RELIABILITY, VALIDITY, AND FEASIBILITY OF REMOTELY CONDUCTING CINICAL BALANCE AND WALKIG ASSESSMENTS VIA VIDEO-CONFERENCTING PLATFORMS FOR PEOPLE FOLLOWING STROKE

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Abstract

This study explores reliability, validity, and feasibility of conducting clinical assessments of balance and walking ability for people post-stroke via videoconferencing.

Twenty-eight people with chronic stroke who completed the in-person Six-minute Walk Test and Community Balance and Mobility Scale were recruited. Five clinical measures were modified as virtual assessments: Five-times Sit-to-Stand (5-times STS), Functional Reach Test (FRT), tandem stance (TS), Timed Up and Go test (TUG), and Thirty-seconds Sit-to-Stand (30-sec STS). Sessions were conducted over video-conferencing platform. Test-retest reliability was examined by Intra-class correlations (ICC) and the standard error of measurement (SEM) to evaluate the reliability and agreement between two testing days. The magnitude of associations among in-person and virtual assessments were used to examine convergent validity using Spearman rank correlation. Feasibility was evaluated by task completion rate, adverse events, and experienced technical difficulties.

Twenty-one participants (52% female) participated both in-person and virtual assessments. There were no adverse events. Challenges of Internet connection or navigating the platform were experienced by 38% participants. The TUG, 30-sec STS, 5-times STS had good-to-excellent test-retest reliability (ICCs=0.97, 0.90, and 0.77 respectively). FRT and TS had moderate test-retest reliability (ICCs=0.54 and 0.50). The TUG, 5-times STS, and 30-sec STS had moderate-to-excellent relationships with in-person assessment (ρ= -0.55 to -0.85, P<0.001). FRT and TS showed no significant relationships with in-person assessments.

The good-to-excellent test-retest reliability of remotely conducting 5-times STS, TUG, and 30-sec STS for people with stroke, together with strong convergent validity of the measures compared to in-person 6MWT is promising. Measurement of walking and balance function in ambulatory people post-stroke over video-conferencing is feasible; however, technical challenges were experienced.

Lay Summary

Due to the outbreak of the COVID-19 pandemic, in-person medical appointments and rehabilitation services were forced to cease. Virtual rehabilitation and health care have gained increasing interest as an alternative way to provide health care services. The current research aimed to explore the utility of performing clinical balance and walking assessments in people following stroke over the video-conferencing platform, Zoom. In this study, we asked individuals with stroke to independently perform balance and walking assessments in their own homes while a physiotherapist assessed their performance over the Zoom video-conferencing platform during two separate sessions. We aimed to provide guidance to clinicians if they intended to deliver similar healthcare approaches and provide evidence of conducting clinical balance and mobility assessments over video-conferencing with people following stroke.

Preface

The present thesis has been completed by the candidate Tzu-Hsuan Peng under the supervision of Dr. Courtney Pollock. The experimental design was done with the collaborations of Dr. Courtney Pollock, Dr. Janice J. Eng, Dr. Brodie Sakakibara, Dr. Ada Tang, and Ms. Anne Harris. The data collection was done by Ms. Anne Harris and the candidate. The analysis of the research data and documentation was done primarily through the candidate.

This thesis work was part of a larger project entitled 'Innovative application of technology to individualize and optimize rehabilitation of walking balance post-stroke'. It was conducted in the Mobility and Balance Rehabilitation Lab. The experiment was approved by the University of British Columbia Clinical Research Ethics Board (H19-01369).

Chapter 2 is an unpublished analysis of data based on work conducted in the Mobility and Balance Rehabilitation Lab. Ethics approval was provided by the University of British Columbia Clinical Research Ethics Board (H19-01369).

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List of Abbreviations

BBS: Berg Balance Scale

BOS: Base of support

CB&M: Community Balance and Mobility Scale

COM: Center of mass

COVID-19: Coronavirus disease of 2019

CTT: Classical test theory

FRT: Functional Reach Test

ICC: Intra-class correlation coefficient

MDD: Minimal detectable difference

RPS: Rate of Perceived Stability scale

SEM: Standard error of measurement

TRAIL: TeleRehabilitation with Aims to Improve Lower Extremity Recovery Post-Stroke

TS: Tandem Stance

TUG: Timed Up and Go test

5-times STS: Five-times Sit-to-Stand test

6MWT: Six-minute Walk Test

30-sec STS: Thirty-seconds Sit-to-Stand test

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Dedication

To my Dad, Mom, brothers and my friends.

