acceptance Model (TAM), perceived ease of use is a critical determinant of adoption of technology as it promotes confidence and competency.[70]

The important roles of the therapist/staff included strong communication,[30,31,36,38,41,42,47,50,51,53,55,56,59,64,66,67] encompassing many different skills such as clear instructions and explanations,[42,47,55,56] active listening,[47,50,55,56,64] friendliness[36,59] and respect,[47,55,56,59] offering safety tips and corrections/feedback on exercises,[30,31,38,50,64,66] encouragement,[30,31,38,51,53,66,67] and answering questions[47,56,59] in a timely manner.[41] Successful communication is pivotal for effective stroke rehabilitation,[71] and especially critical when physical touch is not possible in virtual settings.[72] In fact, that effective communication is vital in virtual rehabilitation settings may explain why technological platforms with acceptable audio and video features was highly cited as a facilitating factor in our review.[50,51,52,55,59,66,67] Taken together, communication integrating visual and audio elements may be a fundamental ingredient for fostering a strong therapeutic alliance between the therapist and participant in virtual rehabilitation settings.[73,74]

The convenience/flexibility of the training schedule,[38,39,41,45,50,61,63,65] and the variety of the games or exercises[38,45,50,51,57,61,62] were the most commonly reported facilitating characteristics of the telerehabilitation interventions. Individuals with stroke may benefit from home-based exercise training programs in a familiar environment and accommodates daily activities and routines.[75,76] These findings suggest advantages of telerehabilitation include the ability to provide a variety of the games to support individualized therapeutic exercise plans, as

well as technological advances that afford therapists the ability to monitor progression and needs.[77] Our finding related to the accessibility of telerehabilitation[31,49–52,65,66] is a well-documented facilitator in the literature.[8] Transportation costs (e.g., public or private services, fuel, parking, etc.) can present as an economical barrier to in-person rehabilitation services,[78] especially for individuals living in rural areas[79] and resource-constrained settings.[80] Limiting travel requirements through telerehabilitation is also a time-efficient alternative to in-person rehabilitation for individuals in both urban[81] and rural[82] settings, and minimizes caregiver strain for individuals with stroke requiring support.[83]

There were many facilitators and few barriers identified under the domain of "reinforcement". Self-reported improvements in upper[30,38,44–46,50,61,63,67] and lower extremity function[39,50,53,63,66] are in line with previous systematic review evidence reporting equivalent effects between telerehabilitation and in-person rehabilitation on performance-based balance (n=3 studies;106 participants) and upper limb function (n=3 studies; 170 participants).[11] Further, we reported that participants identifying as women planned to use their affected arms to perform ADLs,[31] and that telerehabilitation was deemed as viable for addressing unmet lower extremity-related rehabilitation needs in both men and women.[66] While these were two small-scaled qualitative reports, given that women with stroke experience poorer physical and psychological outcomes and disability after stroke,[84] these findings may provoke further evaluation into using telerehabilitation as a rehabilitation tool for women with stroke.

Social support (e.g., support with technology, positive feedback and/or encouragement) from friends and family[30,31,38,41,61 ,65,66] was the most commonly reported facilitating factor mapped onto the "social influences" domain of the TDF. A previous systematic review (n=6 studies; 644 participants with stroke) similarly described that high levels of social support was

positively associated with physical activity engagement,[85] and a proof-of-concept study (n=63) reported clinically meaningful improvements in ADLs and memory function following a caregiver mediated exercise-based telerehabilitation intervention.[86] Although there were very few barriers related to the "social influences" domain, our gender-related findings suggest a potential need for social support among women with stroke, with two studies[57,66] reporting that women with stroke were hesitant to seek support from family, aligning with previous reports of wanting to avoid being a burden.[6] Future research is warranted to explore strategies to reduce gender-related barriers that women face to receiving social support in telerehabilitation programs.

The self-perceived benefit or usefulness of technology-based interventions for rehabilitation was related to positive "intentions" and "reinforcement" domains of the TDF.[32,33,42,46,58,60,63] The TAM suggests that in addition to ease of use, perceived usefulness is a key determinant of the uptake of technology, which is positively associated with intention to use technology (i.e., response efficacy).[70] Exercise-based telerehabilitation programs appear to satisfy the two primary determinants of the technology acceptance and adoption. Many of the included studies[38,44,46,50,51,53,55,59,61,63] reported positive behavioural intention regarding their intention to continue using telerehabilitation in the future, if offered. Moreover, participants expressed positive perceptions by recommending telerehabilitation to others,[37,40,44,47,50–52,55,56] of which aligned with the "optimism" domain of the TDF. Overall, we found that men and women with stroke reported enjoyment with virtual exercise programs[38,40,45,46,51,53,60,61] and overall satisfaction with the delivery of telerehabilitation.[35,37,41,43,44,46,47,50,51,55,56,58,59,64]

We identified few constructs under the TDF domains "memory, attention and processes",[57] "goals",[48] "social/professional roles and identities",[57,64] and "beliefs about

consequences." Future exercise-based telerehabilitation programs may incorporate aspects that tap into cognitive domains such as decision making and attention control, and that integrate goal setting initiatives which can produce positive physical activity behaviours.[87] Future studies may also explore negative outcomes or outcome expectations from not participating in exercise-based telerehabilitation. Finally, studies should further explore how work, social and/or professional identities and roles of stroke survivors facilitate or impede participation, as we have provided preliminary evidence that gender roles possessed by women with stroke may present different obstacles than men.[31,57]

Strengths and Limitations

This scoping review included both an array of quantitative and qualitative study designs, and thus providing a comprehensive analysis of the current literature of studies exploring facilitators and barriers to participation in telerehabilitation. Although this study possesses strengths, there are also limitations. Firstly, our search was limited to research articles published in English and may have led to the exclusion of relevant articles. Secondly, we did not include studies that incorporated the perspectives of therapists and caregivers, which may have provided additional important insight. Given the important roles of family members and therapists observed in our study, future research may consider the facilitators and barriers to exercise-based telerehabilitation from their perspectives. Thirdly, we excluded studies that included any in-person components such as home visits, or conventional care which may have limited our analyses, given that these structured visits could have influenced participants' perceptions of the program. Our study sought to isolate the facilitating and impeding factors to exercise-based telerehabilitation (i.e., delivered remotely), however acknowledge that these studies may have offered important information on the role of hybrid designs in stroke rehabilitation.[68,88–93]

Finally, we were not able to consider gender differences to the extent that we anticipated as few qualitative studies examined gender-based considerations and only one quantitative study disaggregated data by gender. It is critical that future research include sex- and gender-based considerations to provide insight into targeted rehabilitation approaches specific to the needs of men and women with stroke.

2.6 Conclusion

This scoping review identified the facilitators and barriers to participation in exercise-based telerehabilitation among individuals with stroke, using the TDF framework to conceptualize the findings. Findings from this research provide insight into the factors that clinicians should continue implementing into exercise-based telerehabilitation programs. We also highlighted impeding factors that could be adapted to ensure that individuals with stroke experience minimal challenges, which in turn can optimize the delivery of telerehabilitation programs and promote optimal community reintegration among men and women with stroke.

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Table 2.1. Participant Characteristics of Included Studies

Study	Country	Study Design	Total n (baseline), % female, n intervention group, n control group (if applicable), Mean Age in years ± Standard Deviation) Stroke Characteristics	Education and/or cognitive function	Gender-related characteristics
Allegue 2021[30]	Canada	Case report (Mixed methods)	Total n=1, 0 (0%) females, 63 ***Time post-stroke:*** 3 years ***CMSA Arm Score*** – Stage 6	NR	NR
Allegue 2022a[31]	Canada	Case series (Qualitative)	Total n=3, 2 (67.0%) females, 58.8 ± 19.4 ***Time post-stroke:*** P1: ~8 years, P2: ~8 years, P3: ~5 years ***CMSA arm:*** P1: Stage 3, P2: Stage 5, P3: Stage 4	NR	***Living Arrangement:*** P1: Living with Family, P2: Living with daughter, P3: Living with spouse
Allegue 2022b[32]	Canada	Pilot Randomized Controlled Trial	Total n= 9 (I: 4, C: 5) I: 2 (50%), C: 3 (60%) females I: 57.8 ± 21.8, C: 56.4 ± 17.3 ***Time post-stroke:*** I: 8 ± 2; C: 9.8 ± 3.0 years ***Type of Stroke:*** Ischemic – I: 2 (50%), C: 3 (60%) (data missing for one participant); Hemorrhagic – I: 1 (25%), C: 2 (40%) **CMSA-UE:** I: 3.8 ± 1.0; C: 4.8 ± 1.3	NR	***Living Arrangement:*** Living with family – I: 3 (75%), C: 2 (40%); Living Alone – I: 1 (25%); C: 3 (60%)
Bellomo 2020[33]	Italy	Non-randomized single group experimental	Total n=25 baseline, n=22 analyzed, 7 (32.0%) females*, 55.34 ± 8.64* ***Time post-stroke:*** 11.5 ± 2.4 months	***Education:*** 1 primary school; 14 secondary school; 7 university ***MMSE:*** 26 ± 1.8	NR
Benvenuti 2014[34]	Italy	Non-randomized controlled trial	Total n=188 (I: 143, C: 45) I: 65 (45.0%), C: 21 (46.7%) females I: 69.1 ± 1.0, C: 72.2 ± 1.4 years old ***Time post-stroke***: I: 2.7 ± 0.3 years; C: 4.0 ± 0.6 years	***MMSE:*** I: 25.6 ± 0.4; C: 26.2 ± 0.5	NR
Bernocchi 2016[35]	Italy	Non-randomized single group experimental	Total n= 26, 10 (38.0%) females, 70 ± 10 ***Time post-stroke:*** 265 ± 99 days ***Type of stroke:*** Ischemic - 23 (88.0%); Hemorrhagic – 3 (12.0%)	NR	NR

Bindschedler[36] 2024	Germany	Non-randomized single group experimental	Total n=96, 52 (54.2%) females, 54.8 ± 13.1 ***Time post-stroke:*** 6.1 ± 6.6 ***Type of Stroke:*** Ischemic – 42 (52.5%), Hemorrhagic – 17 (21.3%), unknown – 11 (13.8%), TIA – 3 (3.8%)	NR	NR
Burdea 2020[37]	USA	Non-randomized single group experimental	Total n=7, 3 (42.9%) females, 64.1 [48-79] ***Time post-stroke:*** 19 - 180 months	***Education:*** 17 ± 2.31 years (min-max 14-21) ***MoCA:*** 24.4 ± 3.87	NR
Chen 2020[38]	USA	Qualitative	Total n=13, 2 (15.4%), 70.5 ± 11.1 ***Time post-stroke:*** 4-36 weeks	NR	NR
Cherry 2017[39]	USA	Qualitative	Total n=10, 0 (0%) females, 62.2 ± 11.2 ***Time post-stroke:*** 3 months to ~4 years	***Education:*** 12.1 ± 1.85 (min-max: 9-16)	***Marital Status:*** Married: 6 (60.0%); Divorced: 1 (10.0%); Single: 3 (30.0%) ***Living Arrangement:*** Lives Alone: 1 (10.0%); Lives with spouse or family: 7 (70.0%); Lives with other adults: 2 (20.0%) ***Work Arrangement:*** On Disability: 6 (60.0%); Retired: 1 (10.0%); Retired and on Disability: 3 (30.0%)
Cho 2022[40]	USA	Secondary analysis of a randomized controlled trial (Cramer et al., 2019)	Total n=124 (I: 62, C: 62) I: 14 (22.6%), C: 20 (32.3%) females I: 62 ± 14, C: 60 ± 13 years old ***Time post-stroke:*** I: 132 ± 65, C: 129 ± 59 days ***Type of Stroke:*** Ischemic – I: 54 (87.1%), C: 52 (83.9%); Hemorrhagic – I: 8 (12.9%), C: 10 (16.1%) ***NIHSS:*** I: 3 (2-5); C: 3 (2-4) ***mRS:*** I: 2 (2-3); C: 2 (2-3)	**MoCA:** I: 24.9 ± 4.1; C: 24.4 ± 5.0	NR
Conroy 2022[41]	USA	Mixed methods pilot study within randomized controlled trial	Total n=29 (I: 15, C: 14) I: 7 (47.7%), C: 6 (43.0%) females I: 63.5 ± 8.2, C: 58.4 ± 10.6 years old ***Time post-stroke:*** I: 75.0 ± 68.4; C: 63.24 ± 37.3 months ***Type of Stroke:*** Ischemic - I: 12 (80.0%), C: 10 (71.0%); Hemorrhagic- I: 3 (20.0%), C: 4 (29.0%)	***MoCA:*** I: 25.5 ± 2.6; C: 22.3 22.3 ± 3.0	***Living Arrangement:*** Alone –I: 4 (27.0%), C: 4 (29.0%); Living with Spouse/Other – I: 11 (73.0%), C: 10 (71.0%) ***Employment Status:*** Not Employed- I: 14 (93.0%), C: 14 (100%); Employed – I: 1 (7.0%)

Contrada 2022[42]	Italy	Non-randomized single group experimental	Total n=19, 6 (31.6%) females, 61.1 ± 8.3 ***Time post-stroke:*** 595 ± 688.3 days ***Type of Stroke:*** Ischemic: 14 (73.6%); Hemorrhagic: 5 (26.4%)	***Education:*** 12.4 ± 4.3 ***MMSE:*** 25.9 ± 3.0	NR
Corriveau 2013[43]	Canada	Non-randomized single group experimental	Total n=6, 3 (50%) females, Range 67- 92 years old ***mRS***: 2 or 3	NR	NR
Dodakian 2017[44]	USA	Non-randomized single group experimental	Total n=12, 6 (50%) females, 54 ± 17.0 ***Time post-stroke***: 24 [21-36] weeks ***NIH-SS:*** 2 [2-5]	***MMSE:*** 27.5 [25-30]	NR
Donnelly 2023[45]	USA	Qualitative	Total n=4, 0 (0%) females, 63 ± 7.8 ***Time post-stroke***: 7.4 ± 6.2 years ***Type of Stroke:*** Ischemic – 2 (50%); Hemorrhagic – 2 (50%) **mRS:** 1.8 ± 0.5	***MoCA:*** 21.3 ± 0.9	NR
Donnelly 2024[46]	USA	Mixed Methods	Total n= 11, 0 (0%) females, 54 ± 9.5 ***Time post-stroke:*** 75.9 ± 59.4 months	***Education:*** 13.9 ± 2.5	NR
Edwards 2023[47]	USA	Non-randomized single group experimental	Total n=19 baseline; n=16 completed**, 6 (37.5%) females, 61.3 ± 9.4 ***Time post-stroke:*** 20.1 ± 12.0 days ***Type of Stroke:*** Ischemic - 13 (81.3%); Hemorrhagic - 3 (18.8%) ***NIH-SS:*** 4 [3.75, 5.25] ***mRS:*** 3 [2, 4]	***MoCA:*** 24.69 ± 3.98	NR
Fluet 2024[48]	USA	Mixed Methods	Total n=20, 57 ± 12.7, n female NR ***Time post-stroke:*** 57 ± 74.5 months	NR	NR
Gaboury 2022[49]	Canada	Qualitative	Total n=5, 1 (20.0%) females, 73.4 ± 6.19 ***Time post-stroke:*** 7.4 ± 0.89 days ***Type of Stroke:*** Ischemic - 5 (100%) ***mRS:*** 1.8 ± 0.84	NR	NR
Gagnon 2023[50]	Canada	Non-randomized single group experimental	Total n= 9 baseline, n=8 analyzed, 6 (67.0%) females, 60 ± 13 years old ***Time post-stroke:*** 7.0 ± 4.0 years ***Type of Stroke (n=8):*** Ischemic - 5 (62.5%); Hemorrhagic- 3 (37.5%)**	***Education:*** 4 subjects had university education	***Employment Status:*** 6 participants stopped working due to stroke

Galloway 2019[51]	Australia	Non-randomized single group experimental	Total n=21, 9 (42.9%) females, 64.2 ± 11.2 ***Time post-stroke***: 7.5 ± 6.8 years ***Type of Stroke:*** Ischemic - 9 (43.0%); Hemorrhagic – 9 (43.0%); Unknown - 3 (14.0%) ***mRS:*** Level 0 - 2 (10.0%); Level 1 - 1 (5.0%); Level 2 - 9 (43.0%); Level 3 - 8 (38.0%)	***MoCA:*** 24.9 ± 3.4	Living with family member: 20 (95.0%)
Leochico 2023[52]	Philippines	Non-randomized single group experimental	Total n=19, 7 (36.8%) females, 54.9 ± 11.6 ***Time post-stroke:*** 13.8 ± 6.0 years ***Type of Stroke:*** Ischemic – 14 (73.7%); Hemorrhagic- 3 (15.8%); Unknown – 2 (10.5%)	NR	***Marital Status:*** Married - 9 (47.4%), Civil Union – 1 (5.3%), Separated – 2 (10.5%), Widowed – 3 (15.8%), Single – 4 (21.1%)
Lim 2022[53]	USA	Case Series	Total n=3, 1 (33.3%) females, 57.3 ±10.7 ***Time post-stroke:*** 7.9 ± 4.4 years ***Type of Stroke:*** Ischemic – 1 (33.3%); Hemorrhagic – 1 (33.3%); Unknown – 1 (33.3%)	NR	NR
McCormick 2022[54]	UK	Non-randomized single group experimental	Total n=11, 4 (36.4%) females, 56.3 ± 9.8 ***Time post-stroke:*** 20.3 ± 15.7 months	NR	NR
Park 2023[55]	Canada	Non-randomized single group experimental	Total n=32, 7 (21.9%) females, 64.5 [21.0] ***Time post-stroke:*** 334.5 [263.0] days ***Type of Stroke:*** Ischemic – 19 (59.4 %); Hemorrhagic - 8 (25.0%); Other - 5 (15.6%) ***mRS:*** 1- 3 (9.4%); 2 – 15 (46.9%); 14 (43.8%); ***NIH-SS***: 2.5 [3.0]	***Education (years):*** <12 – 3 (9.4%); = 12 – 4 (12.5); >12 - 25 (78.1%) ***SF-MoCA:*** 13.0 [2.8]	***Marital Status:*** Never married – 3 (9.4%); Married/common law – 23 (71.9%); Separated/divorced – 6 (18.8%); Widowed – 0 (0%) ***Employment Status:*** Full-time – 2 (6.3%); Part-time - 0 (0%); Student – 0 (0%); Retired - 16 (50%); Sick leave/long term disability – 11 (34.4%); Unemployed, housekeeping – 2 (6.3%); Unemployed, looking for work – (0%); Other – 1 (3.1%) ***Living Arrangements prior to stroke:*** Alone in house or apartment – 6 (18.8%); With spouse/relatives/others in home or apartment – 26 (81.3%); Assisted living facility, nursing home or paid caregiver – 0 (0%); Other – 0 (0%)

Piron 2008[56]	Italy	Randomized controlled trial	Total n=10 (I: 5, C: 5) I: 3 (60.0%), C: 2 (40.0%) females I: 53.0 ± 15.0, C: 65.0 ±11.0 years old ***Time post-stroke:*** I: 10.0 ± 3.0; C: 13.0 ± 2.0 months ***Type of Stroke:*** Ischemic I: 5 (100%); C: 5 (100%)	NR	NR
Proffitt 2015[57]	USA	Mixed Methods	Total n=4, 2 (50.0%) females, 57.3 ± 4.6 ***Time post-stroke:*** >6 months	NR	NR
Rozevink 2021[58]	Netherlands	Non-randomized single group experimental	Total n=12, 4 (33.3%) females, 64.8 ± 8.5 ***Time post-stroke:*** 22.9 ± 9.3 months ***Type of Stroke:*** Ischemic - 11 (91.7%); Hemorrhagic - 1 (8.3)	***Education:*** Primary school - 2 (16.7%); Pre-vocational education - 6 (50.0%); Higher professional education – 4 (33.3%)	***Marital Status:*** Married - 10 (83.3%); Divorced - 1 (8.3%); Living together - 1 (8.3%) ***Employment Status:*** Did not work before stroke - 1 (8.3%); Stopped after stroke 5 (41.7%); Working 0 (0%); Retired - 4 (33.3%); Other - 2 (16.7%)
Sarfo 2018[59]	Ghana	Non-randomized single group experimental	Total n=20, 9 (45.0%) females, 54.6 ± 10.2 ***Time post-stroke:*** 6 months ***Type of Stroke:*** Ischemic - 10 (50.0%); Hemorrhagic – 4 (20.0%); Unknown - 6 (30.0%)	***Education:*** Primary - 10 (50.0%); Secondary - 5 (25.0%); Tertiary - 5 (25.0%) ***MoCA:*** 18.2 ± 4.3	***Average monthly income:*** $0-100: 7 (35.0%); $101-250: 9 (45.0%); $251-500: 2 (20.0%); > $501: 2 (20.0%)
Simpson 2020[60]	Australia	Non-randomized single group experimental	Total n=10, 5 (50.0%) females, 73.6 ± 9.9 ***Time post-stroke:*** 156.3 ± 162.1 days ***Type of Stroke:*** Ischemic – 9 (90.0%); Hemorrhagic – 1 (10.0%)	NA	NA
Spits 2022[61]	Netherlands	Qualitative	Total n=11, 3 (27.0%) females, 66.0 ± 8.4 ***Time post-stroke:*** 22.5 ± 9.7 months ***Type of Stroke:*** Ischemic - 10 (91.0%); Hemorrhagic – 1 (9.0%)	NR	***Living Arrangement:*** With Partner – 10 (91.0%); Alone – 1 (9.0%)
Szturm 2020[62]	Canada	Mixed Methods	Total n=10, 4 (40.0%) females, 58.0 ± 12.0 ***Time post-stroke:*** 14.0 ± 5.0 months ***Type of Stroke:*** Ischemic - 8 (80.0%); Hemorrhagic - 2 (20.0%)	NR	NR
Toh 2023[63]	China	Mixed Methods	Total n=11, 7 (63.6%) females, 55.9 ± 11.1 ***Time post-stroke:*** 6.3 ± 3.1 years	NR	NR

Torriani-Pasin 2021[64]	Brazil	Mixed Methods	Total n=40, 17 (42.5%) females, 55.1 ± 15.3 ***Time post-stroke:*** 98 ± 63.8 months ***Type of Stroke:*** Ischemic – 26 (65%); Hemorrhagic - 11 (27.5%); Both – 3 (7.5%)	***Education:*** 10.6 ± 5.1 ***MoCA:*** 21.6 ± 4.5	NR
Tyagi 2018[65]	Singapore	Qualitative	Total n=13, 6 (46.2%) females, 59 (range 43-79) ***mRS:*** 1 - 1 (7.7%); 2 - 2 (15.4%); 3 - 0 (0%); 4 - 6 (46.2%)***;*** 5 - 1 (7.7%); NR- 3 (23.1%)	NR	NR
Wiley 2024[66]	Canada	Qualitative	Total n=10, 4 (40%) females, 61.9 ± 16.3 ***Time post-stroke:*** 11.3 ± 4.7 months ***mRS:*** 2 [1], ***NIH-SS:*** 2.5 [1]	NR	***Marital Status:*** Married 6 (60%); Divorced 1 (10%); Single 3 (30%) ***Employment Status:*** Full-Time 1 (10 %); Part-Time 1 (10 %); On Disability 2 (20 %); Retired 5 (50 %); Unemployed 1 (10%)
Yang 2021[67]	Canada	Implementation Study Design with Mixed methods	Total n=9, 4 (44.4%) females, 65.9 ± 14.40 ***Time post-stroke:*** 65.9 ± 111.2 months	NR	NR
*Characteristics of participants in analysis (baseline values not provided). Median with IQR reported with square brackets [X]. **Reporting of # participants inconsistent between baseline and analyzed data. *Abbreviations.* NR= Not Reported; mRS= Modified Rankin Scale; NIH-SS= Nationals Institute of Health Stroke Scale; MoCA= Montreal Cognitive Assessment; SF-MoCA= Short-Form Montreal Cognitive Assessment; MMSE= Mini Mental State Examination; USA= United States of America; UK= United Kingdom					

Table 2.2. Intervention characteristics and data collection, analysis and themes for included mixed method and qualitative studies

Study ID	Intervention Parameters (Frequency, Intensity, Time (minutes), Duration, Type), Rehabilitation Focus	Qualitative Research Question or Purpose	Data Collection & Analysis Methods	Themes (bolded) and Categories
Allegue 2021[30]	**F**: 5x/week exergame sessions with 1-3 sessions videoconference with therapist **I**: difficulty increased weekly during videoconferencing meetings (i.e., number of rounds, repetitions, time, speed, etc.) **Time**: 30 minutes exergames + 60 minutes videoconferencing sessions **D**: 8 weeks **Type**: exergame sessions (asynchronous) and videoconference with therapist (synchronous) **Focus**: upper extremity	Explore factors that influenced the use of technology and its impact on the participant empowerment.	Semi-structured interview Directive content analysis (lens of self-determination a Unified Theory of Acceptance and Use of Technology used to guide analysis) [UTAUT] ***Quantitative Questionnaire:*** NA	**Performance** Advantages of telerehabilitation (exchange of messages, videoconference, follow-up by the clinician, no limited time of therapy, time to reflect, correct, and discuss with clinician), perceived improvement in arm functional performance and impact on daily activities **Effort** Ease of use, complexity **Social Influence** Positive feedback, social agreement including exchange, feedback and support **Facilitating Conditions and Obstacles** Perceived control over internal and external constraints, lack of compatibility of telerehabilitation system (game design and previous experiences) **Attitudes towards system** Satisfaction with the telerehabilitation application, virtual reality exergame, and exercises, eager to experiment virtual therapy **Attitudes towards the affected upper-extremity** Anxiety related to improvement and exercising **Attitudes towards information technology** Eager to experiment with virtual reality
Allegue 2022a[31]	**F**: 5x/week exergame sessions with 1-3 sessions videoconference with therapist **I**: difficulty increased weekly during videoconferencing	Investigate the determinants of VirTele use.	Semi-structured interviews (Questions structured around the UTAUT concepts) Abductive thematic analysis	**Performance** Advantage (access to rehabilitation, and enhancing motivation), perceived limits of exergames (e.g., limited parameters around difficulty of exergames and insufficient rest between reps and sets),

Study ID	Intervention Parameters (Frequency, Intensity, Time (minutes), Duration, Type), Rehabilitation Focus	Qualitative Research Question or Purpose	Data Collection & Analysis Methods	Themes (bolded) and Categories
	meetings (i.e., number of rounds, repetitions, time, speed, etc.) **Time**: 30 minutes exergames + 60 minutes videoconferencing sessions **D**: 8 weeks **Type**: exergame sessions (asynchronous) and videoconference with therapist (synchronous) **Focus**: upper extremity		***Quantitative Questionnaire:*** NA	stroke survivors' perceptions of exergames as instrument of play or therapeutic intervention, perceived change in the affected arm use awareness of usefulness of the technology, stroke survivors' adherence to the exergames, and experience with exergames **Effort** Managing technical issues, perceived ease of use of the technology **Social Influence** Feedback from family and friends, agreement, and assistance with the technology, clinician support, and encouragement **Contextual challenges** Comfort in using the technology, internet access, miscommunication between the stroke survivor and clinician
Chen 2020[38]	**F:** 6x/week (3 supervised & 3 unsupervised) **I:** difficulty of program (i.e., increasing speed of movement, size of targets, etc.) adjusted by therapist **Time:** 30 mins supervised sessions + 35 mins guided by TR system + 5 min education (70 minutes total); 70 mins unsupervised sessions **D:** 6-8 weeks (18 supervised and 18 unsupervised sessions) **Type:** exergame sessions with devices such as PlayStation Move Controller (asynchronous) and	Investigate patient perceived benefits of and barriers to using a telerehabilitation system at home.	Semi-structured interviews Thematic content analysis (Themes following the UTAUT model)	**Performance Expectancy** Perceived improvement in physical ability, mental well-being, and in social-emotional well-being **Effort Expectancy** Easy to learn and use, perceived engaging experience, external and internal motivation to conduct the exercises, convenience of location and time of home-based rehabilitation **Facilitating Conditions** Technical issues, physical space, and schedule (time) **Social Influence** Social influence from caregivers and family members **Behavioural Intention** Difficulty of games and exercises to be adapted to progress over time, visually see progress over time

Study ID	Intervention Parameters (Frequency, Intensity, Time (minutes), Duration, Type), Rehabilitation Focus	Qualitative Research Question or Purpose	Data Collection & Analysis Methods	Themes (bolded) and Categories
	videoconference with therapist (synchronous) **Focus:** upper extremity			
Cherry 2017[39]	**F**: daily **I:** progressive increase in difficulty given improvements in motion and accuracy (therapy began at an easy level requiring small degree of wrist or ankle motion) **Time:** 2 hours/day **D:** 12 weeks **Type:** robotic device with remote monitoring from therapist (asynchronous) **Focus:** upper- and lower extremity	Determine participants' general impressions about the benefits and barriers of using robotic therapy devices for in-home rehabilitation.	Semi-structured interviews Thematic analysis using ethnographic-based anthropological method	**Benefits of Use** Increased mobility, sense of control over therapy and scheduling, outlet for physical and mental tension and anxiety, increased independence and mood improvement **Barriers to Use** Size and placement, wearing and adjusting the device, technical difficulties
Conroy 2022[41]	**F**: 3x/week **I:** NR **Time:** 15.1 hours of therapy over course of training **D:** 6 weeks **Type:** patient-portal with secure messaging capabilities (asynchronous) **Focus:** NR	Investigate the feasibility and utility of a secure messaging-supported e-visits within an established nationwide patient portal to support a 6-week telerehabilitation programme.	Semi-structured interview ***Quantitative Questionnaires:*** Electronic health literacy and web-based learning self-efficacy questionnaire and Patient Portal Satisfaction Survey Thematic analysis using a phenomenological approach Thematic analysis using a phenomenological approach	**Patient Portal Accessibility** Ease of use, challenges **Acceptance of delivery mode** Convenience, caregiver involvement, difficulties with discipline in absence of formal appointment **Effectiveness of therapy** Navigating the therapy, sharing information, using the tablet
Donnelly 2023[45]	**F**: Participants asked to complete 30 sessions **I:** NR **Time:** 60 minutes/session **D:** 6 weeks	Gain insight from stroke survivors' experiences using an electromyography biofeedback	Semi-structured interview Thematic Analysis	**Biofeedback** Reinforced attempted movements, satisfied by actively using affected arm, perceived improvements in motor control, increased awareness of

Study ID	Intervention Parameters (Frequency, Intensity, Time (minutes), Duration, Type), Rehabilitation Focus	Qualitative Research Question or Purpose	Data Collection & Analysis Methods	Themes (bolded) and Categories
	Type: game-based platform with electromyography biofeedback. Approximately half of sessions conducted over videoconference with therapist (synchronous & asynchronous) **Focus:** upper extremity	telerehabilitation system, specifically to identify factors that influence its acceptability.		residual arm movement during daily activities **Gamification** Achievement markers (e.g., levels, high scores) motivated participation, wanted more control over "Blinko" game, enjoyed engagement with research team via videoconferencing **Predictability** Predictable system performance led to longer and more enjoyable sessions, unpredictable system performance was discouraging **Customization** Sensor placement challenge, adjustable game settings enabled appropriate challenge, session structure (e.g., game choice, time of day), quality and accessibility of support from research team
Donnelly 2024[46]*	**F**: Participants asked to complete 30 sessions **I:** NR **Time:** 60 minutes/session **D:** 6 weeks **Type:** game-based platform with electromyography biofeedback. Approximately half of sessions conducted over videoconference with therapist (synchronous & asynchronous) **Focus:** upper extremity	Evaluate the usability and acceptability of an electromyography biofeedback telehealth intervention for poststroke upper extremity motor recovery (Tele-REINVENT).	Semi-structured interview Analysis guided by themes in UTAUT model ***Quantitative Questionnaires:*** Post-Study System Usability Questionnaire, Version 3 and UTAUT model	**Usability** System quality, information quality, interface quality **Acceptability** Effort expectancy, performance expectancy, perceived enjoyment, satisfaction, self-efficacy, behavioural intention
Fluet 2024[48]	**F**: at least 3x/week **I:** game parameters adjusted weekly by therapist	Analyze the user experience of persons with hemiplegia with	Semi-structured interview Qualitative Description	**Intrinsic Motivation** Challenge, Progress, Fun

Study ID	Intervention Parameters (Frequency, Intensity, Time (minutes), Duration, Type), Rehabilitation Focus	Qualitative Research Question or Purpose	Data Collection & Analysis Methods	Themes (bolded) and Categories
	Time: at least 20 minutes **D:** 12 weeks **Type:** game-based virtual rehabilitation system monitored remotely by therapist (asynchronous) **Focus:** upper extremity	home-based virtual rehabilitation to identify specific motivational factors that can be used to inform the design of future technology-based rehabilitation interventions.	***Quantitative Questionnaires:*** Intrinsic Motivation Inventory	**Extrinsic Motivation** Additional Therapy, return to the prior level of function, altruism **Computer/technical literacy**
Gaboury 2022[49]	**F:** NR **I:** NR **Time:** NR **D:** 9-13 (average 11.6, SD: 1.67) weeks based on participants completing the qualitative interview **Type:** videoconferencing with therapist (synchronous) **Focus:** upper- or lower extremity, speech, diet, and/or cognitive function (multi-disciplinary intervention based on participant's individual needs. All participants received physical rehabilitation from an occupational or physical therapist)	Describe the acceptability of a telerehabilitation platform for stroke rehabilitation from the perspective of both patients and therapists and to propose recommendations to ease its implementation.	Semi-structured interviews Qualitative Descriptive; Hybrid inductive and deductive thematic analysis (Sekhon et al., 2017 theoretical framework of acceptability used to conceptualize data)	**Affective Attitude** Ease of use, suitability for personal needs, advantages of staying at home for rehabilitation treatment (energy spared) **Ethicality** Physical and psychological support, preference over in-person rehabilitation (disabilities not exposed to others in virtual environment) **Self-Efficacy** Confidence with platform **Opportunity Cost** Time spared **Intervention Coherence** Understanding need for rehabilitation and motivation (i.e. made sense to be treated through telerehabilitation) **Perceived Effectiveness** Improvement in function and reaching personal goals
Galloway 2019[51]	**F:** 3x/week **I:** moderate to vigorous aerobic exercise based on 55-85% of maximum heart and Borg Rating of Perceived **Time:** 10-20 minutes **D:** 8 weeks	Assess the feasibility of, and level of satisfaction with home-based telehealth-supervised aerobic exercise training post-stroke.	Participant feedback questionnaire with open-ended questions Thematic analysis ***Quantitative Questionnaire:***	**Participant benefits** Discipline and motivation to exercise, self-confidence, improved fitness, health and function, and computer skills **Convenience** Receive rehabilitation services from therapist without leaving home, no travel (decreased burden of transportation)

Study ID	Intervention Parameters (Frequency, Intensity, Time (minutes), Duration, Type), Rehabilitation Focus	Qualitative Research Question or Purpose	Data Collection & Analysis Methods	Themes (bolded) and Categories
	Type: videoconferencing with therapist (synchronous) **Focus:** upper- and lower extremity		Telehealth usability and satisfaction questionnaire	**Instructor-related** External motivation and expertise **Altruism and Satisfaction** Enjoyment and excitement towards telehealth exercise sessions **Barriers (i.e., negative comments)** Difficulties managing monitoring equipment (e.g., difficulties with non-dominant/affected hand, too many buttons to press) and internet speed and reliability
Lim 2022[53]	**F:** 3x/week **I:** progressed to a TheraBand with greater resistance or progressing to standing exercises for strength and balance components **Time:** 20 minutes movement-based priming + 30 minutes lower limb strengthening and balance = 50 minutes total **D:** 8 weeks **Type:** sensor-based monitoring (asynchronous) and videoconferencing with therapist (synchronous) **Focus:** lower extremity	Determine the feasibility, acceptability, and preliminary motor benefits of an 8-week remotely supervised telerehabilitation program utilizing game-based movement priming combined with functional lower limb motor training in chronic stroke survivors.	Open-ended questions Responses presented for all three participants included in study ***Quantitative Questionnaire:*** DIG-I-Prime structured feedback form	Enjoyment, interaction with therapist via videoconference motivational and helpful, benefits of receiving training from any geographical location, technological challenges related to design of foot piece
Proffitt 2015[57]	**F:** ~4 hours/week **I:** progressed and/or modified based on individual physical rehabilitation and exercise treatment plan needs **Time:** duration of each session left to the participant's discretion (varied among participants)	Explore the feasibility and utility of Mystic Isle as a 6-week, game-based, in-home exercise program for individuals with chronic stroke.	Semi-structured interviews Grounded theory ***Quantitative Questionnaires:*** Game Experience Questionnaire and System Usability Scale	**Facilitators** Customized aspect of program (tailored to individual goals), desire to improve body and mind, variety in games (enjoyment of games), motivated by motor and cognitive challenge games **Barriers** Time management (difficulties following schedule due to busy schedule and responsibilities), accessing games on

Study ID	Intervention Parameters (Frequency, Intensity, Time (minutes), Duration, Type), Rehabilitation Focus	Qualitative Research Question or Purpose	Data Collection & Analysis Methods	Themes (bolded) and Categories
	D: 6 weeks **Type:** serious games monitored remotely by therapist (asynchronous) **Focus:** upper- and lower extremity			computer, cognitive deficits impacting processing and ability to follow instructions, limited reliance on caregiver for support with technology
Spits 2022[61]	**F:** 6x/week **I:** difficulty increased by adding more movements and combinations of movements (e.g. grasping, lifting and moving the device) & therapy adjusted to 80% of the maximum range of motion every 2 weeks **Time:** 30 minutes **D:** 6 weeks **Type:** robotic device with serious games remotely monitored by therapist (asynchronous) **Focus:** upper extremity	1) Investigate the experiences and perspectives of chronic stroke survivors on ICF levels (body functions, activities and participation) and ICF factors (external and personal) after using MERLIN to train the upper limb function at home; 2) describe the facilitators and barriers regarding upper limb training at home using MERLIN.	Semi-structured interviews Qualitative approach guided and mapped onto the ICF	**ICF Facilitators** Improvements in upper limb function and range of motion, and memory due to cognitive challenge, feeling proud from being able to do training, positive self-perception from proudness, courage and self-confidence from improvements in arm function, triggered to use arms during activities and try new activities with affected hand, independence with personal limitations (being creative with finding solutions), motivation to improve upper limb function, humour and perseverance as helpful character traits, support from therapists with technical issues, assistance from caregiver for technical support and motivation **ICF Barriers** Pain, temporary muscle pain, emotional response when training not as planned, exhaustion from combination of stroke and telerehabilitation program, stress due to interference with daily routines, lack of intrinsic motivation increasing strain on relationship with caregiver/partner **MERLIN Training System: Facilitators** Variation in games and increasing difficulty, software easy to understand, device not complicated and user friendly, continue

Study ID	Intervention Parameters (Frequency, Intensity, Time (minutes), Duration, Type), Rehabilitation Focus	Qualitative Research Question or Purpose	Data Collection & Analysis Methods	Themes (bolded) and Categories
				participation if possible and recommend therapy to others **MERLIN Training System: Barriers** Shape and size of device, system malfunctions (games freezing or blocked), computational errors, wrong calibration, wear on device (intensive use), feeling annoyed due to repetition of games, challenge and lack of clarity in formulation of instructions for games with *cognitive* component [unrelated to exercise] **Telerehabilitation platform: Facilitators** Monitoring by therapist, convenience of receiving information via chat function **Telerehabilitation platform: Barriers** Intensity of program, psychological strain due to monitoring from therapist, inconvenience of sending messages to therapist **Homebased training: Facilitators** Control of own training session, ability to divide training into shorter sessions, time efficient (no travel), enthusiasm toward flexibility of training schedule, ability to train spontaneously given other obligations, lack of transportation extra beneficial if dependent on others **Homebased training: Barriers** Psychosocial pressure due to physical presence of system, lack of direct assistance in case of technical issues, assistance from relatives needed to operate system, training with partner source of frustration, temptation

Study ID	Intervention Parameters (Frequency, Intensity, Time (minutes), Duration, Type), Rehabilitation Focus	Qualitative Research Question or Purpose	Data Collection & Analysis Methods	Themes (bolded) and Categories
				to cheat with training given no direct supervision
Szturm 2020[62]	**F:** 4x/week **I:** exercise prescription initially based on patient's goals, preferences and functional impairments and progressed throughout the intervention (participants advised to switch to a more challenging game when it became too easy to play) **Time:** 20-30 minutes **D:**16 weeks **Type:** game-based with physical objects and inertial computer mouse (asynchronous) with weekly telephone calls with therapist (synchronous). Clinic-based visits occurred prior to starting 16-week intervention to familiarize participants with technology used. **Focus:** upper extremity	Determine the feasibility and acceptability of the game-assisted home exercise program for upper extremity rehabilitation post-stroke.	Semi-structured interviews Qualitative description; content analysis using general inductive approach	**Need of initial one-on-one clinic-based therapy session** Teaching what exercises to perform, how to use the inertial mouse, games to play, manipulation task difficult to perform, more supervised sessions **Need for monitoring by therapist** Beneficial for therapist to set up computer and install games, importance of regular follow-up sessions by telephone **Benefits and difficulties of the individualized game-assisted programs** Challenging and personalized, variety in games, being competitive and not wanting to lose **Challenges using technology** Difficulty with drifting of inertial mouse, difficulty removing inertial mouse from exercise object
Toh 2023[63]	**F:** at least 3x/week **I:** wearable device allowed participants to track their progress over time **Time:** at least 3 hours/day (30 minutes per session 2-3x/day) **D:** 2 weeks **Type:** wearable Bluetooth wristwatch and app-based remotely monitored by therapist (asynchronous)	Identify three main aspects of the proposed wristwatch: aspects users valued and which ones they disliked, its usability and acceptability according to the participants, and its features that required further modification	Semi-structured interviews Inductive thematic analysis guided by UTAUT ***Quantitative Questionnaire:*** System Usability Scale	**Performance Expectancy** Perceived usefulness of device, perceived physical improvement **Effort Expectancy** Ease of use, convenience, technical and wearability (strap and size) issues **Social Influence** Importance of family support (verbal support) **Facilitating Conditions** Physical location (home as preferred location use technology)

Study ID	Intervention Parameters (Frequency, Intensity, Time (minutes), Duration, Type), Rehabilitation Focus	Qualitative Research Question or Purpose	Data Collection & Analysis Methods	Themes (bolded) and Categories
	Focus: upper extremity			motivation to exercise, flexibility in exercise schedule, more variety of exercise content
Torriani-Pasin 2021[64]	**F:** 2x/week **I:** Individualized exercise intensity **Time:** ~40 minutes **D:** 22 weeks **Type:** pre-recorded videos (asynchronous) **Focus:** upper- and lower extremity	Evaluate adherence and barriers to attend a remote physical exercise program for individuals after stroke	Open-ended question related to perceived barriers Identified barriers clustered into domains and counted ***Quantitative questionnaire:*** Overall Experience Questionnaire	**Health-related barriers** Pain, behavioural issues (lack of motivation), personal issues, fear of falling, fear of injury, dual-task performance, constraints to do mat workout, constraints to use most affected side while exercising, lack of motor skills and physical fitness to workout, grief of losing family member (study occurred during COVID-19 pandemic), lack of time, health condition appointments, pain **Environmental-related barriers** Lack of companion (family member) for support with exercises, lack of safe space to exercise, domestic life, weather conditions, problems with communication and lack of knowledge to use internet devices and tools (internet connection)
Tyagi 2018[65]	**F:** 5x/week **I:** minimum range of motion required for each exercise (difficulty increased at therapist's discretion) **Time:** 312 minutes over 12 weeks. Length of each session NR **D:** 12 weeks **Type:** exercises displayed on tablet with feedback received via sensors (asynchronous) and videoconferencing with therapist (synchronous) **Focus:** upper- and lower extremity	Explore the perceived barriers and facilitators of telerehabilitation by stroke patients, caregivers and rehabilitation therapists in an Asian setting.	Semi-structured interviews Grounded theory (Charmaz cited); inductive thematic analysis	**Facilitators** Affordability, accessibility (flexible schedule), unexpected health benefits **Barriers** Setting up the equipment, scope of exercises, connectivity issues **Patient Characteristics** Age of the patient, patient's disability level influencing motivation, cultural influence, perception of therapist's role, preferred choice

Study ID	Intervention Parameters (Frequency, Intensity, Time (minutes), Duration, Type), Rehabilitation Focus	Qualitative Research Question or Purpose	Data Collection & Analysis Methods	Themes (bolded) and Categories
Wiley 2024[66]	**F:** 2x/week + ≥1 self-managed weekly exercise session **I:** weekly progression in repetitions and sets, and addition of exercises **Time:** 60-90 minutes **D:** 4 weeks **Type:** videoconferencing with therapist (synchronous) and individual self-managed exercise sessions **Focus:** lower extremity	Describe and understand the experiences of the individuals' post-stroke who participated in TRAIL in terms of their perceptions of the program delivery and resources, as well as lower-extremity related rehabilitation outcomes.	Semi-structured interviews Interpretive Description; inductive thematic analysis	**TRAIL Ingredients for success** Strong support from family and peers, expertise of therapist, effective videoconferencing software, provision of comprehensive manuals **Telerehabilitation is a viable option for stroke rehabilitation** Accessibility, extends rehabilitation opportunities into the community, addresses unmet rehabilitation needs (e.g., mobility, lower extremity strength, balance)
Yang 2021[67]	**F:** 1x/week group videoconferencing with therapist (synchronous) and individualised homework exercises logged daily **I:** instructor manual outlined guidelines for progression and modifications Time: 60 minutes (for both weekly group session and individualized daily sessions) **D:**10 weeks **Type:** videoconferencing with therapist (synchronous) and independent homework exercises **Focus:** upper extremity	Evaluate the implementation process from the 2 iterations of the virtual GRASP program delivered via videoconferencing by a non-profit organization using the Reach, Effectiveness, Adoption, Implementation, and Maintenance (RE-AIM) framework	Online Exit Survey (included open ended questions) NR (reported on consensus among participants with counts provided)	**Facilitators:** Positive group dynamic (e.g., learning from instructor and other participants), perceived improvements **Barriers:** Fatigue and pain, difficulty of exercises, cost of program [program fee $85 CAD]

Note. NA=Not Applicable; Not Reported. * We noted overlap between qualitative and quantitative findings in Donnelly 2024. To ensure not to double count facilitators and barriers within the study, we reported on either the quantitative or qualitative data, but not both.

Table 2.3. Intervention characteristics for purely quantitative studies

Study ID	Intervention Parameters (Frequency, Intensity, Time Duration)	Outcomes
Allegue 2022 (b)[32]	**F**: 5x/week exergame sessions + 1-3 sessions videoconference with therapist **I**: difficulty increased weekly during videoconferencing meetings (i.e., number of rounds, repetitions, time, speed, etc.) **Time**: 30 minutes + 60 minutes videoconferencing sessions **D**: 8 weeks **Type**: exergame sessions (asynchronous) and videoconference with therapist (synchronous) **Focus**: upper extremity Control intervention involved time- and- duration matched upper extremity program (Graded Repetitive Arm Supplementary Program) focused on strengthening and range of motion	Management (e.g., technical considerations) and scientific feasibility (e.g., ease of use) indicators (information obtained from clinician logs)
Bellomo 2020[33]	**F**: At least 3x/week **I:** weekly increase in reps/set per PTs discretion **Time:** recommended 30 minutes (minimum 15 minutes) **D:** 12 weeks **Type:** sensor-based biofeedback and exergaming system (asynchronous) with weekly telephone call from therapist (synchronous) **Focus:** upper extremity and balance (lower extremity)	Technology acceptance model (TAM) questionnaire
Benvenuti 2014[34]	**F**: At least 2x/week at telerehabilitation kiosk and 3x/week at home = 5x/week **I:** individualized exercise prescription with level of difficulty chosen to make tasks "challenging, but not impossible" **Time:** varied per participant **D:**12 weeks **Type:** participants recorded exercise sessions that could be viewed by therapist at later time (asynchronous) and/or videoconferencing with therapist (synchronous) and individual home-based sessions **Focus:** upper extremity Control intervention involved duration-matched usual care (general practitioner visits or outpatient rehabilitation delivered on demand). Some participants received no treatment.	Habilis Evaluation Questionnaire (informed by the UTAUT)
Bernocchi 2016[35]	**F:** at least 1x/week **I:** individualized exercise program adapted daily to the patient's progress as required by therapist	Questionnaire on Satisfaction (overall satisfaction,

Study ID	Intervention Parameters (Frequency, Intensity, Time Duration)	Outcomes
	Time: not reported **D:** 12 weeks **Type:** telephone and videoconferencing with therapist (synchronous) **Focus**: upper- and lower extremity	relationship with nurse-tutor, access to service)
Bindschedler 2024[36]	**F:** 6x/week **I:** individualized exercise program adapted daily to the patient's progress as required by therapist **Time:** group session 45-60 minutes **D:** either 6 or 12 weeks based on time of enrolment **Type:** app-based where participants could choose from a pool of 20 exercises (asynchronous) and weekly synchronous session with therapist **Focus**: trunk, upper- and lower extremity	Satisfaction of Coaching Questionnaire
Burdea 2020[37]	**F:** 5x/week (20 sessions) **I:** game difficulty settings adjusted weekly by AI system **Time:** Week 1 - 20 minutes/session; Week 2 - 25 minutes/session; Week 3 - 30 minutes/session; Week 4 - 40 minutes/session **D:** 4 weeks **Type:** AI monitored system with additional remote monitoring from therapist (asynchronous) **Focus:** upper extremity and cognitive function	Participant's Subjective System Evaluation questionnaire
Cho 2022[40]	**F:** 6x/week (3 supervised & 3 unsupervised) **I:** difficulty of program (i.e., increasing speed of movement, size of targets, etc.) adjusted by therapist **Time:** 30 mins supervised sessions + 35 mins guided by TR system + 5 min education (70 minutes total); 70 mins unsupervised sessions **D:** 6-8 weeks (18 supervised and 18 unsupervised sessions) **Type:** exergame sessions with devices such as PlayStation Move Controller (asynchronous) and videoconference with therapist (synchronous) **Focus:** upper extremity Control group was a therapy, intensity, and duration-matched in-clinic rehabilitation program (i.e., 18 supervised and 18 unsupervised sessions over 6-8 weeks)	Patient Satisfaction Questionnaire and Physical Activity Enjoyment Scale *Note.* Authors of this study shared disaggregated data for men and women, upon our request for data.
Contrada 2022[42]	**F:** 5x/week **I:** individually tailored **Time:** 60 minutes **D:** 12 weeks	Satisfaction Questionnaire

Study ID	Intervention Parameters (Frequency, Intensity, Time Duration)	Outcomes
	Type: participant exercised on own time using K-wand and sensors on non-immersive VR platform (asynchronous) and with therapist who controlled tablet and interacted with participant (synchronous) **Focus:** trunk, upper- and lower extremity	
Corriveau 2013[43]	**F:** 2x/week **I:** NR **Time:** 45 minutes **D:** 8 weeks **Type:** videoconference with therapist (synchronous) **Focus:** balance (Tai Chi)	Patients' Health Care Satisfaction
Dodakian 2017[44]	**F:** 3x/week videoconferencing sessions + daily individualized games and home-based exercises **I:** therapists adjusted level of difficulty **Time:** 60 minutes structured (required hour of activities selected by the therapist which included 5 minutes of education) + 60 minutes of optional game-play selected by the patient = 120 minutes total **D:** 28 days (organized as two 14-day blocks of daily telerehabilitation separated by a 1- to 3-week break) **Type:** remotely monitored individualized games and home-based exercises (asynchronous) and videoconference with therapist (synchronous) **Focus:** upper extremity	Questionnaire on Telerehabilitation Experience
Edwards 2023[47]	**F:** 6x/week **I:** progressive increase in difficulty of games **Time:** 70 minutes **D:** 6 weeks (allowed up to 2 additional weeks for missed sessions) **Type:** 18 unsupervised sessions (asynchronous) and 18 videoconferencing sessions with therapist (synchronous) **Focus:** upper extremity	Telerehab Satisfaction Questionnaire
Gagnon 2023[50]	**F:** 2x/week **I:** monitored by kinesiologist through Borg Rating of Perceived Exertion (RPE) scale and ability to converse (Talk Test) **Time:** 60 minutes **D:** 12 weeks **Type:** videoconference with therapist (synchronous) **Focus:** upper- and lower extremity	Study-Specific Satisfaction with Fame@home Questionnaire

Study ID	Intervention Parameters (Frequency, Intensity, Time Duration)	Outcomes
Leochico 2023[52]	**F:** 3x/week **I:** NR **Time:** 30 minutes **D:** 2 weeks **Type:** pre-recorded exercises viewed on Facebook (asynchronous). Participants could interact with other peers and therapist via private chat **Focus:** upper- and lower extremity	Telepractice Questionnaire and Experiences with Program
McCormick 2022[54]	**F:** Goal to perform daily (7x/week) **I:** self-directed exercise program **Time:** 90 minutes **D:** 18 days of therapy (1,620 minutes of therapy prescribed) **Type:** app downloaded on tablet (asynchronous) with weekly telephone calls or emails from therapist (synchronous) **Focus:** upper extremity	System Usability Scale and semi-structured interviews (not reported)
Park 2023[55]	**F:** 2x/week + ≥1 self-managed weekly exercise session **I:** weekly progression in repetitions and sets, and addition of exercises **Time:** 60-90 minutes **D:** 4 weeks **Type:** videoconferencing with therapist (synchronous) and individual self-managed exercise sessions **Focus:** lower extremity	Post-Intervention Satisfaction Survey
Piron 2008[56]	**F:** Daily (7x/week) **I:** visual feedback provided by platform to monitor intensity **Time:** 60 minutes **D:** 4 weeks **Type:** 3D motion tracking (asynchronous) and videoconference with therapist (synchronous) **Focus:** upper extremity The control group followed the same exercise prescription, but involved an in-person (hospital setting) 3D motion tracking virtual reality intervention	Disease and Treatment Specific Satisfaction Questionnaire
Rozevink 2021[58]	**F:** 6x/week **I:** adding more movements and combinations of movements (e.g. grasping, lifting and moving the device) & therapy adjusted to 80% of the maximum range of motion every 2 weeks **Time:** 30 minutes	System Usability Scale, Intrinsic Motivation Inventory, and Dutch-Quebec User Evaluation of Satisfaction with Assistive Technology

Study ID	Intervention Parameters (Frequency, Intensity, Time Duration)	Outcomes
	D: 6 weeks **Type:** robotic device with serious games (asynchronous). *Note* that recalibration of robotic device had to be conducted every other week by a research team member in the participants' homes to ensure consistency of calibration. All protocol operations related to the delivery of the intervention were conducted remotely (i.e. no in-home visits for adjusting/progressing exercises or communication on how to conduct exercises provided). **Focus:** upper extremity	
Sarfo 2018[59]	**F:** 5x/week **I:** adjusted based on level of disability and progress **Time:** 30-60 minutes **D:** 12 weeks **Type:** app-based (asynchronous) and weekly phone calls with therapist (synchronous) **Focus:** upper – and lower extremity	Telehealth Satisfaction Instrument
Simpson 2020[60]	**F:** 184 sit-to-stand sessions (724 repetitions prescribed) collectivity prescribed to participants **I:** goals increased each week if participant performed target repetitions or maintained if targets were not being achieved **Time:** not reported **D:** 4 weeks **Type:** app and sensor-based remotely monitored by therapist (asynchronous) **Focus:** lower extremity	System Usability Scale, Physical Activity Enjoyment, and Perceived Benefits of Activity

`able 2.4. Summary of constructs identified mapped onto the Theoretical Domains Framework (TDF)

Construct	Definition	TDF Domain	Type of Data Reported	Facilitators	Barriers
Ease of Use of Telerehabilitation System/Platform	The degree to which a person believes that using a particular system is free of effort.[70]	Skills	*Qualitative*	Ease of use with using telerehabilitation system[30,38,39,41,45,49,61,63]	NA
			Quantitative	Ease of use of telerehabilitation platform/system or playing games [32,33,42,46,47,50,51,52,53,56,60]	NA
Abilities/capacity to participate in telerehabilitation	Capacity to successfully participate in telerehabilitation intervention and understanding on how to operate and use technology used in telerehabilitation intervention. Could also include previous experiences with technology and/or comfort with using technology.[94]	Skills & Knowledge	*Qualitative*	Need of initial one-one-one sessions to learn how to perform exercises and learn about technological considerations,[62] acquiring computer skills throughout program,[51] comfort with technology,[30] easy to learn[38,63] and understand[61] system	Comfort with using technology (unfamiliarity with operating a computer or tablet),[31,41] general barriers with technical skills,[38] lack of knowledge on use of internet devices[64] and information sharing (e.g., difficulties attaching and sending files, navigating different applications/tabs),[41] lack motor skills and fitness to exercise[64]
			Quantitative	Lack of confusion or challenge and ease of compliance with assignments (included education component),[40] usefulness and/or understanding of procedures and/or instructions,[37,47,53,56] easy to learn games[46] limited need for help with using technology,[51,60] comfort with using technology,[46,52,55,58,59,60,67]	Learning a new software[50]
Perceptions of changes in physical outcomes from participating in a telerehabilitation program	The self-reported changes (positive or negative) in physical outcomes after completing a telerehabilitation program (i.e., post-intervention).[95]	Reinforcement	*Qualitative*	Improvements in arm or hand function and functional performance,[30,38,45,46,61,63,67] increased mobility,[39,66] independence,[39] cardiovascular fitness,[51] lower limb strength[63,66] and balance,[66] improvements in memory function,[38,61] improvements in general health and function (not specific	NA

				to upper or lower extremity),[51] reduced upper extremity pain[63]	
			Quantitative	Improvements in stroke symptoms,[37] improvements in upper extremity function (e.g., increased use of affected arm or hand, and reduced hemiparesis),[44,50] improvements in lower extremity function (e.g., strength, mobility, balance),[50,52,53,64] increased, ability to sit up from bed, reduced fatigue, back pain, support needed to walk backwards and reliance on mobility devices,[50] increased overall health (e.g., boosted immune system and weight loss)[52]	NA
Aspects of the telerehabilitation program influencing physical health	Any aspect of the telerehabilitation program that influenced physical health during intervention period.[1]	Reinforcement & Environmental	*Qualitative*	Outlet to reduce physical tension,[39] receiving telerehabilitation (home-based) spared energy for therapy[49]	Fatigue[67] and exhaustion[61] caused by stroke and telerehabilitation training program, temporary muscle pain,[61,64,67] pain in neck or arm due to bad posture during use of system and painful pressure points on skin[61]
			Quantitative	Limited to no fatigue caused by telerehabilitation program,[40,53] limited to no pain or discomfort felt during program,[37,44,53] less time sitting or laying down[55] and increased use of affected upper extremity[32] during program	Fatigue[32] *(pain also reported by 1 of 4 participants[32])* and temporary muscle pain[52]
Aspects of the telerehabilitation program influencing mental health	Any aspect of the telerehabilitation program that influenced mental health during intervention period.[1]	Reinforcement & Environmental & Emotion	*Qualitative*	Program viewed as an outlet to reduce mental tension[39]	Program caused stress due to interference with daily activities and psychosocial pressures due to physical presence of software[61]
			Quantitative	Limited to no stress caused by telerehabilitation program,[53] no depression experienced during treatment,[53] no interference with mood[64]	NA

Technological Considerations	Any aspect related to technology that could positively or negatively influence participation in a telerehabilitation program.[96]	Environmental	*Qualitative*	Having both video and audio connection,[66] effective videoconference software (i.e., no glitches)[66]	Limited internet access,[30,31] internet[30,31,51,64,65] and modem (used to share data)[39] speed and connectivity, lack of compatibility of telerehabilitation platform design,[30] video camera placement,[38] unresponsive software (e.g., lack of synchronization between real movements and game display, freezing of computer, system hang)[31,39,61,63] wrong calibration of device and wear on device,[61] drifting of inertial mouse,[62] challenges with adjusting and/or wearing device(s),[39, 45,51,53,61,62,63] challenges accessing game on computer (e.g., logging in),[57] unpredictable system performance[45]
			Quantitative	Video and audio quality of platform,[50,51,52,55,59,67] limited difficulties seeing or operating games on tablet,[53] functions of telerehabilitation platform well integrated,[60] limited inconsistencies with platform[60] or technology,[55] general satisfaction with device,[40,58] physical comfortability of technical device,[44] secure[41] and easy[64] communication platform with therapist and limited concerns for privacy risks[46]	Internet speed and connectivity,[42,52] limited internet access,[32] use of tablet, quality of image and sound from other participant in group,[50] challenges with recovering easily and quickly after making a mistake with the system and lack of input from system on troubleshooting protocol,[46] unresponsive software, loss of video, sound and password to software,[32] more than a few technical issues encountered[37]
Logistical considerations of the environment used for telerehabilitation	Considerations related to the physical environment that facilitated or impeded participation.[97]	Environmental	*Qualitative*	Home environment conducive to perform exercises due to privacy and adequate physical space,[63] and virtual environments does not expose disabilities to everyone in a room[49]	Limited spacing to conduct exercises (e.g., crowded spaces),[38,39] inappropriate size of device used (either too small or heavy)[39,41]
			Quantitative	Safety of conducting exercises, sufficient equipment and space to conduct exercises and see instructor at the same time[51]	Safety of conducting exercises in virtual environment and pets as distractions[50] and

					limited spacing,[50,64] climate conditions regarding time of year (i.e., hot or cold)[64]
Telerehabilitation program/intervention characteristics	Any characteristics of the telerehabilitation program/intervention that facilitated or impeded participation[8]	Environmental	*Qualitative*	Satisfaction with VR and exergames, exercises and telerehabilitation application,[30] suitability of program for targeting personal needs,[49,57] challenging and personalized games,[45,62] variety in games,[38,45,57,61,62] flexibility and/or convenience of training schedule (ability to exercise on own time, control over training through being able to divide sessions into multiple shorter bouts, etc.)[38,39,41,45,61,63,65]	Lack of rest between sets,[31] repetition/limited variety of games and/or exercises,[31,61,63,65] parameters of difficulty (limited[31] or too challenging[64,67]), lack of flexibility to adjust reminder prompts based on desired exercise schedule (managed by therapist)[63]
			Quantitative	Appropriate length of sessions and/or training duration,[37,40,50,55] exercise progression and program structure,[50,52] satisfactory intervention components (e.g., education modules, handheld devices, exercise, appointment reminders),[40,44,50] variety in exercises[50,51] and degree of difficulty of exercises (in line with physical abilities),[51] pacing of training,[53] appropriateness of exercises for condition,[52] pleasant interface and organization of information on screens clear and easy to find,[46] training schedule established routine[50]	Explanations of exercise too long, difficulty of exercises, training too early in the morning[50]
Accessibility of Telerehabilitation	How easy it is for a person to access rehabilitation services regardless of physical, educational, social, psychological, or cultural conditions[98]	Environmental	*Qualitative*	Facilitates access to rehabilitation services without need to travel[31,49,51,61,65,66]	NA
			Quantitative	No reliance on transportation and easy access to exercise training[50,52]	NA
Costs	Monetary costs including time and transportation	Environmental	*Qualitative*	Time efficiency of telerehabilitation (no commute[49,61] or wait times prior to	Substantial time commitment of program,[38,57,61,64] program fee[67]

	associated with participating in telerehabilitation program[93]			session)[61] allows for higher dosages of therapy[38] no monetary costs (affordable)[65]	
			Quantitative	NA	NA
Resources	Materials provided to participants that facilitated or impeded participation in telerehabilitation program.[16,17]	Environmental	*Qualitative*	Provision of comprehensive manuals to guide technological and spacing set-up, guidance on conducting exercises, and documenting progress[66]	Lack of clear instructors provided for setting up equipment[65]
			Quantitative	Video resources provided in platform,[41] clear and effective documentation[46]	NA
Service delivery	Logistical considerations related to receiving a healthcare intervention/service through the means of telerehabilitation intervention.[99]	Environmental	*Qualitative*	Opportunity to prolong rehabilitation and continuum of care,[48,66] positive engagement with research team via videoconferencing software,[45] convenient means of service delivery (e.g., receive rehabilitation services from therapist without leaving home),[51,53] convenience of receiving information from therapist via a chat function,[61] adequate training of therapists to delivery telerehabilitation[67]	Lack of direct assistance[61] and physical touch[65] from therapist, inconvenience of sending information to therapist via a chat function and temptation to cheat on exercises given limited supervision in virtual environment,[61] limited to exercising in home environment[63]
			Quantitative	Overall treatment experience and satisfaction with service delivery,[35,37,41,43,44,46,47,50,51,55,56,58,59,64] reasonable wait times to see therapist,[59] access to healthcare service helped patient and their family,[35] comparable satisfaction to in-person therapy,[52,64] convenient means of service delivery[52]	NA
Role of the Therapist and/or Staff	Reflects the roles possessed by the therapist and or staff.[73,100]	Environmental & Social Influences	*Qualitative*	Monitoring by therapist and/or staff (e.g., assistance related to technological challenges and set up,[45,49,62] monitoring progression and general health,[61,63,65] observation/supervision of exercises.[38] Communication skills: provision of verbal support (motivation) and/or encouragement,[30,31,38,51,53,66,67] correct and	Psychosocial strain due to monitoring by therapist,[61] miscommunication between participant with aphasia and therapist[31]

				share feedback on exercises,[30,31,38,66] help build confidence[46]	
			Quantitative	Communication skills: clarity of instructions and/or explanations,[42,47,55,56] answered questions[47,56,59] and timeliness of responses,[41] respect,[47,55,56,59] listened to participants concerns,[47,50,55,56,64] provision of safety tips[50] and feedback,[64] courteous, sensitive and friendly.[36,59] Staff availability,[42] time with therapist,[47,56,59] guidance on avoiding future problems,[47] supervision,[50] thoughtfulness, carefulness/competence and skillfulness of therapist,[36,59] adequate follow-up from staff and/or therapist between sessions,[55] overall strong relationship with healthcare professional,[35,43,64] autonomy support[32]	NA
Psychological factors	Intrinsic psychological factors (e.g., motivation, perception of benefits, attitudes and beliefs, etc.) that drove or limited an individual's participation in a telerehabilitation program/intervention.[101]	Intention & Reinforcement	*Qualitative*	Motivation to improve post-stroke impairments[61] eagerness to experiment with technology,[30] humour and perseverance as helpful character traits,[61] awareness of the usefulness of technology.[31] Liking of the games used in intervention,[31] reminder feature and remote monitoring,[63] and progress/user feedback[38,45,46,48] elicited motivation to engage in program, being competitive and not wanting to lose.[62] Perceived usefulness for creating health benefits (use of device helped establish autonomy to exercise independently)[63]	Disability level from stroke influencing motivation to exercise,[65] lack of intrinsic motivation increasing strain on relationship with caregiver,[61] lack of internal motivation to exercise[63,64]
			Quantitative	Perceived usefulness or benefit of participating in program (e.g., to improve function, as rehabilitation tool, etc.),[32,33,42,46,58,60] positive attitudes towards use of new technology,[33]	NA

				willingness to participate (i.e. carry out telerehabilitation sessions,[47,56] perceived intent to participate (i.e., perceived choice),[58] program did not interfere with relationships with friends/family[64]	
Affective factors	Affective factors (i.e., emotions) influencing participation in telerehabilitation program/intervention. Involves a complex reaction pattern involving experiential, behavioural and physiological elements.[102]	Emotion & Reinforcement	*Qualitative*	*Enjoyment* with telerehabilitation program/platform,[38,45,51,53,61] *enthusiasm* towards flexibility of telerehabilitation,[61] desire to help others with stroke through participation (i.e., *altruism*)[48]	*Anxiety* related to exercising and upper limb improvement,[30] psychosocial pressures due to physical presence of software, and *frustration* from training with partner,[61] *Fear* of injury and falling,[64] feeling *annoyed* due to repetition of exercises[61]
			Quantitative	*Enjoyment* with telerehabilitation program/platform,[40,46,60] lack of *boredom* while exercising,[37] *trust* in software used in program to fulfill rehabilitation needs[46]	NA
Perceptions of changes in mental and/or psychosocial outcomes from participating in a telerehabilitation program	The self-reported changes (positive or negative) in mental outcomes and/or psychosocial outcomes after completing a telerehabilitation program (i.e., post-intervention).[95]	Emotion & Reinforcement	*Qualitative*	Improvements in mental and socio-emotional wellbeing,[38] mood improvement,[39] feelings of pride as a result of improvements[61] and achievements,[46] general increase in self-confidence and/or courage[51,61] and for conducting ADLs with the affected arm,[45] motivation and discipline for exercise[51]	NA
			Quantitative	Improved focus, productivity,[52] mood[55]	NA
Social support from family and/or peer support	Support received from friends, family members or peers that facilitate or impede participation in telerehabilitation program [103,104]	Social Influences	*Qualitative*	Positive feedback/encouragement and support with technology from friends and family[30,31,38,41,61,66] (or paid-worker[65]), positive group dynamic with peer(s) in program[66,67]	Training with assistance from partner deemed as frustrating,[61] limited request for support with technological difficulties from caregiver even though recommended by research team,[57] lack of support from family member or helper[64]
			Quantitative	Class atmosphere and motivation provided by group/peers[50,52]	NA
Cognitive Abilities	Cognitive abilities needed to follow instructions and		*Qualitative*	NA	Cognitive deficits impacting processing and ability to participate[57]

	participate in telerehabilitation program/intervention.[105]	Memory & Attention Processes	*Quantitative*	NA	NA
Self-efficacy	Beliefs in one's capacity to participate in telerehabilitation program/intervention and/or achieve goals (i.e.., ability to perform the target behaviour).[106]	Beliefs about capabilities	*Qualitative*	Confidence to use technology[49]	Doubted abilities to control impaired extremity[46]
			Quantitative	High degree of confidence in physical abilities (e.g., changing directions and hemiparetic leg utilization),[50] confidence learning[41] and using technology[46,60]	Not confident in physical abilities to execute exercises[52]
Sustained use of telerehabilitation	Perspective and/or behaviours around intention to continue using telerehabilitation in the future or intention to sustain behaviours acquired from participation in program.[107]	Intention & Behavioural Regulation	*Qualitative*	Positive Behavioural Intention[38,46,61,63]	NA
			Quantitative	Positive Behavioural Intention,[44,50,51,53,55,59] maintained use of affected limb after end of intervention[32]	NA
Recommended use of telerehabilitation for others	Encouragement or recommendation of telerehabilitation services/programs to other individuals with stroke.[108]	Optimism	*Qualitative*	NA	NA
			Quantitative	Would encourage or recommend telerehabilitation to other individuals [37,40,44,47,50,51,52,55,56]	NA
Desired Goals	Perceived desired physical, psychosocial, emotional result of participation in telerehabilitation program/intervention[109]	Goals	*Qualitative*	Goal to return to pre-stroke functioning[48]	NA
			Quantitative	NA	NA
Roles and responsibilities	Reflects the prioritization of participating in telerehabilitation program or adherence to the exercise prescription given other roles and/or responsibilities.[75]	Social Identity & Roles	*Qualitative*	NA	Difficulties with following recommended exercise prescription (lacked time) due to social and domestic activities (e.g., book clubs and stroke support groups, relatives' appointments)[57,64]
			Quantitative	NA	NA

Note. NA= Not Applicable. Mean or median scores reflecting neutral/mixed values were qualitatively described in the results section and were not included in the count of facilitators and barriers.

Appendix 2.1. Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	29
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	30
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	32-33
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	33
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	33
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	33-35
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	NA
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Appendix 2.1
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	36
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	37
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	35 (define facilitators and barriers + guiding framework)

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	40-41
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	37-40
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	42
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	43-44
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	Appendix 2.5
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Tables 2.2 and 2.3
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	35-49 and Table 2.4
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	50-54
Limitations	20	Discuss the limitations of the scoping review process.	54
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	55
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	NA

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.
* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.
† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).
‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.
§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

Appendix 2.2. MEDLINE Search Strategy

1. exp Ischemic Stroke/ or Thrombotic Stroke/ or exp Hemorrhagic Stroke/ or exp "National Institute of Neurological Disorders and Stroke (U.S.)"/ or exp Stroke/ or exp Embolic Stroke/ or Stroke.mp. or exp Stroke, Lacunar/
2. Brain Ischemia.mp. or exp Brain Ischemia/
3. ((online or virtual) adj3 rehab*).mp.
4. telerehabilitation.mp. or exp Telerehabilitation/
5. Tele-rehabilitation.mp.
6. Telemedicine.mp. or exp Telemedicine/
7. virtual rehab*.mp.
8. virtual care.mp.
9. Telerehab*.mp.
10. Communication tech*.mp.
11. distance rehab*.mp.
12. remote rehab*.mp.
13. stroke telerehabilitation.mp.
14. Barrier*.mp.
15. facilitat*.mp.
16. Experience.mp.
17. imped*.mp.
18. challenge*.mp.
19. enabl*.mp.
20. Satisfaction.mp. or exp Personal Satisfaction/
21. Participat*.mp.
22. compl*.mp.
23. compliance.mp. or exp Compliance/ or exp "Treatment Adherence and Compliance"/
24. accept*.mp.
25. feasib*.mp.
26. user satisfaction.mp.
27. participant satisfaction.mp.
28. (surveys and questionnaires).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
29. self-report.mp. or Self Report/
30. qualitative research.mp. or exp Qualitative Research/
31. randomized controlled trial.mp. or exp Randomized Controlled Trial/
32. feasibility study.mp. or exp Feasibility Studies/
33. 1 or 2
34. 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13
35. 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27
36. 28 or 29 or 30 or 31 or 32
37. 33 and 34 and 35 and 36

Appendix 2.3. Operationalized definitions for each domain, guided by established definitions by Atkins & Cane

Domain of TDF	Atkins & Cane Definition	Operational Definition used in current study
1. Knowledge	An awareness of the existence of something (e.g., procedural knowledge, knowledge of task environment)	a. Understanding and/or awareness on how to operate and use technology used in telerehabilitation intervention. b. Understanding and/or awareness of procedures involved with telerehabilitation intervention (e.g., set up, using videoconferencing software) c. Knowledge of the rationale for the intervention (e.g., improve physical function) Example: Lack of information from healthcare provider
2. Skills	An ability or proficiency acquired through practice (e.g. competence, ability, interpersonal skills)	a. Competence/proficiency/ability to successfully engage/participate in telerehabilitation intervention. b. Competence/proficiency/ability to navigate technology used in the telerehabilitation program. Example: Skills needed to use equipment properly
3. Social/professional role and identity	A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting (e.g., professional identity, professional role, leadership, professional confidence)	a. Work, social, professional identity (*could encompass gender roles*) that influence participation in a telerehabilitation program
4. Beliefs about Capabilities	Acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use (e.g., self-efficacy, self-esteem, empowerment, self-confidence)	a. Perceived self-efficacy and/or self-esteem needed to participate in a telerehabilitation program. *Note that the beliefs about capabilities can be in any capacity (could be their self-efficacy with technology, balance self-efficacy, etc.).* ***Improvements*** in these psychosocial domains from participating in a telerehabilitation program, would be mapped onto the reinforcement domain
5. Optimism	The confidence that things will happen for the best (e.g., optimism, pessimism)	a. Optimism OR pessimism that participation in telerehabilitation will lead to health improvements or any other outcomes Example: Positive health outlook, recommendation of telerehabilitation to others due to own personal positive experiences
6. Beliefs about consequences	Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation (e.g., outcome expectations, anticipated regret, beliefs)	a. Outcome expectations (negative) and/or beliefs about the consequences of not participating in telerehabilitation program *Note the beliefs can be related to physical, social, or mental outcomes.*
7. Reinforcement	Increasing the probability of a response by arranging a dependent relationship, or	a. Reward, incentive, punishment associated with participating in telerehabilitation program

Domain of TDF	Atkins & Cane Definition	Operational Definition used in current study
	contingency, between the response and a given stimulus (e.g., rewards, incentive, punishments)	*Note the reinforcement can be related to physical, social, or mental outcomes.* Example: Physical/mental benefits enjoyment, fatigue, tired, improved physical outcomes, improved mood (specific to incentives of participating in a telerehabilitation program)
8. Intentions	A conscious decision to perform a behaviour or a resolve to act in a certain way (e.g., stability of intention, stages of change model)	a. Intention (willing to make health change) and motivation to engage in behaviour (e.g., engage in telerehabilitation program). Readiness and/or motivation to exercise Example: Possessing or lacking motivation, prioritizing exercise over other activities, intention to engage in telerehabilitation in the future, if offered
9. Goals	Mental representations of outcomes or end states that an individual wants to achieve (e.g., goals, goal priority, action planning)	a. Personal goals and desired end state of participating in telerehabilitation program (e.g., goal and outcome of improving physical function), objectives of participating in a telerehabilitation program Example: Better health, social interaction, weight loss
10. Memory, attention and decision processes	The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives (e.g., decision making, attention, control)	a. Decision making capabilities and cognitive function (e.g., memory, attention) needed to successfully participate in the different aspects of a telerehabilitation program. Influence on cognitive function on ability to exercise
11. Environmental contexts and resources	Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence and adaptive behaviour (e.g., environmental stressors, resources/materials)	a. Any factors (time, costs, home environment, characteristics of telerehabilitation program, technological considerations) that encourage or discourage participation in a telerehabilitation program. b. Any resources (e.g., study manuals, access to and/or guidance from a therapist) that encouraged or discouraged participation in a telerehabilitation program
12. Social Influences	Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours (social pressures, social norms, social support, power, modelling)	a. Influence/Effects (positive or negative) of *external* social influences on participation in telerehabilitation program. *Note the social support can be received from friends, family, etc.*
13. Emotion	A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a	a. Affective factors (e.g., fear, stress, anxiety, depression) that impacted ability to participate in telerehabilitation program b. Feelings, mood, and/or emotions held after participating in a telerehabilitation program

Domain of TDF	Atkins & Cane Definition	Operational Definition used in current study
	personally significant matter or event (e.g., fear, anxiety, stress, depression)	
14. Behavioural Regulation	Anything aimed at managing or changing objectively observed or measured actions (e.g., self-monitoring, action planning, breaking habit).	a. Ability to maintain exercise (based on intervention received in a telerehabilitation program) behaviours through self-monitoring, action plan development, etc. Example: Develop new routine, combining exercise with other behaviours

Appendix 2.4. Scoring System for Quantitative Studies

Table (example Likert Scale 1-5) provides ranges of means or medians used to determine if items in quantitative questionnaires were facilitators (e.g., agree to strongly agree for positive experiences with the telerehabilitation program or strongly disagree to disagree for negative experiences with telerehabilitation program) or barriers (e.g., strongly disagree to disagree for positive experiences with the telerehabilitation program or agree to strongly agree for negative perceptions with the telerehabilitation program).

In this example, participants would have been asked to provide a rating from 1 (Strongly Disagree) to 5 (Strongly Agree) to items in a questionnaire. See below for a mock example of how facilitators or barriers were inferred.

	Raw Likert values for individual questionnaire items	Range used for overall mean/median classification (facilitator or barrier)
Strongly Disagree	1	1.00-1.80
Disagree	2	1.81-2.60
Neutral	3	2.61-3.40
Agree	4	3.41-4.20
Strongly Agree	5	4.21-5.00

This is example is reflective of the responses from a study with n=10 participants.

Statement	Mean score across n=10 participants
The therapist provided feedback on the exercises	4.3
Facilitator or Barrier based on overall mean?	*Facilitator.* ***Why?*** *4.3 falls within the range of* ***strongly agree*** *for this positively framed statement.*

Note that most of the quantitative studies included a 5-point Likert Scale system, and as such this scoring system was applied.

Appendix 2.5. Quality Appraisal Tables

NIH Quality Assessment Tool for Before- After (Pre-Post) Studies with No Control Group

Study	1. Was the study question/ objective clearly stated?	2. Were eligibility criteria for the study population pre-specified and clearly described?	3. Were the participants in the study representative of those who would be eligible for the intervention in the population of interest?	4. Were all eligible participants that met the prespecified entry criteria enrolled?	5. Was the sample size sufficiently large to provide confidence in the findings?	6. Was the intervention clearly described and delivered consistently across the study population?	7. Were the outcome measures prespecified, clearly defined, valid, reliable, and assessed consistently across all study participants?	8. Were the people assessing the outcomes blinded?	9. Was the loss to follow-up after baseline 20% or less? Were those lost to follow-up accounted for in the analysis?	10. Did the statistical methods examine changes in outcome measures before to after the intervention? Were statistical tests done that provided p values for the pre-to-post changes?	11. Were outcome measures taken multiple times before and multiple times after the intervention?	12. Did the statistical analysis take into account individual - level data to determine effects at the group level?	**Rating**
Bellomo 2020 (33)	Yes	Yes	Yes	Yes	Yes (sample size calculation conducted)	Yes	Yes	No	Yes	Yes	NA	NA	Good
Bernocchi 2016 (35)	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	NA	NA	Fair
Bindschedler 2024 (36)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes (8.3%) attrition)	Yes	NA	NA	Good
Burdea 2020 (37)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	NA	NA	Good
Cho 2021 (40)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NA	NA	NA	Good

Contrada 2022 (42)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	NA	NA	Good
Corriveau 2013 (43)	Yes	Yes	Yes	NR	No	No	No	No	Yes	Yes	NA	NA	Poor
Dodakian 2017 (44)	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	NA	NA	Fair
Edwards 2023 (47)	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	NA	NA	Fair
Gagnon 2023 (50)	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	NA	NA	Fair
Leochico 2023 (52)	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	NA	NA	Fair
McCormick 2022 (54)	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	NA	NA	Fair
Park 2023 (55)	Yes	Yes	Yes	Yes	Yes (effect size analyses conducted)	Yes	Yes	No	Yes	Yes	NA	NA	Good
Rozevink 2021 (58)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes (blinded to progress)	Yes	Yes	NA	NA	Good
Sarfo 2018 (59)	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	NA	NA	Fair
Simpson 2020 (60)	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	NA	NA	Fair

Note. Majority of studies were feasibility studies and as such did not have large sample sizes and scored poorly on the sample size criteria. Only 1 study performed a sample size calculation, and study assessors were not blinded to the participants timepoint (pre-post), thus were mostly downgraded to fair. Studies did not use interrupted time series designs and as such were coded as NA to avoid downgrading quality of the studies.

Joanna Briggs Institute Critical Appraisal Checklist for Qualitative Research

Study	1. Is there congruity between the stated philosophical perspective and the research methodology?	2. Is there congruity between the research methodology and the research question or objectives?	3. Is there congruity between the research methodology and the methods used to collect data?	4. Is there congruity between the research methodology and the representation and analysis of data?	5. Is there congruity between the research methodology and the interpretation of results?	6. Is there a statement locating the researcher culturally or theoretically?	7. Is the influence of the researcher on the research, and vice- versa, addressed?	8. Are participants, and their voices, adequately represented?	9. Is the research ethical according to current criteria or, for recent studies, and is there evidence of ethical approval by an appropriate body?	10. Do the conclusions drawn in the research report flow from the analysis, or interpretation, of the data?	**Overall Appraisal**
Chen 2020 (38)	Yes	Yes	Yes	Yes	Yes	*No	*No	No	Yes	Yes	Seek further info
Cherry 2017 (39)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Include
Donnelly 2023 (45)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Include
Gaboury 2022 (49)	Yes	Yes	Yes	Unclear	Unclear	No	No	No (limited illustrative quotes from participants)	Unclear (not specific on what funding body)	Yes	Seek further info
Spits 2022 (61)	Unclear**	Unclear**	Unclear**	Unclear**	Unclear**	Yes	Yes	Yes	Yes	Yes	Seek further info
Tyagi 2018 (65)	Yes	Yes	Yes	Not clear	No	No	No	Yes	Yes	Yes	Seek further info

Wiley 2024 (66)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Include
Note.*COREQ checklist provided in appendix but not addressed in methods of the manuscript. **Qualitative methodology used in study not reported (solely mentions that a qualitative approach was taken).											

Mixed Methods Appraisal Tool, Version 2018

Study	1. Is there an adequate rationale for using a mixed methods design to address the research question?	2. Are the different components of the study effectively integrated to answer the research question?	3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?	4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?	5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?	**Comments**
Conroy 2022 (41)	Yes	Yes	No	Yes	No	Qualitative component lacks detail on methodology, analysis, and interpretation of results. Reflexive statement not present in qualitative portion of methodology section.
Donnelly 2024 (46)	Yes	No	No	Yes	No	Qualitative component lacks detail on methodology, analysis, and interpretation of results. Reflexive statement not present in qualitative portion of methodology section.
Fluet 2024 (48)	Yes	Yes	Yes	Yes	No	Reflexive statement not present in qualitative portion of methodology section.
Galloway 2019 (51)	Yes	No	No	NA	No	Qualitative component lacks detail on methodology, analysis, and interpretation of results. Reflexive statement not present in qualitative portion of methodology section. Few illustrative quotes provided.
Proffitt 2015 (57)	Yes	Yes	No	Yes	No	Qualitative component lacks detail on methodology, analysis, and interpretation of results. Reflexive statement not present in qualitative portion of methodology. Few illustrative quotes for qualitative portion provided.
Szturm 2020 (62)	Yes	Yes	No	Yes	Yes	Reflexive statement not present in qualitative portion of methodology. No illustrative quotes for qualitative portion provided.

Toh 2023 (63)	Yes	Yes	Yes	Yes	Yes	Both quantitative and qualitative components adequately addressed in all sections of manuscript.
Torriani-Pasin 2021 (64)	Yes	Yes	Yes	NA	No	Illustrative quotes provided for only a few barriers analyzed from the open-ended qualitative component. Results on item 10 in quantitative analysis do not match in Table 5 and overview of results.
Yang 2021 (67)	NR	NR	No	NR	No	Use of mixed methods emphasized, however no insight how the two different methodologies were incorporated or analyzed. Insufficient detail of methodologies used to perform adequate quality appraisal.
Note. Tool does not come up with overall rating, but instead encourages providing comments on each section						

Cochrane Risk of Bias Summary (RoB 2)						
Study	Randomization Process	Deviations from Intended Interventions	Missing Outcome Data	Measurement of the Outcome	Selection of the Reported Result	Overall Bias
Allegue 2022b (32)	Some Concerns	High	High	High	Low	**High**
Piron 2008 (56)	Some Concerns	Low	Low	Low	Some Concerns	**Some Concerns**

Joanna Briggs Institute Critical Appraisal Checklist for Qualitative Research for Case Reports

Study	1. Were patient's demographic characteristics clearly described?	2. Was the patient's history clearly described and presented as a timeline?	3. Was the current clinical condition of the patient on presentation clearly described?	4. Were diagnostic tests or assessment methods and the results clearly described?	5. Was the intervention(s) or treatment procedure(s) clearly described?	6. Was the post-intervention clinical condition clearly described?	7. Were adverse events (harms) or unanticipated events identified and described?	8. Does the case report provide takeaway lessons?	**Overall Appraisal**
Allegue 2021 (30)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**Include**

Joanna Briggs Institute Critical Appraisal Checklist for Qualitative Research for Case Series

Study	1. Were there clear criteria for inclusion in the case series?	2. Was the condition measured in a standard, reliable way for all participants included in the case series?	3. Were valid methods used for identification of the condition for all participants included in the case series?	4. Did the case series have consecutive inclusion of participants?	5. Did the case series have complete inclusion of participants?	6. Was there clear reporting of the demographics of the participants in the study?	7. Was there clear reporting of clinical information of the participants?	8. Were the outcomes or follow up results of cases clearly reported?	9. Was there clear reporting of the presenting site(s)/clinic(s) demographic information?	10. Was statistical analysis appropriate?	**Overall Appraisal**
Allegue 2022a (31)	Yes	Yes	Yes	Yes	No*	Yes	Yes	Yes	Yes	Yes	**Include**
Lim 2022 (53)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**Include**
Note. *Authors noted that 2 of the 5 participants of interest were not included in the case series.											

Risk of Bias in Non-randomised studies – of Interventions (ROBINS-I) to assess the quality of non-randomised interventional studies

Study	Confounding	Selection Bias	Classification of Intervention	Intended Intervention	Missing Data	Measurement of Outcomes	Reported Results	**Overall**
Benvenuti 2014 (34)	Moderate	Low	Moderate	Moderate	High	High	Low	**High**

CHAPTER 3: Exploring the experiences of an exercise-based telerehabilitation program among Canadian community-dwelling adults with stroke

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Key words: Telerehabilitation, exercise**,** stroke, virtual rehabilitation, qualitative

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Implications for Rehabilitation

- Exercise-based telerehabilitation for individuals with stroke can be delivered safely when clinicians are trained, and social support and program resources are available.
- Exercise-based telerehabilitation may be viable and accessible for men and women with stroke to extend the opportunity for rehabilitation services within the first year post-event.
- Synchronously-delivered telerehabilitation programs using user-friendly videoconference software is recommended for optimal participant satisfaction.

3.1 Abstract

Introduction: Telerehabilitation is emerging as a means for delivering stroke rehabilitation to address unmet lower extremity rehabilitation needs. However, there is currently limited and low-quality evidence supporting the use telerehabilitation interventions for lower extremity recovery after stroke. Thus, we developed an exercise-based telerehabilitation program (TRAIL) for safe and effective promotion of lower extremity function after stroke. This study reports on the qualitative findings from the feasibility study of the TRAIL program.

Methods: An interpretive description methodology and inductive thematic analysis approach were undertaken. One-on-one semi-structured interviews were conducted on a subset of participants who completed the TRAIL feasibility study. Participants were recruited via email and enrolled into the study based on pre-determined purposeful sampling strategies.

Results: Ten participants (6 men, 4 women) completed a semi-structured interview. Two main themes emerged: (i) TRAIL ingredients for success and (ii) telerehabilitation is a viable option for stroke rehabilitation.

Conclusion: Exercise-based telerehabilitation appears to be well-received by men and women post-stroke when social support, professional guidance, and program resources are offered. TRAIL may also prolong the continuum of care that individuals receive once they are discharged back into the community, and contribute to improvements in mobility, lower extremity strength and balance.

3.2 Background

With over 80 million individuals living with stroke worldwide [1], acute and long-term support systems are paramount to promote stroke recovery [2]. Unfortunately, however, mobility impairments [3], balance and falls concerns [4,5], and lower extremity strength deficits [6,7] are among the unmet rehabilitation needs commonly reported by individuals post-stroke. If left unaddressed within 1-year of stroke, such unmet needs are likely to reduce quality of life [8], reduce the ability to perform activities of daily living (ADLs) and increase the risk for institutionalization [9]. Thus, physical therapy-based rehabilitation is paramount for the recovery of lower extremity limitations.

Telerehabilitation is emerging as a means for delivering stroke rehabilitation services to address unmet lower extremity rehabilitation needs, due to key factors such as its accessible, economical, and time-efficient nature for both patients and therapists [10]. A recent Cochrane review of three trials involving 106 participants post-stroke reported equivalent improvements in mobility and balance outcomes between in-person and telerehabilitation interventions [11]. These findings are limited, however, by the small number of trials and low quality of evidence for lower extremity recovery with telerehabilitation interventions [11].

Thus, we developed a new exercise-based telerehabilitation program, TeleRehabilitation with Aims to Improve Lower extremity function post-stroke [TRAIL] designed to safely and effectively promote lower extremity recovery after stroke. The TRAIL program is a 4-week, therapist-led progressive intensity exercise and self-management program, delivered using videoconferencing platforms in a ≤2:1 participant-to-physiotherapist (PT) ratio. Participants received two 60-90-minute synchronous telerehabilitation sessions per week (total 8-12 hours of telerehabilitation). In addition to the real-time guidance provided by a trained PT, participants

received an *Exercise Manual* that offered visual illustrations and written instructions for modifying the level of difficulty of the lower extremity-focused exercises.

The TRAIL program was also designed to include a self-managed exercise component, of which was modeled after systematic review evidence that positive self-management behaviours promote sustainable long term exercise behaviours [13]. This portion of the program was facilitated by a *Participant Exercise Log* consisting of action plans of TRAIL exercises. The action plans were developed collaboratively between each participant and their PT, with participants being instructed to independently execute the action plan of TRAIL exercises at least once per week, in addition to their formal bi-weekly sessions. At the beginning of each week, the participant and PT debriefed on whether the successful undertaking of their action plan was achieved. If not feasible, evaluation and further refinement of the action plan was enforced.

We recently completed a single group pre-post feasibility study of TRAIL with 32 participants post-stroke, with findings indicating high treatment fidelity, program satisfaction, and program adherence with no dropouts or serious adverse events [14]. We also noted positive trends in mobility (Timed Up and Go) and motor impairment (Fugl-Meyer Lower Extremity Assessment) [14]. These quantitative findings are encouraging, but seeking the perspectives of stakeholders and end-users involved with telerehabilitation programs is also of value to understand the acceptability of stroke telerehabilitation, and exploring opportunities for further refinement in TRAIL program delivery.

Indeed, previous qualitative studies have explored the acceptability of telerehabilitation in individuals with stroke and found that participation is facilitated by perceived improvements in physical and psychological impairments [15–18], enjoyment [15,16,19], ability to track progress [16], accessibility [15,17–20], affordability [17], and external support from the

therapist and family members [15]. Documented barriers to participation in exercise-based telerehabilitation include challenges with technological setup and interface [15–18], lack of physical touch from the therapist [17,20], repetition in the types of exercises [17], and inadequate spacing in the physical environment [15]. We note however that the themes arising from these previous studies involved virtual reality [16], robotic or exergame style (i.e., sensor-based) [15,17] or multi-component (e.g., goal-setting, information sharing and exercise) [20] with limited emphasis on real-time therapist instructed and guided programs for lower extremity recovery after stroke [21]. We note that asynchronous virtual reality-based platforms may be limited to the delivery of auditory prompts (e.g., automated claps and cheers) as the primary method of performance feedback [16], thereby further limiting opportunities for live interactions with therapists. Thus, there remains a need to understand the experiences with synchronously delivered telerehabilitation programs among individuals with stroke.

This study reports on the qualitative findings from the feasibility study of the TRAIL program. The primary objective of this study was to develop a deeper understanding of the complex interactions of experiences in relation to telerehabilitation post-stroke. Specifically, our emphasis was to describe and understand the experiences [22] of the individuals post-stroke who participated in TRAIL in terms of their perceptions of the program delivery and resources, as well as lower-extremity related rehabilitation outcomes.

3.3 Methodology

Study Design

We used an interpretative description (ID) qualitative study design to address our study aims [23,24]. The study was approved by the University of British Columbia Clinical Research Ethics Board (ID# H21-00133) and McMaster University Hamilton Integrated Research Ethics

Board (ID #13361), and was completed with a subset of participants involved with the multi-centred TRAIL feasibility study (NCT04265664). All study procedures were followed in accordance to the COsolidated criteria for REporting Qualitative research (COREQ) checklist [25] and guidelines outlined by the respective institutional research ethic committees. Informed written consent was obtained from all participants.

Participants

For the TRAIL feasibility study, individuals were eligible if they were 19 years of age or older, within 18 months of stroke with lower extremity hemiparesis, able to walk 10 metres without physical assistance of another person, able to tolerate 50 minutes of activity with rest breaks, had a helper available to provide physical support during the assessment sessions, had cognitive-communicative ability to participate, and were able to provide informed consent. Potential participants were excluded if they were receiving in- or outpatient rehabilitation focused on lower extremity recovery, living in long-term care, had severe vision or hearing loss or other neurological conditions, presented with significant comorbidities, were not medically stable, or if they had planned surgery that would preclude or affect safe participation in TRAIL.

To maximize participant safety in the TRAIL study, precautionary measures were implemented. Firstly, the delivery of all study procedures were by a physical therapist registered to practice in the same jurisdiction as the participant, who also received 3-hours of comprehensive training and detailed written manuals. Furthermore, pre- and post-participation checklists that included emergency contact information and considerations for current health status and room/technological setup were completed for each participant. Finally, all exercises could be modified (graded from less to more challenging) to suit participants' abilities and/or to minimize risk of harm.

Additionally, as older adults tend to possess lower levels of knowledge and confidence with technology [26], the onboarding process for the TRAIL program involved two orientation sessions (i.e., familiarizing the participant with the videoconferencing platform, establishing camera angles and adequate placement of the device). Participants also received a *Participant Manual* which reinforced the space requirements (e.g. dimensions, lighting, free from trip hazards), technology requirements (e.g. device specifications), and safety requirements (e.g. pre-participation checklist, availability of hand support during standing exercises).

Participants were recruited from 5 sites (Halifax, Winnipeg, Vancouver, London, Toronto) from the CanStroke Recovery Trials Platform which is a network of Canadian sites to facilitate participant recruitment and quality trial practices [27]. Based on institutional licenses held at each site, the videoconferencing program used to administer the telerehabilitation program was either Microsoft Teams© or Zoom©.

To be included in this qualitative study of TRAIL, participants needed to have completed the TRAIL program and consented to be contacted for future studies.

Recruitment and Sampling Strategies

Participants were recruited via email by the study coordinator of the feasibility study (SP). Prior to applying our specific sampling strategies, all 32 participants were eligible to participate as they had all completed the TRAIL program. Purposeful sampling strategies including criterion-i (i.e., meeting program inclusion described above) and maximum variation [28] were employed. We performed maximum variation sampling based on geographic location and on gender identity, to understand whether these factors influenced how participants experienced TRAIL. Individuals residing in rural areas tend to have lower incomes, access to technology can be limited [29], and substantial travel time requirements and costs pose as barriers to

accessing stroke care [30]. Previous studies have also shown that women possess lower exercise self-efficacy and motivation for exercise than men [31–33], which may be a product of receiving less external social support [34,35]. Older men also are known to have higher levels of proficiency and enjoyment in internet and technology use [36] and experience fewer barriers to participation in stroke rehabilitation than women [37]. To fulfill our maximum variation sampling strategy on gender identity and geographical location, we aimed to interview one man and woman from each of the five sites. Eight out of the 32 participants who completed the feasibility study identified as women, whereby one site did not enroll any women over the course of the feasibility study due to challenges with recruitment of women with stroke. Thus, a total of 4 women and 6 men were enrolled into the qualitative study. One potential participant declined to participate in the study, and another did not respond to the research team's communications.

Interviews were guided by the principle of evolving conceptualizations arising from the ongoing data analysis, allowing for elaboration on the emerging themes and interpretations not only within, but also between participant accounts [38]. We note that there were no other sampling strategies employed throughout the iterative data collection and analysis processes, as there were no deviant or extreme cases observed and the aforementioned sampling strategies allowed for a rich understanding of the research question.

Data Collection

Informed written electronic consent was obtained using a University of British Columbia licensed Qualtrics form. The survey link was sent to the participant a week in advance for their review, and completed in real-time with the study coordinator over Zoom prior to the interview. At this time, any questions or concerns expressed by the participant were addressed. After

participants provided informed consent, a date and time was scheduled for a one-on-one semi-structured interview, held and recorded over Zoom© videoconferencing software. Each participant completed one interview. With the participant's consent, the audio and video features of Zoom© were used to conduct the study. Interviews approximated 45 minutes in length, and were facilitated by EW and guided by a pre-established interview guide (created in May 2021) with questions related to the overarching concepts of: (i) stroke rehabilitation and recovery (e.g., *What was the recovery journey like for you? What resources or supports, if any, were available to you? What did you use?*) (ii) TRAIL program experience (e.g., *How easy/difficult was it for you to participate in the TRAIL program?; How did you find the exercises?*), (iii) delivery of the program (e.g., *How would you describe your experience with your therapist using video conferencing technology*), and (iv) program resources (e.g., *How did you use the manuals that were provided to you?*). The interviewer (EW) also paid close attention the participants' facial expressions and emotional reactions or responses, and made note of relevant observations that were added as memos during the coding process. The interview guide also included a set of potential follow-up questions, to account for vague or ambiguous responses. The interviewer also asked specific and relevant follow-up questions in scenarios where a more in-depth discussion was warranted.

Data Analysis

Interview transcripts were transcribed verbatim by a trained transcriptionist. Identifiable data were removed and replaced with a participant identification number during transcription. Data analysis involved inductive thematic approach with themes being derived from the data [38,39].

Repeated readings of each transcript were conducted by the primary author (EW) prior to embarking on the coding process [23]. This process was critical to facilitate the emergence of novel perspectives and insights throughout each reading. Data were analyzed using a hand coding approach on Microsoft Word and Excel. As we followed an ID methodology, codes were identified in the data using a broad-based coding approach (i.e., avoiding excessive line-by-line coding) [39] and a codebook with relevant codes and definitions was created after analyzing the initial two transcripts. As the analysis process evolved, the codebook was refined where new codes were added and defined. Next, categories (i.e., sub-themes) were identified [23,40] by grouping coding segments with similar properties and provided with a label [23]. To facilitate this process in Excel, a color-coded legend with each category was provided. Finally, key categories were consolidated into overarching key themes and generated a thematic map of the analysis [23].

Trustworthiness and Rigour

The primary research team engaged in many steps to uphold trustworthiness and rigour in this qualitative study [41]. Each member of the research team noted their reflective biases. The first author, EW (she/her), is a graduate student in Rehabilitation Science and interested in sex and gender considerations in stroke telerehabilitation research. SP (she/her) is a former graduate student in Rehabilitation Science with an interest in stroke telerehabilitation and was the study coordinator for the TRAIL feasibility study. The co-primary investigators of the TRAIL studies (BMS PhD, he/him and AT PT PhD, she/her) shared research expertise on telehealth, exercise, and self-management after stroke was leveraged in the conception of the interview guide and data analysis. Data analysis was also informed by the collective perspectives of team members with research expertise in virtual stroke rehabilitation research. All other co-authors (MB, RB,

JJE, AH, EI, ML, JCM, SeP, CP, RT, and JY) were instrumental in reviewing the different iterations of the manuscript.

To further enhance trustworthiness and rigour, data source triangulation (i.e., use of multiple data sources) was implemented. Prior to the interviews, EW observed 2 participants during TRAIL sessions, taking field notes on participant engagement in TRAIL and interaction with their therapist. As well, EW conducted all interviews, with SP observing the initial two interviews and debriefing with EW on the field notes from those interviews.

Stepwise replication of coding involved EW and SP independently coding the first 2 transcripts and discussing the derived codes to ensure consistency and dependability of the initial codebook [23,42]. EW then independently coded the remaining transcripts using the initial codes, as well as continued to add new codes. Near the final stages of data analysis, frequent meetings were held between EW, SP, BSM, and AT to discuss and refine the identified themes. If present, the team also planned to discuss any deviating themes or concepts. Finally, an audit trail was created to capture the decisions involved with the analysis process that led to the final interpretation of the data [38].

3.4 Results

Participant demographics (6 men; 4 women) are provided in Table 3.1.

Table 3.1. Participant Demographics (n=10)

Sex (n, %)	
Male	6 (60%)
Female	4 (40%)
Gender Identity (n, %)	
Man	6 (60%)
Woman	4 (40%)
Age, mean (SD), min-max	61.9 (16.3), 26-80
Time post-stroke (months), mean (SD), min-max	11.3 (4.7), 5.68 – 18.3

Affected Limb (n, %)	
Right	5 (50%)
Left	4 (40%)
Bilateral	1 (10%)
Recurrent Stroke (n, %)	
Yes	2 (20%)
No	8 (80%)
Dominant Limb (n, %)	
Right	10 (100%)
Left	0 (0%)
Work Status (n, %)	
Working Full-Time	1 (10 %)
Working Part-Time	1 (10%)
On Disability	2 (20 %)
Retired	5 (50 %)
Unemployed	1 (10 %)
Marital Status (n, %)	
Married	6 (60%)
Divorced	1 (10%)
Single	3 (30%)
Type of Technological Device Used for Trail, (n, %)	
Desktop	3 (30%)
Laptop	6 (60 %)
Tablet	1 (10 %)
mRS (median [IQR], min - max)	2 [1], 1-3
NIH-SS (median [IQR], min - max)	2.5[1], 1-5

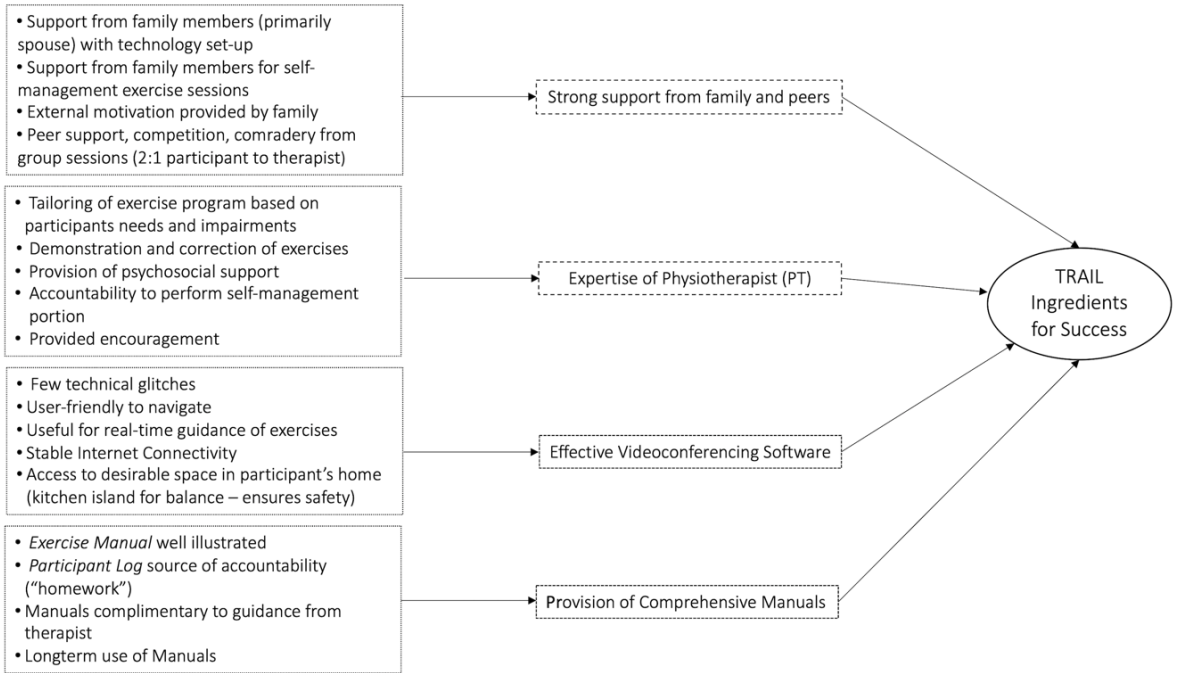
Abbreviations. MrS= Modified Rankin Scale; NIH-SS=National Institutes of Health Stroke Scale; IQR= Interquartile Range

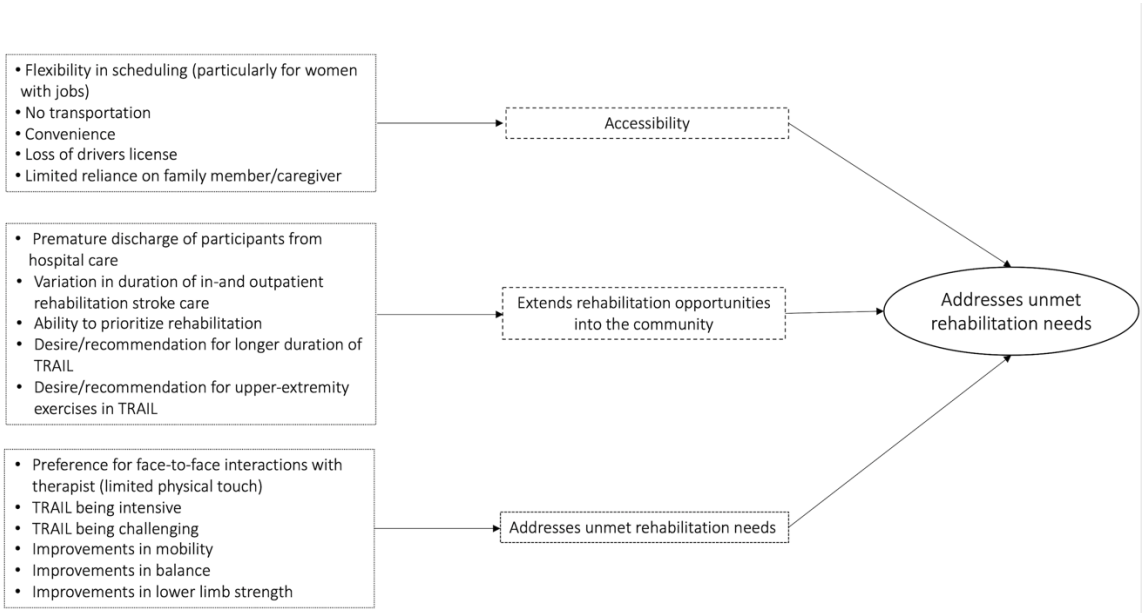
Two main themes were identified in the data: 1) TRAIL ingredients for success, and 2) telerehabilitation as a viable form of stroke rehabilitation. The main themes and corresponding categories (sub-themes) are provided in Table 3.2 and Figure 3.1. We provided illustrative quotes for each sub-theme, along with the participant's identification number and gender, age and time post-stroke (months).

Table 3.2. Identified Themes and Categories

Theme	Category
TRAIL ingredients for success	• Strong support from family and peers • Expertise of Physiotherapist (PT) • Effective Videoconferencing Software • Provision of Comprehensive Manuals
Telerehabilitation is a viable option for stroke rehabilitation	• Accessibility • Extends rehabilitation opportunities into the community • Addresses unmet rehabilitation needs

Figure 3.1. Coding Diagram illustrating the relationship between codes, categories, and themes





Alternative Text: Depiction of analytic process of interview transcripts, from initial codes on left side of figure, to categories and overarching themes on right side.

TRAIL ingredients for success

Participants shared many factors that contributed to a positive and successful experience with the TRAIL program, which included strong support from family and peers, the expertise of the physiotherapist (PT), effective videoconferencing software, and the provision of comprehensive manuals.

Strong support from family and peers

Nine out of the 10 participants received a form of support from family members and/or peers ranging from verbal encouragement to overseeing the exercise sessions and assisting with technological set-up, which served as motivation to participate in TRAIL. P09 [Man (M), 47 years old, 5.7 months post-stroke] described the support from his roommate as motivation to exercise: "*I did all the exercises on my own and he [roommate] encouraged me… it's just verbal support, like, keep going on the exercises, you can do it*". For other participants, family members were critical to their success and participation; interestingly, most were wives of participants identifying as men. P02 [M, 69 years old, 11.9 months post-stroke] stated "*I mean, I wouldn't*

have been self-motivated enough to do any of that on my own [reference to TRAIL exercises]. *I mean, I would have – my wife would have pushed me"* and P08 [M, 72 years old, 11.3 months post-stroke] described that *"[wife] was involved 100% of the time",* and *"that was the main thing"*.

Family members were also helpful in providing support for the initial technological set up, including downloading and logging into the respective platforms prior to the first session. P01 [Woman (W), 54 years old, 10.7 months post-stroke] shared "*I'm technophobic - my daughter did a lot of it for me at the beginning",* and P03 [M, 79 years old, 9.7 months post-stroke] reported that his wife managed the computer so that he *"didn't have to worry about that".* In contrast, one participant identifying as a woman (P010) shared her hesitation around seeking support from family members due in part to her daughter starting a new job, although it did not detract from her positive experience with TRAIL.

Peer support was also a positive factor related to participation in TRAIL. Four participants involved in this qualitative study had the TRAIL program delivered in a 2:1 participant-to-therapist ratio. The group format was well-received, with the peer participant seen as a source of motivation and friendly competition. For example, P06 [M, 60 years old, 17.6 months post-stroke] stated: "… *I thought it was a little bit of camaraderie. Not that we beat each other, well I did a few times, that sense of a team being part of something, I think that that does help. And also, the fact that there are persons there as well, you actually want to make sure that you do your part so you can be equal in your training"*. P01 [W, 54 years old, 10.7 months post-stroke] shared that "*we* [her and TRAIL partner] *got to a stage where we were competing against each other, but in a nice way. He was a lot older than me. He gave me incentive – I think that's a good thing, having somebody younger and somebody older. Because you know, I thought if he*

can do it, so can I, do you know what I mean, when I was struggling right, though. So that was a nice thing".

Expertise of the Physiotherapist (PT)

The importance of the expertise and role played by the TRAIL PTs was evident in all interviews. All participants reported that balance exercises in TRAIL were challenging, particularly variations of tandem standing, but also noted that it was the modifications provided by PT that were critical to their success with completing the program. P09 [M, 47 years old, 5.7 months post-stroke] shared "*I couldn't really do the tandem stand or the tandem walk. And then also with the left arm, that's where* [PT's name] *came in handy, like with my bad left arm … So, you know, she's like, raise your one arm and do that. And, you know, at least she was getting me through them the best I could*". Participants appreciated how their PT ensured that the program was individualized to ensure safety, allowing them to build self-confidence. For example, P09 [M] stated: "*She* [TRAIL PT] *was great, because she made me feel comfortable in the whole thing. ..like she said, instead of doing it this way and risking a fall, try it this way, right. That's why I said she was really good"*.

Participants also appreciated when the PT demonstrated the exercises and provided verbal encouragement and corrections where necessary. P08 [M, 72 years old, 11.3 months post-stroke] who was interviewed with his wife shared that "*She* [TRAIL PT] *was encouraging, she showed how to do the exercises. She was pleased with the progress and let you know. She corrected you if you didn't do the exercises properly*".

Effective Videoconferencing Software

Participants reported that once the initial technological set up was complete, the videoconferencing software platforms were user-friendly with few issues such as internet

instability, even with some participants living in rural areas. P03 [M, 79 years old, 9.7 months post-stroke], who lived in a rural area, was the only participant that experienced technological downtime that was brief and easily resolved, and did not detract from their experience with TRAIL. They shared: "*Once my computer kept blacking out and I had to keep coming, leaving, you know, things like that...but I could just trot over here and do my button here* [indicates Zoom© icon] *and it would come back on… But that was the only glitch"*.

Participants reinforced that real-time, synchronous video communication with the PT was critical, and that an audio-only option would not allow the PT to demonstrate the exercises and observe the participants. P02 [M, 69 years old, 11.9 months post-stroke] noted that "*Zoom was sometimes difficult when I couldn't understand what my PT was saying. And I'm sure it went the other way too. But in terms of setup and the screen…I've got an 18 inch monitor, so that, you know, I could swing it around to the other - the kitchen's behind – the other room just, so I could just swing it around on the counter and she could see me, you know"*.

Provision of Comprehensive Manuals

The *Participant Manual, Exercise Manual, and Participant Exercise Log* were highly valued resources. Many participants validated the information provided in the *Participant Manual* for safety and positive engagement, noting that the suggested supports in their home environment (e.g., kitchen counter, chair with arm rests) increased their confidence in their ability to maintain balance in the virtual environment. For example, P010 [W, 67 years old, 6.4 months post-stroke] stated ".. *Yeah, I didn't have any problem that way.. I took advantage of being able to lean on a counter or whatever. And myself since my stroke, I've always felt very, very important that I didn't fall or injure myself*".

The *Exercise Manual* was helpful for supplementing the visual demonstrations by the PTs, particularly during the independent self-managed exercise sessions. P04 [W, 80 years old, 6 months post-stroke] shared that "*Well, well, they* [Exercise Manual] *were well illustrated and describe each exercise. And sometimes I think, oh, am I doing everything? This exercise manual tells you what to do and I reviewed it. It was very good*". Furthermore, the *Participant Exercise Log* was particularly valuable for tracking the self-management portion of TRAIL, providing a sense of accountability by tracking the number of sets and repetitions from the action plan to reinforce positive exercise behaviours. P03 [M, 79 years old, 9.7 months post-stroke] who was interviewed with his wife shared that "..*We wanted to get better. But of course, you know, with any exercise you get lazy, but this kept us on track...We had to decide when we were going to do our homework* [reference to self-management exercise sessions].. *But we always did them as much as we were supposed to. So being accountable is a big thing*". P06 [M, 60 years old, 17.6 months post-stroke] stated ".. *and because it's written down there* [reference to number of repetitions for each exercise]*, I found that good, and easy to follow".* P01 [W, 54 years old, 10.7 months post-stroke] raised that the *Exercise Log* was particularly helpful to manage cognitive impairments she experienced after stroke, stating "*It* [exercise log] *gave you the motivation, and to be honest with you, the checklist helped, because you've had stroke your memory is not particularly the brightest, so it made sure you didn't miss out on anything, that you were just following it and also as the weeks went past, you had different exercises you had to do so it wasn't confusing*".

Five participants mentioned that they continued to engage in modified TRAIL activities, even after the 4-week intervention program. P09 [M, 47 years old, 5.7 months post-stroke] shared "*I currently go through the TRAIL, but I don't get up to the speed that it was*", while P01

[W, 54 years old, 10.7 months post-stroke] "*I'll be standing at the kitchen sink, and I'll go on to one foot, you know, to try to see how I'm doing*".

Telerehabilitation is a viable option for stroke rehabilitation

Participants described many factors that contributed to telerehabilitation being a viable form of stroke rehabilitation, including its accessibility, abilities to extend rehabilitation opportunities into the community and address unmet rehabilitation needs.

Accessibility

Being able to access real-time rehabilitation services without the need for travel contributed to positive engagement and adherence to the TRAIL program. All participants were able to successfully prioritize the TRAIL program around other roles or responsibilities at home and in the community, particularly for participants living in rural areas or when experiencing inclement weather. For example, P04 [W, 80 years old, 6 months post-stroke] stated that "*And because of the isolation and so on of this winter, it was terrific. And [location] winters, it was very easy for me to do it. I didn't have to go someplace else and park and you know, the whole thing"*. Another participant living in a rural area which required a ferry ride to access the nearest hospital, appreciated the accessibility of the telerehabilitation program.

Six out of the 10 participants described that their driver licenses had been suspended or lost as result of their stroke but fortunately, the TRAIL program minimized this barrier to accessing stroke rehabilitation services.

Extends rehabilitation opportunities into the community

Substantial variation was noted in terms of the duration and intensity of in- and out-patient rehabilitation participants received, yet the TRAIL program extended opportunities for

community-based rehabilitation to all 10 participants. For example, P01 [W, 54 years old, 10.7 months post-stroke] shared that she completed 7 outpatient rehabilitation sessions with a PT, but credited her improved health outcomes to the rehabilitation that she subsequently received in TRAIL. P01 stated *"I wouldn't be where I am today or been able to do what I am today without the* [TRAIL] *trial. And I'd say it's one of the best things, it basically gave me my life back really… there's nothing that I can't really do within reason"*. P02 [M, 69 years old, 11.9 months post-stroke] also shared "*I guess my point is if it had continued I probably wouldn't have to go to physio and pay $25 every session*". In fact, all 10 participants expressed a common desire for the TRAIL program to extend beyond 8 synchronous sessions (4 weeks) in order to continue progressing with their stroke recovery.

While participants appreciated the specificity of TRAIL targeting their lower extremity impairments, half shared that they would have also benefited from exercises that targeted their upper-extremity impairments. When asked if any elements of the TRAIL program could be changed P05 [M, 65 years old, 15.8 months post-stroke], who experienced severe upper limb hemiparesis, shared "*Maybe I would change to stuff* [exercises] *that would help me with my arm"* while P06 [M, 60 years old, 17.6 months post-stroke] with moderate upper limb hemiparesis said "*… since lots of therapy out there tends to focus on the legs, it would be nice to see a little bit of a component for shoulders or upper limb. They tend to be left behind, in general"*. Thus, telerehabilitation programs combining both upper- and lower-extremity exercises may be perceived as the most optimal and viable for individuals with stroke.

Addresses unmet rehabilitation needs

There was a general consensus that face-to-face interactions with the therapist were preferred over telerehabilitation due to the importance of physical interaction provided during in-

person care. P05 [M, 65 years old, 15.8 months post-stroke] noted: "*You seem to get more out of it when you're in person because the person is there. They can touch me*". Nonetheless, all participants shared that the weekly progression in the TRAIL program was intensive, the exercises were challenging, and the outcome was substantial improvements in their lower extremity strength, balance, and mobility. For example, P09 [M, 47 years old, 5.7 months post-stroke] shared that "*I live in a 4 level house and I will come up from the basement level to the main level and I will go to kitchen table and I will sit down and the quad cane will be back sitting by the door. So I am walking and I am forgetting the quad cane everywhere. So my walking has improved a lot from TRAIL*", while P05 [M, 65 years old, 15.8 months post-stroke]. shared that "*She [PT] engaged me and in a way that, you know, helped me improve my mobility*". P03 [M, 79 years old, 9.7 months post-stroke] specifically mentioned that TRAIL contributed to improvements in leg strength and allowed him to be able to get out of his chair, while P10 [W, 67 years old, 6.4 months post-stroke] shared that she benefited from being able to lift her leg over the bathtub.

3.5 Discussion

We identified strong support from family and peers, the expertise of the physiotherapist (PT), effective videoconferencing software, and the provision of comprehensive manuals as the primary contributing factors to the positive experiences with the 4-week TRAIL program. We also found that telerehabilitation appeared to be a viable form of stroke rehabilitation, due to its accessibility, ability to extend the continuum of stroke rehabilitation, and address unmet lower extremity rehabilitation needs.

Previous qualitative studies have also reported the importance of family and peers in facilitating participation in telerehabilitation [15,43]. Telerehabilitation allows individuals with

stroke to engage in rehabilitation from their own homes, which in turn have provided opportunities for greater engagement and support from friends and family members at home that otherwise may not have been available during in-person programs. Thus, the virtual setting may have fostered motivation to exercise, a key driver for positive long-term physical activity behaviours among individuals with stroke [44]. Given the supportive roles of family members and helpers observed in this study, future qualitative may consider exploring the perspectives of family and peers of individuals with stroke participating in telerehabilitation programs.

The men and women who engaged in TRAIL in a group format (2:1 participant-to-therapist ratio) enjoyed the sense of competition and camaraderie provided by their peer. This is not specific to virtual settings; participants after stroke have expressed a preference to exercise with others with similar conditions, as opposed to exercising with individuals that do not possess lived experiences of stroke [45]. In fact, peer-support is a technique commonly used in self-management programs for individuals with chronic conditions [46] with previous research indicating that support from other individuals post-stroke is the most commonly reported motivator for engaging in physical activity [44]. Group-based stroke telerehabilitation sessions can reduce clinician use of healthcare resources by limiting the number and duration of sessions offered [11] but, at the same time, can provide participants the opportunity to benefit from peer-driven social support [44].

While previous work has demonstrated that therapists are skilled in transferring critical motivational strategies from in-person to virtual forms of stroke rehabilitation [48], our findings concur with others [49] that patient satisfaction is enhanced when therapists receive specific training in telerehabilitation. Indeed, participants noted that TRAIL therapists played a critical role by such as providing encouragement, correcting of movements, and progression or

modifications of exercises based on the individuals' physical abilities. These attributes are consistent with published evidence supporting strategies of active listening, providing praise, supporting enjoyable communication, provision of a suitable environment for effective rehabilitation, and modifying exercise difficulty to promote satisfaction in, and adherence to, stroke rehabilitation [50]. Importantly though, participants offered that the virtual environment removed the ability for physical touch by the therapist, which has also been noted in other synchronously exercise-based telerehabilitation programs [17]. In this respect, a hybrid model combining in-person and concurrent, synchronously delivered virtual rehabilitation opportunities [48] warrants further attention.

It is encouraging that technological considerations related to the virtual nature of the TRAIL program were not perceived as barriers by participants in both urban and rural areas. This finding contrasts with earlier qualitative studies in which challenges with technology, such as high costs of equipment [16], connectivity issues [17], limited resources to consult in case of technological glitches [15,16,18,20] and interface-related problems (e.g., screen size and tablet placement) [17] have been reported as barriers to participation in telerehabilitation programs. We acknowledge that these previous studies predated the pandemic and likely used older technologies before advanced videoconferencing features in accessible and user-friendly format were widely available. Nonetheless, technological barriers are likely difficult to avoid completely, but a few strategies in the TRAIL protocol may have minimized these common challenges. The TRAIL team was able to mitigate barriers of high equipment costs and internet connectivity by loaning a study tablet and providing a videoconferencing account to participants with limited access to technology. This was particularly important for participants living in rural areas, where low digital literacy, reduced confidence and motivation to use technology, and lack of access to

stable internet and other technological resources are more common [47,51]. As well, the 2 orientation sessions provided to each participant may have helped to alleviate some of the technological barriers reported in other studies.

In cases where communication over the videoconferencing software was challenging due to hearing or visual impairments, the *Exercise Manual* provided participants with an additional resource to consult for instructions and modifications/progressions of the exercises, while the *Participant Manual* provided guidance on the technological set-up. As also shown in our study, individuals with stroke may benefit from technological support from family members [52], but having other resources in place remains important to avoid relying heavily on support from others, particularly for women who more likely to be widowed [53] or possess a belief of not wanting to be a burden to others [37]. Indeed, the hesitation to seek support from family members was observed with one female participant, in our current study. Overall, technological barriers may be minimized when resources are accessible and account for the additional considerations and challenges presented by individuals with stroke [54].

Not only were the study manuals helpful in mitigating technological challenges, they also provided an additional source of accountability, especially for the self-management portion where participants were required to self-monitor their action plans and exercise sessions. This strategy was founded on evidence supporting the use of action planning and self-monitoring to promote positive long-term physical activity behaviours and reduce sedentary behaviours among older adults [55]. Programs such as TRAIL that aim to promote positive physical activity behaviours beyond the duration of the intervention may be particularly important for women with stroke who experience consistently poorer functional capacity than men with stroke over time [56]. Encouragingly, participants identifying as women reported continued engagement in

the TRAIL exercises beyond the 4-week program. Overall, study manuals were beneficial for the successful delivery and uptake of TRAIL, and thus we recommend that manuals be an integral component of telerehabilitation programs. Clinicians may benefit from consulting newly developed toolkits, which aim to share helpful resources and knowledge on the implementation of telerehabilitation in individuals with stroke [57].

The accessibility of telerehabilitation, through limited need for transportation [17,20], flexibility in scheduling [17], time efficiency, and cost savings [10], have been previously reported as facilitators for participation in stroke rehabilitation. In TRAIL, the primary factor related to accessibility was transportation; a critical consideration given that 60% of our participants experienced suspension of their driver licences and evidence that has shown that 70% of individuals between 3 months and 6 years after stroke do not return to driving [58]. The accessibility of telerehabilitation may be particularly beneficial for older women with stroke who may not have support for their transportation needs [37]; the logistical constraints around coordinating transportation has been cited as one of the most substantial barriers to accessing care for older women living in rural areas [59]. Telerehabilitation programs may also minimize barriers to participation in stroke rehabilitation for women with primary caregiver roles by offering greater flexibility in scheduling when travel time does not need to be accounted for [37]. Further research is warranted to further explore the acceptability and effectiveness of exercise-based telerehabilitation in a large cohort of women with stroke.

The improvements reported by all participants across a variety of domains of lower limb recovery such as mobility, strength and balance are encouraging and important given that balance and mobility are cited as the top priority areas for individuals with stroke [60,61]. Indeed, higher balance abilities and motor function are key facilitators for community

reintegration among individuals with stroke, a fundamental objective of stroke rehabilitation [62]. Furthermore, self-reported improvements in physical disabilities may be clinically meaningful and can play in integral role in increasing overall self-rated health after stroke [63].

Rehabilitation services are critical in the early stages of stroke to promote recovery [2] and lower risk of institutionalization and dependence with ADLs [9]. Concerningly however, less than 7% of individuals with stroke in North America are referred to [64] or receive outpatient rehabilitation services [65]. In that regard, the TRAIL program addressed a service gap by providing an opportunity to extend the continuum of stroke rehabilitation. Indeed, we noted the wide variability in course of in- and out-patient rehabilitation care that participants received, and in some cases, TRAIL was their first exposure to stroke rehabilitation services beyond limited in-patient care. Thus, our study adds to a growing body of evidence supporting the use of telerehabilitation when exposure to in-person stroke rehabilitation is not possible or limited [10,43,47].

Strengths and Limitations

This study has many strengths. We employed multiple sampling strategies that allowed us to interview individuals living in both rural and urban areas of Canada, as well as a similar representation of men and women with stroke. By employing these strategies, we were able to explore the positive aspects of the TRAIL program and the viability of telerehabilitation to support stroke recovery, while accounting for experiences of individuals in areas of the country where access to rehabilitation is limited. We were also able to consider, in a preliminary way, potential gender-based considerations that might have influenced participation in telerehabilitation. Moreover, the participants included in the qualitative study were representative of those enrolled in the feasibility study of TRAIL, with regards to age, time-post stroke, stroke

severity, and lower extremity impairment. Overall, telerehabilitation was well-received by individuals with stroke in urban and rural areas, as well as both men and women. Thus, we are currently conducting a large-scaled randomized controlled trial (RCT) of the TRAIL program to establish its effectiveness at addressing lower extremity impairment among individuals with stroke. We hope that the findings from the RCT provide further insight into the widespread implementation of telerehabilitation for stroke recovery among men and women across Canada.

This qualitative study does present with limitations. First, our findings describe the personal experiences and perceptions of individual stroke survivors and cannot be generalizable to all individuals living with stroke. NIH-SS and mRS scores suggest mild to moderate stroke severity; thus these findings may not be generalizable to individuals with severe lower extremity impairment. Secondly, although we designed TRAIL with the intention to be delivered in 2:1 participant-to-therapist ratio to promote peer-support, slower recruitment rates experienced during the COVID-19 pandemic limited our ability to offer group sessions to all participants in the feasibility study. Third, we acknowledge that our study included a small proportion of the population of individuals with stroke, where if we had a larger sample size, greater issues with connectivity and internet instability may have been observed. Next, the current qualitative study did not incorporate the perspectives of therapists that were involved in the delivery of the TRAIL program. The clinical perspectives offered by therapists are critical to obtaining a better understanding of the facilitators and barriers to the implementation of lower extremity-focused telerehabilitation. We are in the process of analyzing data acquired from the TRAIL therapists. Finally, interviews were completed at the end of the feasibility study. As a result, three interviews were conducted close to one year after participants had completed the TRAIL program, and thus potentially introducing recall bias.

3.6 Conclusion

The TRAIL program is a viable means of rehabilitation to enhance lower extremity recovery after stroke by increasing access to stroke rehabilitation, extending the continuum of stroke care, and increasing satisfaction with the services rendered. Synchronously delivered telerehabilitation programs may be an acceptable alternative or supplement for community-based in-person stroke rehabilitation, when therapists are trained to deliver virtual stroke rehabilitation and comprehensive resources (e.g., exercise manuals) are available. Further research of exercise-based telerehabilitation is warranted to further understand its role in the stroke rehabilitation continuum, and inform policy and clinical guidelines on the use of telerehabilitation in practice. Additionally, research is warranted on the perspectives of informal caregivers who are involved in care of stroke survivors and their experiences with telerehabilitation. This exploration of the experiences of the TRAIL participants will inform future initiatives in the design and implementation of safe and effective stroke telerehabilitation programs.

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Declaration of Interest Statement

The authors have no conflicts of interests to declare.

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CHAPTER 4: Sex-and gender-based characteristics influence responses to a 4-week exercise-based stroke telerehabilitation program: A multiple case study

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Key words: Sex, gender, telerehabilitation, stroke rehabilitation, exercise

Target Journal: *Disability and Rehabilitation*

4.1 Abstract – 200/200 words

Background: Sex- and gender-based factors can act as barriers to stroke recovery. This study aimed to 1) Describe and explore potential sex- and gender-based characteristics that may be associated with the clinical responses of six participants to a 4-week telerehabilitation program, and 2) Explore adherence, adverse events, and program satisfaction.

Methods: Using a multiple case study design and homogeneous sampling (age and stroke severity), we contrasted and compared responses of three male and three female participants. Participants completed 4 assessments: pre-post-intervention, 3- and 6-month follow-up. Outcome measures were the Stroke Impact Scale-3 (SIS-3), 30s-sit-to-stand test (30s-STS), and Activity-Specific Balance Confidence Scale. Sex- and gender-based characteristics were reported, and individual trajectories were described.

Results: Female participants had more favourable trajectories in emotion, memory & thinking, mobility, participation domains of the SIS-3, and activity-specific balance confidence. Female participants also had sustained improvements in 30s-STS. Stroke type and marital status are among the personal characteristics of female participants that may explain the responses observed.

Conclusion: The more favourable trajectories in many domains demonstrated by females could be explained by sex- and gender-based characteristics. Males possessed personal characteristics often associated with poorer functional recovery, contradicting sex- and gender-based disparities generalized to females with stroke.

4.2 Introduction

Stroke is the third-leading cause of disability worldwide,[1] whereby physical and psychosocial impairments, including lower extremity motor impairment,[2] gait and balance disorders,[3] reduced quality of life and high rates of depressive symptoms[4] are commonly reported. Unfortunately, women with stroke experience greater levels of disability and are less likely to seek rehabilitation services.[5] This may be attributed to sex-based factors (i.e., biology, physiology),[6] as higher incidence of severe strokes, number of comorbidities, poorer pre-stroke function[7,8] may contribute to lower functional capacity and mobility that are clinically meaningful.[9] Gender-based factors (i.e., societal and behavioral norms),[6] such as a perceived obligation to resume caregiving roles and responsibilities may limit the ability of women to prioritize their own recovery,[10] and in turn may increase stress levels and reduce quality of life.[11]

Fortunately, innovative forms of service delivery such as telerehabilitation may help overcome barriers related to accessing rehabilitation services for women with stroke.[12] Individuals with stroke have reported that the affordability and accessibility of telerehabilitation facilitates participation in stroke rehabilitation services,[12–14] and thus reducing cost and transportation barriers to traditional in-person programs that are commonly expressed,[15,16] especially by women.[17] There is strong systematic review evidence suggesting that telerehabilitation improves falls self-efficacy and quality of life (n=13 studies)[18] and mobility and balance after stroke (n=3 studies).[19] Furthermore, qualitative studies have reported self-perceived enhanced motor and limb function,[12,13,20,21] enjoyment,[22,23] and positive engagement from social support by the therapist and family[12,13,20] as positively influencing participation behaviours in telerehabilitation after stroke.

Telerehabilitation generally appears to be well-accepted[12,13,20,21,22,23] and effective[18,19] among individuals with stroke, however no studies to date have described how responses to telerehabilitation vary based on sex- and gender-based characteristics. Thus, the purpose of this study was to describe and explore sex-and gender-based characteristics associated with the clinical responses of six participants to a 4-week telerehabilitation program for lower extremity recovery after stroke. Our secondary aim was to explore adherence, adverse events, and satisfaction with the telerehabilitation program.

4.3 Methods

Study Design

We used a multiple case study design which allows for the description of an intervention and the real-life setting in which it occurred, and provide evidence on context, complexity and mechanisms for understanding, how, where and why interventions have their observed effects.[24] Moreover, the description of multiple case studies allows for an in-depth exploration into differences and similarities between cases, based on their clinical presentation.[25] Case studies offer flexibility with using qualitative and/or quantitative data, although are not intended to test quantitative differences between groups.[24] To address our study aims, we analyzed quantitative data from a multi-site, parallel group, assessor-blinded randomized attention-controlled trial (Clinical Trials Unique Identifier: NCT04908241). The main trial aims to examine the effects of the 4-week TeleRehabilitation with Aims with Improve Lower extremity recovery post-stroke [TRAIL] exercise-based telerehabilitation program on lower extremity recovery among Canadian adults within one year of stroke.

Eligibility Criteria

Participants transitioning from in- or outpatient rehabilitation programs were recruited from 5 sites in Canada (Halifax, Winnipeg, Vancouver, London, Toronto) within the CanStroke Recovery Trials Platform which is a network of Canadian hospital sites that are affiliated with academic institutions to facilitate participant recruitment and quality trial practices.[26] Informed written consent was obtained from all participants. The study protocol is described elsewhere.[27]

Inclusion criteria for the main trial: 19 years of age or older; within 12 months of stroke with lower extremity hemiparesis at time of enrollment; able to walk 10 metres without physical assistance of another person; able to tolerate 50 minutes of activity with rest breaks, as needed; have cognitive-communicative ability to participate as per clinical judgement; able to provide informed consent. Individuals were excluded if they were currently any rehabilitation focused on lower extremity recovery, living in long-term care; severe vision or hearing loss; other neurological conditions (e.g., Parkinson's disease); presence of significant comorbidities, pain or other symptoms that may significantly impact lower extremity function (i.e., not medically stable); planned surgery that would preclude or affect participation in the telerehabilitation program. The current study involved participants assigned to the TRAIL group only.

Intervention: ***Exercise-based telerehabilitation program -TRAIL***

TRAIL is a 4-week, twice-weekly progressive intensity, lower extremity exercise and self-management telerehabilitation program delivered in a ≤2:1 participant-to-therapist ratio. Participants received two synchronous telerehabilitation sessions per week delivered by a trained physiotherapist, with each session taking 60-90 minutes to complete, and totalling 8-12 hours of telerehabilitation. The exercises in the TRAIL program addressing strength, endurance, balance, stepping, and walking were adapted from the Fitness and Mobility Exercise community-based program for individuals with stroke,[28] with considerations of the virtual environment and space

available in the home setting (e.g., having a kitchen counter or stationary chair as balance supports). The TRAIL program also included a self-managed, independent exercise component to supplement the synchronous sessions, whereby participants and therapists co-developed action plans of TRAIL exercises to be completed ≥1 time per week.

Sampling Strategies

In line with case method methodology,[24] we engaged in purposeful sampling, specifically around homogeneous sampling (i.e., describe a particular subgroup in depth, reduce variation).[29] The selection process involved sampling participants 40-65 years of age to reflect middle-aged adults[30,31] with mild to moderate stroke severity (based on National Institute of Health Stroke Severity Scale (NIH-SS)[32] scores (1-15) representative of the largest proportion of stroke cases[33]). Sampling on age and severity was designed to minimize possible confounding effects of stage of life course and degree of disability on sex and gender characteristics; for example, work status may differ between a middle-aged individual with mild stroke and an older adult with severe stroke. Responses from the first 3 female (Participants 1-3) and 3 male (Participants 4-6) participants in TRAIL with complete data collection were analyzed.

Assessments

This study involved 4 assessment timepoints: baseline, post-intervention (4-weeks; primary endpoint), and 3- and 6-month post-intervention. All assessments were conducted virtually by a trained, blinded assessor (physical or occupational therapist).

Guiding Framework Used to Inform Outcome Selection and Reporting

The selection of outcome assessments reported in our study was informed by the International Classification of Functioning, Disability and Health Framework (ICF).[34] The ICF provides a conceptual basis for the definition and measurement of health and disability.[34] In the

model, functioning and disability are multi-dimensional concepts relating to body functions and structures and impairments (e.g., mental, neuromusculoskeletal, movement-related functions), activities and activity limitations (e.g., communication, mobility, self-care) participation and participation restrictions (e.g., domestic life, community, social, and civic life), personal and environmental (e.g., physical, social and attitudinal environment where people conduct their lives) contextual factors.[34]

Sex-and gender-based characteristics

Sex-based characteristics of interest (i.e., biological/physiological factors known to be related to stroke recovery outcomes in males and females) included baseline demographic information (age, smoking history, diagnosis of hypertension), stroke type, previous history of stroke, affected brain hemisphere and limb(s), time post-stroke (days), cognitive function, degree of disability (Modified Rankin Scale,[35]) and degree of neurologic deficit (NIH-SS).[32] The Functional Comorbidity Index (FCI) was used to determine the number and type of comorbidities (18 items – e.g., diabetes, depression, asthma, angina, etc.).[36] Scores on the FCI range from 0 to 18 with higher scores indicating more comorbid conditions. In our study, because participants had stroke (which is also a comorbid condition on the FCI), total scores range from 0 to 17), with a score of 0 indicating stroke as the only health condition reported. The short-form Montreal Cognitive Assessment (SF-MoCA) was administered to screen for cognitive impairment.[37] The SF-MoCA assesses attention, memory (delayed recall) and orientation and is scored from 0 to 14 (one additional point added if education is less than 12 years), with higher scores indicating better cognitive function. The short-form MoCA (72.6% classification) has comparable accuracy to the standard MoCA (71.9% classification) and superior accuracy to the Mini-Mental State Examination (67.4%) among older adults with normal cognitive function,

Alzheimer's Disease and mild cognitive impairment.[37] The cut-off for detecting mild cognitive impairment is <12/14.[37] Notably, participants with scores <12 were included in the main trial, as long as the trained assessor deemed that they possessed adequate cognitive-communicative ability to participate.

To inform our exploration of potential gender-based characteristics that may explain the varied responses of each participant, we reported on variables that are known to differ between men and women, including financial, marital, caregiving, employment status, and level of education. Being a widow[38] and a primary caregiver to children or an older parent[39] are typically associated with older women. Women also have shorter work tenures and lower income and pensions than men,[40] despite Statistics Canada (2021) reporting that women are more likely to pursue higher-education (i.e., bachelor's degree and above).[41] Self-described gender identity, as well as ethnicity were also reported for each participant to acknowledge its intersectionality with sex and gender factors.[42]

Performance-based Outcome Measure

30-seconds sit-to-stand test [30s-STS]: The 30s-STS was conducted as an assessment of lower extremity strength. In this test, participants are seated in a chair with their arms crossed and then subsequently instructed to raise from the chair and complete as many repetitions as possible over the span of 30 seconds. A higher number of repetitions is indicative of greater lower extremity strength. The virtual administration of the 30s-STS has high test-retest reliability ($ICC_{2,1}$=0.90) and is comparable to the in-person administration of the test in individuals with stroke.[43] The threshold to detect real change (i.e., standard error of measurement) on the 30s-STS in research settings conducted in people with stroke is 2 repetitions.[44]

Questionnaire-based Outcome Measures

Stroke Impact Scale Version 3.0 (SIS-3): The 59-item SIS-3 is a stroke-specific self-report questionnaire that evaluates eight domains of disability and health-related quality of life.[45] Specific domains include strength, memory and thinking, emotions, basic and instrumental activities of daily living (ADLs/IADLs), communication, mobility, hand function, and participation. The questionnaire is scored on a 1-5 Likert Scale, with higher scores indicative of lower disability.[45] The scoring system involves inputting domain-specific data into an equation [(actual raw score – lowest possible raw score) / possible score range x100], whereby a transformed scale ranging from 0 to 100 is determined for each domain. [45] Notably, three items on the emotion domain are reverse scored.[45] The SIS-3 also included a question around perceived recovery, where participants were asked: "on a scale of 0 to 100, with 100 representing full recovery and 0 representing 0 recovery for your lower extremity, how much have you recovered from your stroke?". The SIS-3 is valid (internal consistency 0.93- 1.00) and the domains are unidimensional (fit statistic >1.3), the items have excellent range of difficulty and accurately place individuals in multiple strata.[46] The clinically important difference on the strength, ADLs/IADLs, mobility, and hand subdomains are 9.2. 5.9, 4.5, and 17.8, respectively.[47] Moreover, the minimal detectable change on the strength, ADLs/IADLs, mobility, and hand subdomains are 24.0, 17.3, 15.1, 25.9, respectively.[47] There are currently no clinically important difference or minimal detectable change values available on communication, memory and thanking, emotion, and participation subdomains.

Activity-Specific Balance Confidence Scale [ABC]: The 16-item ABC is a self-report questionnaire that is used to assess an individual's self-efficacy to perform a variety of scenarios or activities without losing balance.[48] The questionnaire contains 16 scenarios and participants are asked to rate their self-efficacy from 0 to 100 percent. The percentages from each item are

summed and divided by 16 to calculate a mean total score, with higher mean scores indicative of higher balance self-efficacy. The ABC has high person reliability (0.93), does not have a ceiling effect, and is able to separate individuals with stroke in 5 distinct strata (separation index=3.71).[49] The minimal detectable change for the ABC is 14%.[50,51] The ABC scale was included to capture the phenomena around how mastery of lower extremity exercises can promote balance self-confidence, and in turn increase participation.[52]

Program Satisfaction, Adherence and Adverse Events: A study specific participant satisfaction survey was administered upon completion of TRAIL (post-intervention assessment, i.e. 4 weeks from baseline). The survey included 5-point Likert scale ratings on factors important for satisfaction with virtual stroke care:[53] staff communication and facilitation, usefulness of the services, equipment, program structure, and perception of program. Higher scores indicated better satisfaction with the telerehabilitation program.

Adherence was calculated as a percentage of sessions completed out of the 8 total telerehabilitation sessions. Adverse events associated with the intervention were recorded by TRAIL therapists and were reported as frequencies with a brief description of the event, if applicable.

Table 4.1 outlines how the 8 domains of the SIS-3 and the clinical outcome measures were mapped to the most relevant component of the ICF. Given the strong bi-directional relationship between activity limitations and participation restrictions, these are combined into one concept by the World Health Organization, “Activity and Participation”.[34] Geographical location, completion of outpatient rehabilitation at time of enrolment, and living arrangements represented environmental factors, while ethnicity and all sex and gender factors reflected personal factors of the ICF.

Table 4.1. Outcomes mapped onto relevant ICF components

Outcome	ICF Components	Example of Item within Domain
30-seconds sit-to-stand test	Body Function and Structures	Number of repetitions achieved
Stroke Impact Scale -3		
Strength	Body Function and Structures	In the past week, how would you rate the strength of your leg that was most affected by your stroke?
Memory and Thinking	Body Functions and Structures	In the past week, how difficult was it for you to concentrate?
Emotion	Body Functions and Structures (includes psychological function)	In the past week, how often did you feel sad?
Communication	Activities and Participation	In the past week, how difficult was it to have a conversation on the telephone?
Basic and Instrumental Activities of Daily Living	Activities and Participation	In the past 2 weeks, how difficult was it to shopping?
Mobility	Activities and Participation	In the past 2 weeks, how difficult was it to get in and out of a car?
Hand Function	Activities and Participation	In the past 2 weeks, how difficult was it to use your hand that was most affected by your stroke to tie a shoelace?
Participation	Activities and Participation	During the past 4 weeks, how much of the time have you been limited in your social activities?
Activity-Specific Balance Confidence Scale	Body Function and Structures (includes psychological function)	How confident are you that you will not lose your balance or become unsteady when you sweep the floor?

Analysis

Baseline participant demographics, gender-based considerations, program satisfaction adherence, and adverse events were described using frequency counts and raw scores for each participant. The absolute change in SIS-3, ABC and 30s-STS scores between baseline and each timepoint (i.e., 4-weeks post-intervention, 3- and 6-month follow-up) were calculated and reported for each participant. We presented trends in outcome data based on the trajectories of the 3 male and 3 female participants, respectively.

4.4 Results

Personal Factors (Sex-and gender-based characteristics)

The characteristics of the six participants are presented in Table 4.2. In terms of gender identity, all females identified as women and all males identified as men. The sample was diverse in terms of affected hemisphere and limbs, number of comorbidities, smoking history, ethnicity, and education. Participant 1 (female) and Participant 4 (male) had experienced a recurrent stroke. All female participants experienced ischemic stroke, two male participants experienced hemorrhagic stroke, one male reported unknown stroke type. All participants were married, had a diagnosis of hypertension and similar cognitive function. None were currently working as a result of medical leave or disability from stroke. Most Participants except Participant 5 reported having enough finances to meet their basic needs, and all had previous caregiving roles, most commonly to children (except Participant 4).

Environmental Factors (Context)

Five of 6 participants completed outpatient rehabilitation at time of enrolment into the TRAIL study and all participants resided in a rural or suburban area and were living with a spouse and/or other relatives.

Body Functions and Structures

Baseline scores for the outcomes of interest were similar between males and females (Table 4.3). Change scores between baseline and each timepoint are shown in Panels A-K of Figure 4.1. Table 4.4 provides the interpretability of changes from baseline for outcomes of interest at 3 timepoints to contextualize the magnitude of improvements or declines. Appendix 4.1 provides the raw values for changes between baseline scores and each follow-up timepoint.

With the exception of Participant 6, all other male and female participants demonstrated improvements at the primary endpoint in *self-reported strength*, with 3 exceeding clinically important differences (Figure 4.1, Panel A). However, substantial variation in responses between and within sexes were noted at 3- and 6-months follow-up. For *30s-STS*, baseline scores were similar between sexes, and four participants (3 females, 1 male) exceeded the standard error of measurement at the primary endpoint, and at the 3-and 6-month follow-up (Figure 4.1, Panel K).

There appeared to be between-sex variability in changes in SIS-3 *memory and thinking* scores favouring positive responses in females. All three female participants improved slightly or did not change, while two male participants (Participants 4 & 5) generally declined. Similarly, all three males declined in self-reported emotions from baseline to all three 3 timepoints, whereas female participants had higher scores that generally did not change (Figure, Panels B & C).

ABC scores mirrored the trajectories of SIS-3 *participation* subdomain for female participants, while Participants 2 and 3 each had improvements beyond the minimal detectable change value on two separate occasions. All male participants improved balance self-efficacy post-intervention, which was only maintained by Participant 6 at subsequent follow-up data collection timepoints (Figure 4.1, Panel J). Female participants perceived positive changes in *overall recovery of lower extremity function* (Figure 4.1, Panel I), whereas each male participant demonstrated different responses (declined, stable, or improved).

Activities and Participation

Between sex responses were most similar on the *communication* subdomain, where most male and female participants demonstrated consistently small changes over time (except Participant 4 who improved 21.1 points at post-intervention) (Figure 4.1, Panel D). Conversely, the greatest sex differences were observed in the *ADLs/IADLs* subdomain with all three female

participants demonstrating marginal changes post-intervention (2/3 change scores in the positive direction) and fluctuating and varied follow-up responses. Male participants each had distinct responses: Participant 4 consistently declined, Participant 6 consistently improved, and Participant 5 improved at the primary endpoint but meaningful declines at follow-up visits (Figure 4.1, Panel E).

Differences between sexes favouring positive trajectories among females were observed in *mobility* subdomain trajectories. Two female participants improved and one (Participant 2) did not change post-intervention, but all three participants exhibited positive responses at 3-month follow-up when compared to baseline values. In contrast, all male participants demonstrated relatively small changes post-intervention (2/3 change scores in the negative direction), but two had substantial declines beyond minimal detectable change values at 3-month follow-up (Figure 4.1, Panel F).

Two distinct trajectory profiles were observed in the *hand function* subdomain that did not be appear to differ by sex. Participants either did not change or declined over time (1 male (Participant 6) and 2 females (Participants 1, 2)) or demonstrated improvements at the primary endpoints but fluctuated thereafter (1 female (Participant 3) and 2 males (Participant 4, 5)). (Figure 4.1, Panel G).

Participation subdomain scores were low at baseline in all participants (Table 4.2), though the follow-up trends favoured positive responses among females. The participation of two females declined, relative to baseline, at post-intervention but improved beyond baseline at both follow-up timepoints, while Participant 3 had sustained improvements until the 6-month follow-up. Two male participants reported lower participation, relative to baseline, at all

subsequent timepoints, while Participant 6 improved substantially from baseline at all timepoints (Figure 4.1, Panel H).

Program Satisfaction and Adherence

Participants completed all 8 telerehabilitation sessions and at least 1 weekly self-managed exercise session each week. All participants were satisfied or highly satisfied with the TRAIL program, based on their ratings of each of the 5 constructs assessed. There were no adverse events reported by any participants (Table 4.2).

4.5 Discussion

This multiple case study described the responses of middle-aged females (3 participants) and males (3 participants) with mild to moderate stroke to a 4-week lower extremity exercise and self-management TRAIL program. Using the ICF framework we mapped study outcomes into relevant body functions and structures or activity and participation components, and organized explanatory sex-and gender-based characteristics into personal and environmental factors. Overall, all participants were satisfied with TRAIL, completed all TRAIL sessions with no adverse events and either lived in rural or sub-urban areas, reinforcing the accessibility offered by telerehabilitation to healthcare services.[12]

Positive changes in the strength domain of the SIS-3 and the performance-based 30s-STS at the primary endpoint were noted in almost all participants. This is not surprising as the TRAIL protocol included task specific functional exercises such as repetitive chair raises[54] and corroborate our qualitative study of self-reported improvements in strength acquired from TRAIL[12] and a previous study of 21 sub-acute stroke participants completing a 6-week lower extremity functional exercise protocol.[55] The current case study approach adds to the evidence by allowing a closer examination of sex- and gender-based characteristics potentially associated

with changes observed. For example, we note that only Participant 4 (male) demonstrated substantial gains in both self-reported strength and 30s-STS at most time points. This participant had low baseline scores (for example, 30s-STS was as many as 14 repetitions lower than age- and sex-specific reference values),[56] potentially explained by his history of a previous hemorrhagic stroke (had recurrent stroke) and current smoking history, key factors associated with poorer functional outcomes.[57,58] Indeed, the lower baseline scores may have allowed for greater magnitude of improvement relative to the other participants. We also observed that females not only reported positive outcomes from the exercise program but had sustained performance-based physical strength over time, presenting an exciting opportunity for future larger-scaled sex-disaggregated analyses of performance-based measures following structured exercise protocols. Our preliminary findings may suggest that lower extremity-focused telerehabilitation can be used to mitigate the long-term declines in physical function in females.[9]

Three distinct observations were made based on the trajectories of participants. Firstly, some observations *aligned* with previous literature on sex-and gender-based differences in analyzed outcomes. Female participants reported more favourable responses than males on self-reported memory and thinking, activity-specific balance self-confidence, participation, and perceived lower extremity recovery, of which is supported by previous literature. Firstly, despite high SF-MoCA scores and balanced educational levels across participants, only female participants presented with high and stable scores in self-reported memory and thinking. This observation relates to the body and structures domain and aligns with previous evidence reporting superior longitudinal memory and processing function in middle-aged females compared to males.[59,60] Secondly, we noted that the responses exceeding the minimal detectable change value of the ABC, and perceived lower extremity recovery in at least one follow-up

timepoint mirrored self-reported improvements in participation in the SIS-3 among female participants. These observations are supported by previous research that higher balance confidence[61] and lower limb function[62,63] independently predict greater involvement in meaningful activities post-stroke. Further, in a previous study of 62 adults with stroke, female sex, younger age, lower self-discrepancy (perception that actual self is distanced from ideal self), and greater perceived recovery as reported by the SIS-3 were associated with greater participation.[64] Indeed, our female participants mostly reported positive changes in lower extremity recovery, whereas two males had poorer overall lower extremity recovery. Thus, the combination of female sex, greater balance self-efficacy per the ABC, and greater perceived recovery in lower extremity function (assessed by SIS-3 open-ended item) could be explanatory factors associated with the observed trajectories in participation.

Secondly, several observed trends in our case studies *contrasted* literature on sex- and gender-based differences in activity and participation outcomes, namely emotional state, ADL/IADLs, and mobility. Female participants reported more favourable responses than males on self-reported emotional state. While this seemingly contrasts previous evidence that post-stroke depression is more prominent in females,[65] depression may be more associated with widowhood[66] and hemorrhagic stroke[67] whereas our female cases were all married and all experienced ischemic stroke. In contrast, two male cases experienced hemorrhagic stroke, which may partially explain less favourable trajectories observed among males. Thus, we identified that sex- and gender-based characteristics (i.e., personal factors) including marital status and stroke type may have influenced participants' responses on the emotion domain. Of additional importance, upon taking a closer examination of Participant 5 (male), it may be that personal factors, namely financial and work status, may explain in part the considerable decline in

emotional state observed. Only Participant 5 reported both not having enough money to meet basic needs and being on long-term disability. Financial and job insecurities exacerbate post-stroke depression[70,71] which is often characterized by a lack of energy and motivation to engage in activities,[72] and is related to participation restrictions, limitations in ADLs, and worsening of function.[73,74] These associations may help explain the large declines in participation and activity-related domains of the SIS-3 and 30-STS observed in Participant 5 at the 3-month follow-up timepoint.

There were no apparent positive outcomes of TRAIL or trends in the trajectories on the ADLs/IADLs subscale between and within sexes, despite evidence of functional lower extremity exercises improving independence after stroke[73] and females being at a higher risk of loss of independence.[74,75] Greater stroke severity,[76] depression,[77] and older age[78] have all been attributed to the poorer trajectories in ADL/IADLs recovery in females, but as previously alluded, all female participants in our study had ischemic stroke, stable emotional responses, and were middle-aged thus potentially explaining the relatively neutral trajectories in ADL/IADL function compared to males. Further examination into the effects of lower extremity functional exercise programs using telerehabilitation as the modality of service delivery on self-reported independence is needed. Similar speculations can be made regarding the more favourable trajectories in the mobility domain among female participants. Previous studies that observed poorer self-reported mobility among older female participants (mean age 67.0[11]-73.6[79]) also reported that participants were more likely to be living alone and widowed. These characteristics did not apply to our participants, suggesting an important association between life-stage and recovery outcomes after stroke.

It may also be that better responses in self-reported mobility observed in female participants are related to other salient gender-based characteristics not collected in our study. For example, a recent study of individuals with stroke found that women performed better on outcomes of mobility (i.e., longer walking durations and engagement in light physical activity), which authors attributed to women spending greater time spent on household chores.[80] We did not collect data on household chores; exploring the potential association between gender roles and mobility may be a focus for future studies.

Third, and finally, there were some outcomes with *no clear inferences* of sex- and gender characteristics that could explain the observations in communication and hand domains, which were both mapped onto the activities and participation component of the ICF. Both males and females maintained high scores over time on the communication domain (females had slightly higher scores), possibly reflecting a cohort with minimal communication impairments (e.g., hearing, speech, language) owing to the eligibility criteria for the main trial[81] and evidenced by the lack of communicative impairments identified on the Functional Comorbidity Index. Finally, the trajectories observed in the hand subdomain suggest that half of the sample, including both male and female participants, reported minimal upper extremity impairment, while half reported poor upper extremity function. While TRAIL was a program focused on lower extremity recovery after stroke, we postulate that gains reported could be attributed to the nature of some of the questions in the hand subdomain that require hip, knee and ankle kinematics such as tying a shoelace or carrying a heavy bag of groceries.[82] Thus, TRAIL may also be beneficial for a wide array of activities including upper extremity activities.

Overall, the multiple case study design allowed us to thoroughly explore sex- and gender-based characteristics that could influence telerehabilitation participation behaviours and

outcomes, thereby identifying potentially pertinent personal variables for clinicians and researchers to consider in future telerehabilitation trials. The more favourable trajectories in many domains that were demonstrated by female case studies may have been influenced by personal sex- and gender-based characteristics. Interestingly, we found that male cases included personal characteristics often associated with poorer functional recovery, contradicting sex- and gender-based disparities generalized to females with stroke.

Limitations

We acknowledge that this study has limitations and present opportunities for future research. The majority of participants in the TRAIL trial were middle-aged and had strokes of mild to moderate severity. Our observations, particularly among female participants, do not reflect the poorer functional recovery[9] and health-related quality of life[83] trajectories reported in older females with stroke. Thus, exploration of personal and environmental factors associated with responses to exercise-based telerehabilitation is warranted in older stroke survivors. We were also limited to the sex- and gender-based variables assessed in the main TRAIL study and acknowledge that other factors such as household roles and stress may have influenced participants' trajectories.[84] Nevertheless, the variables included in our study were guided by previous literature on salient on sex and gender variables in health research.[6,85] Participants had high communication scores that were stable over time, which may be a reflection of eligibility criteria for the main trial. Future research may expand study eligibility to ensure study samples are inclusive and representative of individuals with common communication impairments. Finally, sex- and gender-based variables were only collected at baseline and we acknowledge the fluidity of health status and socio-cultural factors[7] that may warrant these demographics be collected at multiple timepoints.

4.6 Conclusion

This study used a multiple case studies approach to explore sex- and gender-based characteristics that may explain the trajectories of changes in subdomains of the SIS-3, ABC, and 30s-STS observed following an exercise and self-management telerehabilitation program. While some observations were illustrated that align with what we know about potential mechanisms for sex/gender differences in recovery after stroke, the cases also demonstrated that group differences reported in the literature do not always apply at an individual level, and that an array of sex- and gender-related personal and environmental factors will contribute to variation in treatment response.

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Declaration of Interest Statement

The authors have no conflicts of interests to declare.

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Table 4.2. Participant Characteristics

Participant	**1**	**2**	**3**	**4**	**5**	**6**
Sex	Female	Female	Female	Male	Male	Male
Gender Identity	Woman	Woman	Woman	Man	Man	Man
Age	50	64	43	55	52	54
Days post-stroke	62	177	161	83	251	63
Stroke Severity (NIH-SS)	2	7	5	5	4	3
Degree of Disability (mRS)	2	3	3	3	2	2
Stroke Type	Infarct	Infarct	Infarct	Hemorrhagic	Hemorrhagic	Unknown
Recurrent Stroke?	Yes	No	No	Yes	No	No
Diagnosed Hypertension?	Yes	Yes	Yes	Yes	Yes	Yes
Smoking Status	Previous Smoker	Current Smoker	Never Smoked	Current Smoker	Never Smoked	Never Smoked
Education	University Degree	Some high-school, not completed	University Degree	Completed high-school	College Diploma	College Diploma
Ethnicity	Indigenous	White	Filipino	White	Filipino	Black
Marital Status	Married/ Common Law	Married/ Common Law	Married/ Common Law	Married/ Common Law	Married/ Common Law	Married/ Common Law
Finances	Enough money to meet basic needs	Enough money to meet basic needs	Enough money to meet basic needs	Enough money to meet basic needs	Do not have enough money to meet basic needs	Income range between 30,000-49,999*
Living Arrangements (prior to stroke)	Spouse and/or other relatives	Spouse and/or other relatives	Spouse and/or other relatives	Spouse and/or other relatives	Spouse and/or other relatives	Spouse and/or other relatives
Caregiving Status	Current and previous	Previous	Previous	Never	Previous	Current and previous
Working Status	On sick leave and longterm disability	On sick leave	On sick leave	On sick leave	Longterm disability	On sick leave
Geographical Area	Rural	Rural	Rural	Rural	Sub-urban	Sub-urban
Global Cognitive Function (short MoCA)	13	14	14	14	14	14
List Comorbidities	Stroke, type II diabetes, anxiety or panic disorders, visual impairment, arthritis, obesity	Stroke, obesity	Stroke, visual Impairment	Stroke	Stroke, types II diabetes, upper gastrointestinal disease	Stroke, obesity
Body Mass Index, kg/m^2	35.7	30.9	21.5	25.8	24.4	31.6

Outpatient rehabilitation	Still Awaiting	Complete	Complete	Complete	Complete	Complete
Attempted ≥1 weekly self-management action plan?	Yes	Yes	Yes	Yes	Yes	Yes
Adherence	100%	100%	100%	100%	100%	100%
Satisfaction with TRAIL (/5)						
Staff Communication and Facilitation	5	5	5	4	4.8	4.6
Usefulness of the services	5	5	5	3.3	5	4.6
Equipment	5	5	5	3.7	5	4.6
Program Structure	5	5	5	3.3	5	4.3
Perception of the Program	5	5	5	3.5	5	4
Overall Satisfaction	5	5	5	3.6	4.96	4.4
Adverse Event(s)?	No	No	No	No	No	No

Note. *Participant #6 did not provide statement of how well financial needs were met, however provided income range. *Abbreviations.* NA= Not Applicable, NR= Not Reported, mRS= Modified Rankin Scale; NIH-SS= National Institutes of Health Stroke Severity Scale. Blue fill denotes female participants and orange fill denotes male participants

Table 4.3. Baseline scores of outcomes of interest

Participant	**1**	**2**	**3**	**4**	**5**	**6**
Stroke Impact Scale (/100)						
Strength	81.2	31.3	50.0	56.3	75.0	68.8
Memory & thinking	78.6	100.0	92.9	75.0	82.1	85.7
Emotion	88.9	69.4	91.7	66.7	80.5	88.9
Communication	89.3	100	100	71.4	75.0	100
Activities of Daily Living	90.0	65.0	67.5	52.5	90.0	70.0
Mobility	80.5	72.2	69.4	44.4	95.0	94.4
Hand function	90.0	90.0	5.0	25.0	75.0	90.0
Participation	46.9	46.9	71.9	43.8	59.4	31.3
Perceived recovery	70.0	70.0	50.0	60.0	70.0	80.0
Activity-Specific Balance Confidence (/100)	84.4	66.9	71.9	55.0	86.3	80.0
30-second sit-to-stand test, n repetitions	8	10	6	5	10	13

Note. Solid black lines denote female participants and dashed lines with grey fill denote male participants

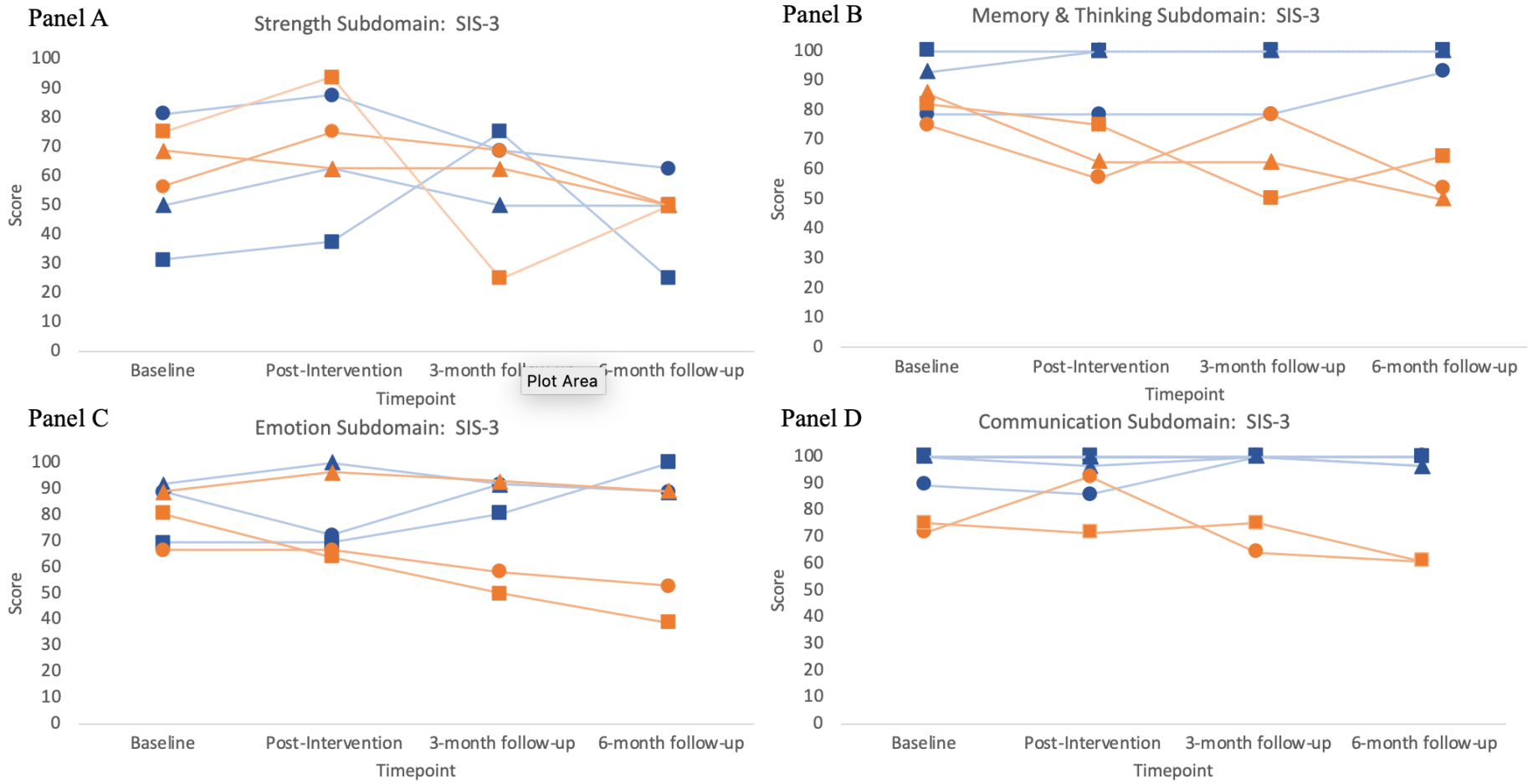
Table 4.4 Interpretability of changes from baseline for outcomes of interest at 3 timepoints (post-intervention, 3- and 6-month follow up)

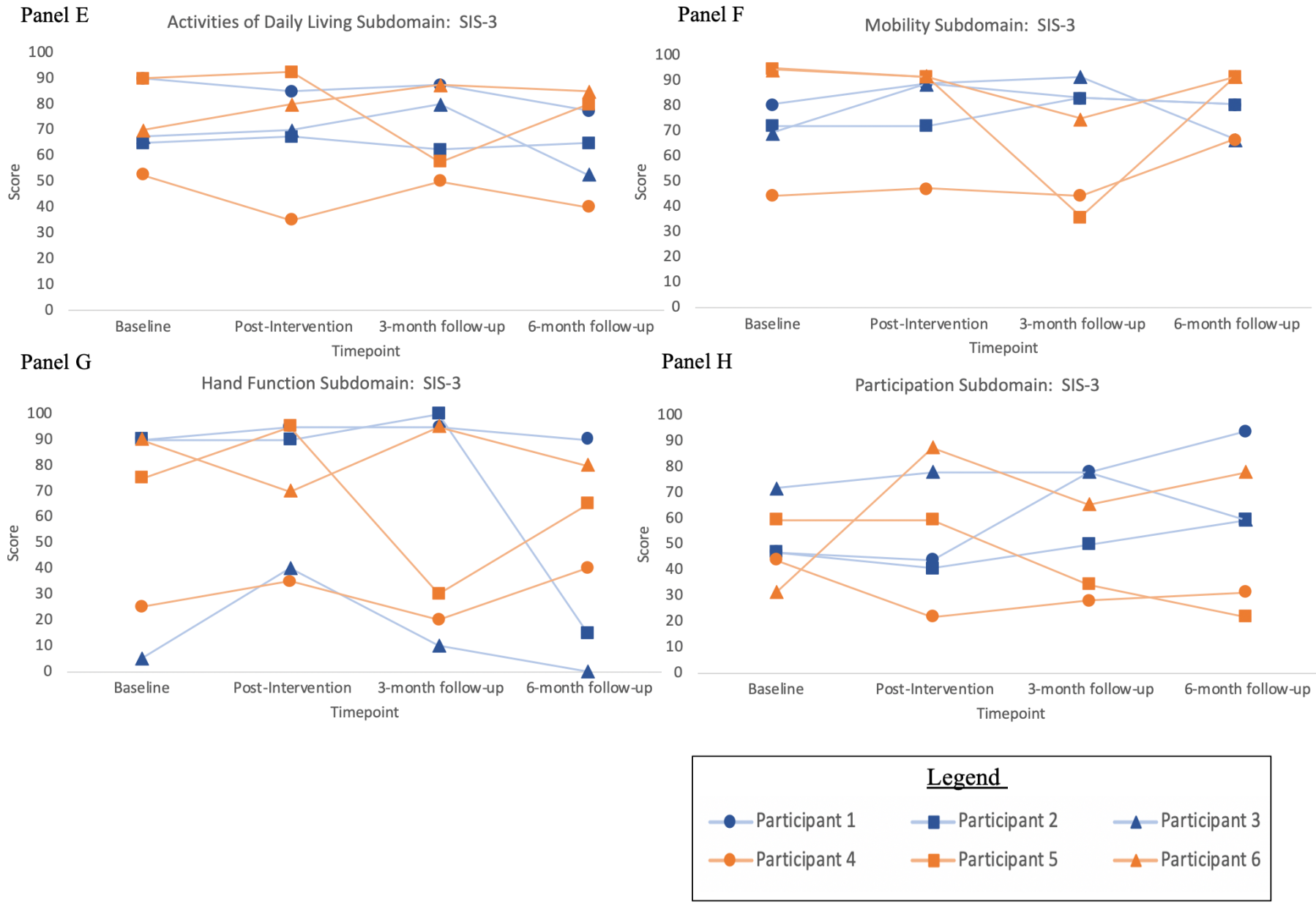
Participant	**1**			**2**			**3**			**4**			**5**			**6**		
Timepoint	Post	3	6	Post	3	6	Post	3	6	Post	3	6	Post	3	6	Post	3	6
Stroke Impact Scale																		
Strength			↓CID		↑MDC		↑CID			↑CID	↑ CID		↑CID	↓MDC	↓MCD			↓CID
Memory & thinking																		
Emotion																		
Communication																		
ADLs/IADLs			↓CID					↑CID	↓CID	↓MDC		↓CID		↓MDC	↓CID	↑CID	↑CID	↑CID
Mobility	↑CID				↑CID	↑CID	↑MDC	↑MDC				↑MCD		↓MDC			↓MDC	
Hand function						↓MDC	↑MDC						↑ CID	↑MDC		↓CID		
Participation																		
Perceived recovery																		
ABC				↓MDC	↑MDC	↑MDC	↑MDC	↑MDC						↓MDC				
30s-STS	↑SEM	↑SEM	↑SEM		↑SEM	↑SEM	↑SEM	↑SEM	↑SEM	↑SEM	↑SEM	↑SEM	↑SEM	↓SEM			↑SEM	

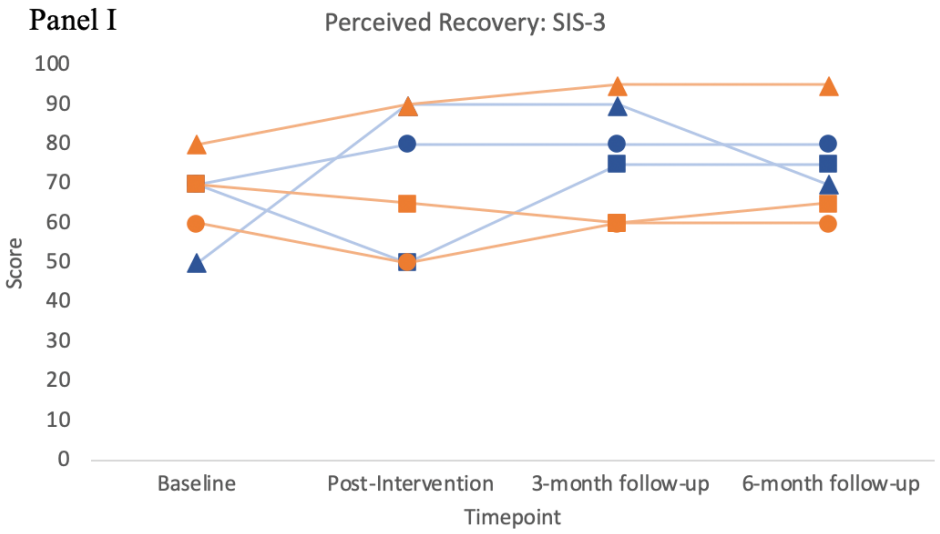
Note. ↑ denotes improvement from baseline; ↓ denotes decline from baseline

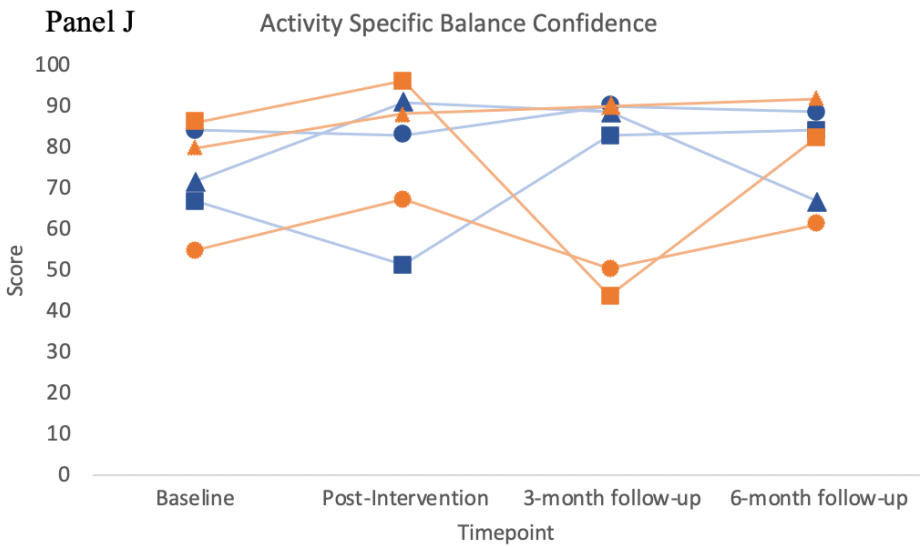
Abbreviations: 3 = 3-month follow-up; 6 = 6-month follow-up; MDC = minimal detectable change; CID = clinically important difference; SEM= standard error of measurement; ABC= Activity-Specific Balance Confidence; 30s-STS= 30s Sit-to-Stand. Blue fill denotes female participants and orange fill denotes male participants

Figure 4.1 Changes in Stroke Impact Scale-3 Subdomains (Panels A-I), Activity-Specific Balance Confidence Scale (Panel J), and 30-Second Sit-to-Stand (Panel K) over time. Trajectories for female participants (Participant 1-3) are denoted by blue fill, while trajectory for male participants are denoted by orange fill (Particpants 4-6).




Panel E
Activities of Daily Living Subdomain: SIS-3
Score
Timepoint
Baseline
Post-Intervention
3-month follow-up
6-month follow-up
Panel F
Mobility Subdomain: SIS-3
Panel G
Hand Function Subdomain: SIS-3
Panel H
Participation Subdomain: SIS-3
Legend
Participant 1
Participant 2
Participant 3
Participant 4
Participant 5
Participant 6


Panel I
Perceived Recovery: SIS-3
Score
100
90
80
70
60
50
40
30
20
10
0
Baseline
Post-Intervention
3-month follow-up
6-month follow-up
Timepoint


Panel J
Activity Specific Balance Confidence
Score
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90
80
70
60
50
40
30
20
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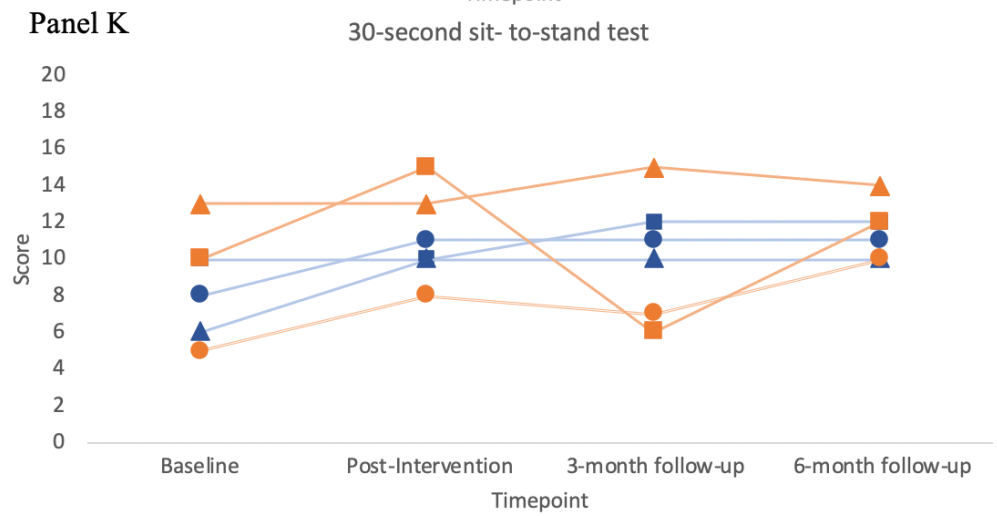
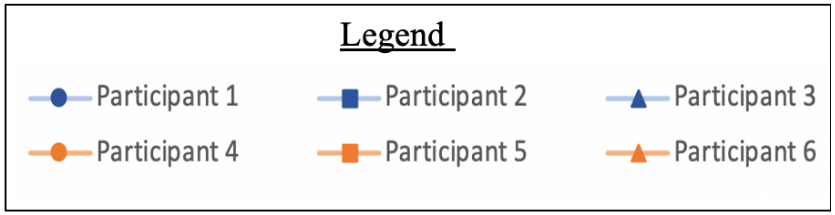
Baseline
Post-Intervention
3-month follow-up
6-month follow-up
Timepoint


Panel K
30-second sit- to-stand test
Score
20
18
16
14
12
10
8
6
4
2
0
Baseline
Post-Intervention
3-month follow-up
6-month follow-up
Timepoint


Legend
Participant 1
Participant 2
Participant 3
Participant 4
Participant 5
Participant 6

Appendix 4.1. Changes from baseline for outcomes of interest at 3 timepoints (post-intervention, 3- and 6-month follow up)

Participant	**1**			**2**			**3**			**4**			**5**			**6**		
Timepoint	Post	3	6	Post	3	6	Post	3	6	Post	3	6	Post	3	6	Post	3	6
Stroke Impact Scale																		
Strength	87.5	68.8	62.5	37.5	75.0	25.0	62.5	50.0	50.0	75.0	68.8	50.0	93.8	25.0	50.0	62.5	62.5	50.0
Change	*+6.3*	*-12.5*	*-18.7*	*+6.2*	*+43.7*	*-6.3*	*+12.5*	*0*	*0*	*+18.7*	*+12.5*	*+6.3*	*+18.8*	*-50.0*	*-25.0*	*-6.3*	*-6.3*	*-18.8*
Memory & thinking	78.6	78.6	92.9	100.0	100.0	100.0	100.0	100.0	100.0	57.1	78.6	53.6	75.0	50.0	64.3	96.4	92.9	89.3
Change	*0*	*0*	*+14.3*	*0*	*0*	*0*	*+7.1*	*+7.1*	*+7.1*	*-17.9*	*+3.6*	*-21.4*	*-7.1*	*-32.1*	*-17.8*	*+10.7*	*+7.2*	*+3.6*
Emotion	72.2	91.7	88.9	69.4	80.5	100.0	100	91.7	88.9	66.7	58.3	52.8	63.9	50.0	38.9	80.5	72.2	83.3
Change	*-16.7*	*+2.8*	*0*	*0*	*+11.1*	*+30.6*	*+8.3*	*0*	*-2.8*	*0*	*-8.4*	*-13.9*	*-16.6*	*-30.5*	*-41.6*	*-8.4*	*-16.7*	*-5.6*
Communication	85.7	100.0	100.0	100.0	100.0	100.0	96.4	100.0	96.4	92.6	64.3	60.7	71.4	75.0	60.7	100	100	96.4
Change	*-3.6*	*+10.7*	*+10.7*	*0*	*0*	*0*	*-4.6*	*0*	*-4.6*	*+21.2*	*-7.1*	*-10.7*	*-3.6*	*0*	*-14.3*	*0*	*0*	*-3.6*
ADLs/IADLs	85.0	87.5	77.5	67.5	62.5	65.0	70.0	80.0	52.5	35.0	50.0	40.0	92.5	57.5	80.0	80.0	87.5	85.0
Change	*-5.0*	*-2.5*	*-12.5*	*+2.5*	*-2.5*	*0*	*+2.5*	*+12.5*	*-15.0*	*-17.5*	*-2.5*	*-12.5*	*+2.5*	*-32.5*	*-10.0*	*+10.0*	*+17.4*	*+15.0*
Mobility	88.9	83.3	80.5	72.2	83.3	80.5	88.9	91.7	66.7	47.2	44.4	66.7	91.7	36.1	91.7	91.7	75.0	91.7
Change	*+8.4*	*+2.8*	*0*	*0*	*+11.1*	*+8.3*	*+19.5*	*+22.3*	*-2.7*	*+2.8*	*0*	*+22.3*	*-3.3*	*-58.9*	*-3.3*	*-2.7*	*-19.4*	*-2.7*
Hand function	95.0	95.0	90.0	90.0	100.0	15.0	40.0	10.0	0	35.0	20.0	40.0	95.0	30.0	65.0	70.0	95.0	80.0
Change	*+5.0*	*+5.0*	*0*	*0*	*+10.0*	*-75.0*	*+35.0*	*+5.0*	*-5.0*	*+10.0*	*-5.0*	*+15.0*	*+20.0*	*-45.0*	*-10.0*	*-20.0*	*+5.0*	*-10.0*
Participation	43.8	78.1	93.8	40.6	50.0	59.4	78.1	78.1	59.4	21.9	28.1	31.3	59.4	34.4	21.9	87.5	65.6	78.1
Change	*-3.1*	*+31.2*	*+46.9*	*-6.3*	*+3.1*	*+12.5*	*+6.2*	*+6.2*	*-12.5*	*-21.9*	*-15.7*	*-12.5*	*0*	*-24.0*	*-37.5*	*+56.2*	*+34.3*	*+46.8*
Perceived recovery	80.0	80.0	80.0	50.0	75.0	75.0	90.0	90.0	70.0	50.0	60.0	60.0	65.0	60.0	65.0	90.0	95.0	95.0

Change	+10.0	+10.0	+10.0	-20.0	+5.0	+5.0	+40.0	+40.0	+20.0	-10.0	0	0	-5.0	-10.0	-5.0	+10.0	+15.0	+15.0
ABC	83.2	90.3	88.9	51.3	83.1	84.4	91.3	88.8	66.9	67.5	50.6	61.3	96.3	43.8	82.5	88.4	90.3	92.2
Change	*-1.2*	*+5.9*	*+4.5*	*-15.6*	*+16.2*	*+17.5*	*+19.4*	*+16.9*	*-5.0*	*+12.5*	*-4.4*	*+6.1*	*+10.0*	*-42.5*	*-3.8*	*+8.4*	*+10.3*	*+12.2*
30s-STS	11	11	11	10	12	12	10	10	10	8	7	10	15	6	12	13	15	14
Change	+3	+3	+3	0	+2	+2	+4	+4	+4	+3	+2	+5	+5	-4	-1	0	+2	+1

Note. + denotes improvement from baseline; - denotes decline from baseline. Abbreviations: ABC= Activity-Specific Balance Confidence; 30s-STS= 30s-Sit-to-Stand; 3 = 3-month follow-up; 6 = 6-month follow-up. Blue fill denotes female participants and orange fill denotes male participants.

CHAPTER 5: DISCUSSION

The overall aim of this PhD thesis was to examine the intersection between sex- and gender-based considerations and exercise-based telerehabilitation among individuals with stroke. Specifically, I employed different research methodologies to explore facilitators and barriers to participation, experiences, and long-term responses in performance-based and health-related quality of life outcomes to a synchronously-delivered lower extremity-focused telerehabilitation program in men and women with stroke. Collectively, the studies in this thesis provide evidence of the viability of telerehabilitation for the delivery of stroke rehabilitation to women who are disproportionally impacted by stroke. Researchers and clinicians may further expand on our preliminary findings of self-reported improvements in physiological outcomes and health-related quality of life in both men and women with stroke.

In this Discussion chapter, I will provide a summary of the findings from my three studies that comprise this thesis, describe the implications of these findings on clinical practice, outline strengths and limitations of this research, and conclude with remarks on my academic journey and future plans as a rehabilitation scientist.

5.1 Summary of findings and contributions to the literature

The first study was a scoping review that aimed to identify and describe the facilitators and barriers to participation in exercise-based telerehabilitation programs among men and women with stroke. Our secondary aim was to explore whether gender-related facilitators or barriers existed to participation in telerehabilitation. The analysis and interpretation of findings were guided by the TDF framework, which is commonly used to identify facilitators and barriers influencing health-related behaviours.[1] The identified constructs were mapped onto one or more

of the 14 domains of the TDF.[1] Among the 38 primary research identified (n=882 participants), the "environmental context and resources" domain was represented by the most constructs, while the least commonly reported domains were "beliefs about consequences", "memory, attention, and decision processes", "social identity and roles", and "goals" related to participation in telerehabilitation.

Within the identified domains, we reported on many common facilitators and generally few barriers to participation in exercise-based telerehabilitation. The most commonly reported facilitators were ease of use (n=19 studies; TDF domain: "skills"), comfort with technology (n=8 studies; TDF domains: "knowledge" and "skills"), self-perceived improvements in physical function (n=14 studies; TDF domain: "reinforcement") and enjoyment (n=8 studies; TDF domain: "emotion" and "reinforcement"). Environmental-related facilitators included accessibility (n=8 studies), acceptable audio and video features (n=7 studies), convenience/flexibility of the training schedule (n=8 studies), variety of games (n=7 studies), and therapist communication skills (n=16 studies; TDF domains: "environmental" and "social influences"). Positive feedback/encouragement from family and friends (n=7 studies; TDF domain: "social influences") and the self-perceived usefulness of telerehabilitation (n=7 studies; TDF domains: "intentions" and "reinforcement") also facilitated participation. Finally, participants reported positive behavioural intention (n=10 studies; TDF domain: "intentions") regarding the continued use of telerehabilitation in the future and recommended use of telerehabilitation for others (n=9 studies; TDF domain: "optimism"). Conversely, the most commonly reported barriers to participation were environmental-related factors including challenges with internet speed and connectivity (n=7 studies) and wearing and/or adjusting the technological device(s) (n=7 studies).

The findings arising from this scoping review builds on a previous systematic review of 11 studies (6 exercise-based interventions encompassing 220 participants) reporting satisfaction outcomes and some facilitators and barriers to participation.[1] These included improved access to therapists and less disruption than in-person care on daily routines, while poor internet connectivity and dissatisfaction with the aesthetics of technological devices were also reported.[2] I note however that the previous systematic review included RCTs only and did not include studies that explored lived experience of and satisfaction with telerehabilitation. Moreover, the previous review included a broad range of interventions including counselling support, cognitive and psychosocial behavioral therapy.[2] Isolating exercise-based interventions focused on improving physical function in the current scoping review allowed me to explore unique considerations related to camera placement and guidance on modification and progression of exercise.[3,4]

Very few of the included studies in my scoping review provided data that could be used to explore gender-related facilitators and barriers to participation in telerehabilitation. Positively, however the one study that conducted a disaggregated analysis reported that men and women were satisfied with program material and possessed skills and knowledge to participate in telerehabilitation,[5] with two additional studies noting some women received support from family with navigating technological challenges.[6,7] While it has been previously reported that older women had lower proficiency with using technology compared to men,[8] the findings of this scoping review are encouraging that women felt that telerehabilitation was easy and not confusing to use. These findings may suggest that technology is now generally more accessible to a wider portion of the population, and thus potentially narrowing the gender gap in perceptions of and use of technology.

Moreover, the flexibility of the training schedule and accessibility (i.e., limited need for transportation) of telerehabilitation may help navigate obstacles around the substantial time commitments of household and caregiving roles commonly held by women with stroke.[9] These findings prompted an opportunity to further integrate gender-based considerations in the exploration of the acceptability of telerehabilitation in individuals with stroke, which was the focus of my second study.

My second study aimed to subjectively explore the experiences of a synchronously-delivered exercise-based telerehabilitation program among Canadian community-dwelling adults with stroke. Specifically, the emphasis of this qualitative study was to describe and understand the experiences[10] of the individuals post-stroke who participated in a 4-week lower-extremity exercise and self-management program (TeleRehabilitation with Aims to Improve Lower extremity recovery post-stroke [TRAIL]) in terms of their perceptions of the program delivery and resources, as well as lower-extremity related rehabilitation outcomes. An interpretive description methodology and inductive thematic analysis approach were undertaken. Importantly, purposeful sampling strategies focused on maximum variation related to gender identity and geographical location were employed, to understand whether these factors influenced how participants experienced TRAIL, given the greater barriers to participation in stroke rehabilitation faced by women[9] and individuals residing in rural areas.[11] Semi-structured interviews were conducted among 10 participants (4 women; 6 men) who completed the TRAIL program.

Two main themes emerged including TRAIL ingredients for success and telerehabilitation is a viable option for stroke rehabilitation. Participants described that strong support from family and peers, the expertise of the physiotherapist, effective videoconference software, and provision

of comprehensive manuals were critical components to be able to successfully participate in a lower extremity-focused telerehabilitation program. Moreover, the TRAIL program was deemed to be accessible with regards to limited need for transportation especially when considering that the majority of our participants experienced either temporary or permanent suspension of their driver licenses, extended rehabilitation opportunities into the community, and addressed unmet lower extremity-related rehabilitation needs in both men and women with stroke.

Findings corroborate facilitators identified in our scoping review (Study 1) including social support from family,[6,12–16] communication skills of the physiotherapist,[3,6,12–14,17–27] opportunities for further rehabilitation,[28] self-perceived improvements in lower extremity function,[19,21,26,29–31] acceptable audio and video features[3,19,20,23,24,31] and accessibility,[6,13,16,19,20,31,32] but also offer novel perspectives that had yet to be reported. The TRAIL program integrated unique features that enabled satisfactory participation among our participants. First, some participants received the intervention in a 2:1 participant-to-therapist ratio, whereby these participants noted a sense of camaraderie with their peer when completing an exercise program together in real-time. Indeed, through my scoping review, we identified that TRAIL is one of two[19] group-based, synchronously-delivered program for lower extremity recovery after stroke. Peer support plays an important role in supporting community reintegration, as it promotes interpersonal connections from mutual experiences.[33] Our qualitative study supported that the positive elements of peer support could be experienced even in virtual settings, and thus advancing our knowledge of the facilitators around social influences (domain of the TDF[1]) in exercise-based telerehabilitation.

Secondly, the study manuals provided to participants (e.g., Exercise and Participant Manuals) were a unique, yet integral element of the TRAIL program, with participants sharing

that the written and visual guidance were complementary to live communication with the physiotherapist. Whereas our scoping review suggested that resources are not commonly provided in exercise-based telerehabilitation, findings from Study 2 suggest that study manuals are indeed beneficial to facilitate participation in synchronously-delivered telerehabilitation by providing guidance on setting up the virtual environment and conducting, progressing and/or modifying exercises. Lastly, the use of maximum variation sampling strategies on gender identity and integration of gender-related questions into the interview guide (e.g., "How did your roles at home and/or in the community impact your ability to participate in TRAIL?") ensured that the observed themes were applicable to both men and women with stroke, and provided preliminary evidence of the viability of telerehabilitation in women. This finding lays the foundation for larger-scaled sex and gender-disaggregated research studies to establish the effectiveness of telerehabilitation in women.

My third study sought to build on the qualitative study of Study 2 by providing a closer examination of sex- and gender-based factors potentially associated with participation in and self-reported physical and health-related quality of life outcomes following the 4-week TRAIL telerehabilitation program. Study 3 included 6 case studies comprised of 3 females and 3 males purposefully sampled based on age and stroke severity per the NIH-SS. All participants resided in either rural or sub-urban geographical locations, were satisfied to highly satisfied with telerehabilitation, and did not experience any adverse events. Interestingly, many of the observed trends did not align with literature on the disproportional effects of stroke in women, namely in emotional state, ADL/IADLs, and mobility domains of the SIS-3. Greater stroke severity,[34] depression,[35] older age,[36] and widowhood[37] have all been attributed to the poorer trajectories in functional outcomes in females after stroke, however all female participants in our study had

mild to moderate ischemic strokes and stable emotional responses, were middle-aged, married and living with a spouse, thus potentially explaining the relatively positive responses. In contrast, male participants often possessed characteristics that are associated with poorer psychological outcomes, such as having experienced hemorrhagic strokes[38] and reporting the combination of being on disability and not having enough money to meet basic needs.[39,40] Moreover, a male participant with a poor baseline prognosis in the performance-based strength outcome had a recurrent hemorrhagic stroke and was a current of smoker, of which are personal factors associated with poorer functional outcomes after stroke.[41,42] Overall, this study suggested a need to consider the personal and environmental characteristics of individuals with stroke when exploring clinical outcomes, and thus reinforcing the importance of the unique needs of each individual in the development of therapy plans.[43] These findings are reinforced by the Canadian best practice recommendations for virtual rehabilitation that provide strong recommendation of the need to assess patients' environmental factors related to stroke rehabilitation prior to delivering treatment with the goal of providing safe and acceptable care.[44] A comprehensive understanding of individuals' personal and environmental factors may be captured through sex and gender indices.[44]

5.2 Clinical implications

Findings arising from this thesis provide preliminary evidence of the use of telerehabilitation to address sex- and gender-based disparities experienced by women with stroke. The results from my scoping review and qualitative study provides evidence for clinicians and stroke rehabilitation scientists of key facilitators that optimize satisfaction and positive participation behaviours in exercise-based telerehabilitation in men and women with stroke. The multiple case studies approach allowed a thorough exploration sex- and gender-based factors that could

influence participation behaviours and outcomes, and thereby providing a foundation for researchers of pertinent personal variables to consider in future larger-scaled telerehabilitation trials.

A consensus of few technological challenges, critical role of the therapist and self-reported improvements in lower extremity function can be clearly drawn from all three studies. Men and women in our studies (Chapters 3 & 4) experienced negligible connectivity challenges when participating in telerehabilitation, despite some participants residing in rural areas of Canada. Indeed, these findings challenge cited concerns of limited internet connection in rural areas that can limit the implementation of telerehabilitation.[46] The role of the therapist also appeared to be a key facilitating factor to participation, and speaks to their ability to effectively apply skills in virtual settings when they cannot rely on physical contact despite previously prompted concerns that remotely-delivered stroke rehabilitation may reduce the therapeutic relationship.[47] Findings from this thesis suggest that strong communication skills may support the therapeutic relationship in these virtual settings, whereby participants have benefited from therapists providing clear instructions and/or explanations,[3,17,18,22] active listening,[3,18,19,22,26] friendliness[23,27] and respect,[3,18,22,23] correcting and sharing feedback on exercises,[12,13,19,25,26] offering encouragement,[6,13,20,21,24,25] and answering questions.[18,22,23] Indeed, a previous systematic review comprising of individuals with brain injury, musculoskeletal and cardiac conditions (n=14 studies) identified that a strong patient-therapist relationship involving communication skills and competency can improve patient outcomes including reductions in depressive symptoms, increased quality of life, adherence and satisfaction with treatment. Thus, therapists are encouraged to leverage their communication skills in virtual environments.[48]

Canadian best practice recommendations state that clinicians should be trained and competent to deliver safe and appropriate telerehabilitation,[44] but there was limited reporting of therapist training procedures in studies included in our scoping review making it challenging to comment on the degree of training received. It is worth noting however that therapists involved with the TRAIL studies received 3 hours of comprehensive training which included set up and delivery of exercises in the virtual environment (e.g., camera angles, spacing requirements, pre-participation safety checklist, etc.), as well as detailed manuals on conducting, modifying, and progressing exercises. Overall, therapists involved with the delivery of exercise-based telerehabilitation should continue to uphold best practice recommendations around training standards to optimize their skillset, and in turn promote the therapeutic relationship with their patients. Newly developed clinical implementation toolkits, which aim to share helpful resources and knowledge on the implementation of telerehabilitation in individuals with stroke,[49] may also facilitate knowledge uptake.

The third overarching finding observed in all three studies was the potential of exercise-based telerehabilitation to improve self-reported balance, strength and mobility (Chapters 2 and 3) and performance-based strength (Chapter 4). It is encouraging that participants not only benefited from the limited need for travel involved with telerehabilitation, but were also able to achieve functional benefits. The most notable contribution to the literature relates to our observation that women, whom are reported to have poorer prognoses after stroke,[50,51] not only demonstrated meaningful improvements in lower extremity strength from an exercise program, they also had sustained performance-based physical strength over time (Chapter 4). Thus, the preliminary evidence generated from our multiple case studies provides a basis of viability of

telerehabilitation in women with stroke, and prompts exciting opportunities for future research to build on these findings.

Lastly, it is important to acknowledge that although not substantial, there were reports in our scoping review and qualitative study of participants desiring some in person interaction with their therapist.[3,20,26,16] Thus, the option of a hybrid model combining in-person and concurrent virtual rehabilitation opportunities [52] may be recommended to optimize positive experiences with stroke rehabilitation services. Moreover, given the importance of real-time interactions between the therapist and patient, synchronously-delivered may be preferred over remotely monitored asynchronous programs. Future research is needed to confirm this speculation.

5.3 Strengths and limitations

There are both strengths and limitations within individual studies and broadly across this thesis. The primary strength of this thesis is the use of different research designs and methodologies that were purposefully selected to build on each other, and address gaps identified in the previous chapter(s). Guided by the theoretically sound Theoretical Domains Framework,[1] the scoping review (Study 1) provided a comprehensive synthesis of any primary research studies of facilitators and barriers to exercise-based telerehabilitation, as well as any reports of gender-related facilitators and barriers to participation. The study identified two key gaps: 1) a lack of studies investigating perspectives of individuals with stroke with synchronously-delivered lower extremity telerehabilitation; 2) a lack of studies incorporating gender-based considerations into all stages of the study. These gaps were explored further in the qualitative study (Study 2), where we reported synchronously-delivered lower extremity telerehabilitation [TRAIL] to be a viable form of stroke rehabilitation service delivery in both and women, as well as individuals in urban and rural areas. This was the first study to incorporate gender-based

considerations into the sampling, analysis, reporting and interpretation of findings. Finally, the multiple case studies approach (Study 3) added to evidence from our qualitative study of self-reported improvements in strength acquired from TRAIL by allowing a closer examination of sex- and gender-related characteristics potentially associated with changes observed.

Importantly, all three studies adhered to international sex and gender reporting guidelines (Sex and Gender Equity in Research Guidelines) in every aspect of the research.[53] Thus, this thesis provided rigorous and multidimensional insights into the intersection between sex- and gender-based considerations and exercise-based telerehabilitation in individuals with stroke.

It is important to acknowledge the limitations of this thesis as whole. Most studies included in our scoping review were conducted in high-resource countries, while our qualitative and multiple cases studies were conducted in community-dwelling individuals with stroke in Canada. Emerging research conducted in resource-constrained settings contrast some of our observations, whereby inaccessibility and low technological literacy have been reported.[54] Thus, the application of our findings to these settings should be avoided, and further exploration is warranted. Moreover, our study using a multiple case study approach sampled middle-aged individuals (min-max: 43-64 years old) with mild to moderate stroke (represented the majority of the study sample), and thus may not be generalizable to older adults (>65 years) and/or individuals with severe strokes.

This thesis does not include insights from therapists involved with the delivery of telerehabilitation, nor from caregivers and family members of individuals with stroke who participated in telerehabilitation. Physiotherapists have corroborated that telerehabilitation platforms have increased access and improved patient outcomes,[55] contributing to helping address a service gap for community dwelling individuals with stroke.[16] Physiotherapists have

also noted limited knowledge on how to use the technology as a key barrier to providing telerehabilitation.[16,56] Moreover, caregivers and family members of individuals with stroke have benefited from the limited travel involved,[16] stable and effective videoconferencing software,[57] the professionalism of the therapist,[57] and the individualization of asynchronously-delivered telerehabilitation.[58] Physiotherapists and family members perspectives possess additional insight into the acceptability of telerehabilitation; thus future research should aim to integrate their insights around the delivery of exercise-based telerehabilitation for individual with stroke.

Finally, given that this thesis aimed to provide preliminary evidence of the use telerehabilitation to help overcome barriers related to accessing to rehabilitation services for women with stroke, the expertise of a woman with lived experience of stroke would have been an asset to developing the research questions, methodology, analysis and reporting, and interpretation of findings. As a rehabilitation scientist, it is important to conduct research that fosters active collaborations, and is meaningful and relevant to individuals with stroke.[59] Thus, my future research will seek to engage community members as valued study team members who will be engaged from study inception to end of study knowledge dissemination efforts.

5.4 Personal reflection and next steps

I am grateful for the research experiences that have led to where I am today. Between 2014-2018, I completed a B.Sc in Exercise Physiology at the University of Miami, where I was also incredibly privileged to be a member of the Division 1 varsity rowing team. Through my position as a student-athlete, I acquired valuable time-management, teamwork and leadership qualities, of which I strongly believe have contributed to molding the researcher that I am today. As a result of a busy competition schedule during the regular school year, I undertook a required internship course through Brock University's Power Cord program, in the summer of 2017. Power Cord is

an adapted community exercise program for individuals with physical disabilities, and I had the absolute privilege to oversee a multi-component exercise program of an older man with stroke. This rewarding experience exposed me to the power of exercise and social connection in this population. In the final year of my undergraduate degree, I was able to continue to solidify my newfound passion for research in stroke rehabilitation, through a volunteer role on an American Heart Association-funded trial examining the safety and feasibility of a combined aerobic, resistance, and cognitive training to improve recovery after stroke.

The combination of my undergraduate experiences truly solidified my passion for research in stroke rehabilitation. This led to an ambition of completing a M.Sc. Between 2018-2020, I moved back home to Canada and completed my M.Sc in the Rehabilitation Science program at McMaster University, under the supervision of Dr. Ada Tang, a physical therapist and Professor in the School of Rehabilitation Science, and leading expert in the exercise and cardiovascular health post-stroke. As a trainee in the MacStroke Canada lab, I have been exposed to other high-achieving trainees, whereby collaboration is at the forefront of our research endeavours. I have also tremendously valued opportunities to act as a graduate student supervisor to undergraduate students at McMaster (Life Science, Health Sciences and Kinesiology programs) pursuing undergraduate research practicum or theses, as well as mentor MSc trainees in the lab. Seeing their success and growth is one of the most rewarding aspects of research.

Thanks to the support and guidance from Dr. Tang throughout my M.Sc, I developed a profound interest in sex and gender considerations in stroke rehabilitation. I have not looked back since. In the early stages of my doctoral training (September 2020-August 2024), Dr. Tang exposed me to the CanStroke Recovery Trials platform, where I was introduced to Dr. Brodie Sakakibara, an Assistant Professor in the Faculty of Medicine at the University of British

Columbia (UBC). As co-primary investigators, Drs. Tang and Sakakibara entrusted me to lead the Canadian Institutes of Health Research-funded, TeleRehabilitation with Aims to Improve Lower extremity recovery post-stroke (TRAIL) clinical trial, paving a path to forming a rich and diverse collaborative network. These strong relationships have led me to pursue a post-doctoral fellowship at UBC (Fall 2024), under the co-supervision of Drs. Sakakibara and Jennifer Davis. Dr. Davis is an emerging expert in health economic research, and am I excited to expand my research toolkit by undertaking new and exciting methodologies in chronic disease self-management. Specifically, my post-doctoral research will explore the natural history of chronic disease self-management and health resource utilization after stroke. I am also excited to continue fostering my collaborative relationships with people with lived experience of stroke.

With regards to my career goals, I envision holding an academic position at a Canadian university, leading a research program focused on examining sex- and gender-based considerations in innovative interventions to optimize health in stroke survivors. I envision that my research program will contribute to informing clinical practice and providing evidence-based knowledge that result in rehabilitation strategies shaped to target the unique needs of men and women with stroke and narrowing the gap in achieving health equity in Canada. My ultimate goal is to be an internationally-renowned expert as it relates to advancing rehabilitation outcomes and participation in women with stroke.

5.5 Conclusion

Collectively, findings from studies reported in this thesis suggested that there are many facilitators and few barriers to participation in exercise-based telerehabilitation in people with stroke. Most notably, self-reported improvements in functional abilities were consistently reinforced in women across all three studies, alluding to opportunities to leverage virtual

rehabilitation to promote stroke recovery in women who are disproportionally impacted by the effects of stroke and experience barriers to accessing rehabilitation services.[9] Taken together, this research provides promising insight into the use of telerehabilitation to deliver exercise interventions to both men and women with stroke. Findings also provide rationale for further consideration of sex- and gender-based factors and analyses in telerehabilitation-related interventions.

5.6 References

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