Chapter 1: Introduction

1.1 Stroke

Cerebrovascular accident, or stroke, could be described as “the sudden onset of neurological deficits caused by vascular injury to the brain.” [1] The diagnosis depends on clinical features and brain imaging made by computed tomography or magnetic resonance imaging scan. The two main types of vascular damage are ischemia and hemorrhage. An ischemic stroke is caused by the brain blood vessel blockage, whereas hemorrhagic stroke results from the rupture of the cerebral blood vessel. Ischemic stroke accounts for 80% of stroke as the most common type of stroke.[2] Hemorrhagic stroke accounts for 15% and results in a higher mortality rate.[1, 2] The long-term impacts of stroke is determined by the type, location, and size of initial stroke lesion.[1, 2]

Stroke is the leading cause of neurological disability in adults worldwide.[3] According to the global report, about 10.3 million new stroke survivors and 6.5 million people died from stroke in 2013.[3] In Canada, over 400 thousand people were estimated living with the impacts of stroke,[4] and over 60 thousand people have a diagnosis of stroke or transient ischemic attack each year.[5] Although around 10% of stroke survivors were estimated to fully recover after stroke, there were about 25% people likely to experience mild impairment, 40% people likely to experience moderate to severe impairment, and 10% of people with stroke may require long-term care in a nursing home or facility.[1] The largest proportion of neurological and functional recovery happens in the first 6 months post-stroke,[2] however, the recovery trajectory can continue for years.[1]

Among all the neurological impairments after stroke, the most common deficit is weakness or paralysis of one side of the body.[1] Stroke patients with hemiparesis experience motor impairment and reduced mobility.[2] Regaining the ability to walk independently is usually the primary goal of people post-stroke.[2, 6] About 80% of stroke survivors have mobility and balance problems, and 33% are able to walk, however, present with limited balance capacity.[7] Stroke survivors usually present with lower extremity functional impairments that persist for years and are associated with dependence in activities of daily living.[1] Up to 40% of stroke survivors require assistance with daily living activities,[4] and more than 20% of people are reported to have a poor quality of life for several years post-stroke.[8]

People post-stroke have a higher risk of falls compared to their age-matched peers.[9] One clinical definition of a fall is “an event that results in a person coming to rest inadvertently on the ground or other lower level.” [10] Falls are a leading cause of activity limitation and injury in the elderly, and approximately 30% of community-dwelling elderly aged 65-year-old and older will fall each year.[11] In both acute and chronic phases, people with stroke have a higher risk of falls than their unimpaired peers, resulting in decreased physical activity status, hip fracture, or even death.[9] Thus, fall prevention and improving mobility are critical rehabilitation focuses for clinicians involved in stroke care.

1.2 Definition of balance

1.2.1 Standing balance

Generally, balance could be described as maintaining a body’s center of mass (COM) within its base of support (BOS) with minimal sway.[10, 12] There are two main categories of postural reactions people respond with when experiencing a perturbation in a standing position. ‘In-place strategies’ are postural reactions without any movement of the feet, including the ankle strategy and hip strategy. The ankle strategy involves shifting the COM about the ankle joints with limited movement in the hips or knees. It is used in response to modest anterior-posterior sway perturbation.[12] A hip strategy involves shifting COM with the movement of the trunk initiated at the hips, and people utilize this strategy in response to larger perturbations.[12]

In contrast to the in-place strategies, a stepping strategy adjusts the COM over a re-established BOS with a reach, rapid steps, or hops.[12] When people receive larger or unexpected perturbations, such as being pushed on the shoulder, in-place strategies may not be sufficient to maintain balance fully. Under these scenarios, a reach or a step would be used to adjust the BOS in order to regain the COM within the re-established BOS and maintain the upright standing balance.[10]

1.2.2 Walking balance and mobility

Walking balance can be described as maintaining a subject's COM within the BOS while walking.[13] It can also include the range of walking-related tasks that challenge people's balance. When people walk, the COM often falls outside the BOS,[10] especially between the single stance phase and swing phase. To prevent falls, the swinging foot is placed forward and ahead as it recaptures the BOS, and it ensures the control of COM relative to the moving BOS during walking.[10] Therefore, the body is in a continuous state of relative imbalance during walking.[10]

Generally, mobility could be described as "moving about the home and community" [1] According to the definition by American Occupational Therapy Association, mobility can be identified as functional mobility and community mobility. Functional mobility refers to changing the position of the body.[1] It includes the transfers, such as moving to and from a chair. On the other hand, community mobility relates to moving around in the community.[1] It includes walking, bicycling, and driving, to name but a few.

1.3 Evaluation of clinical measures

In clinical practice, treatment plans are guided by assessments using established clinical measures. With the well-established psychometric properties of clinical measures, the effects of intervention can be properly measured and applied in evidence-based practice. The two major measurement properties to establish the utility of a clinical measure are reliability and validity.

1.3.1 Reliability

Reliability is "the extent to which a measurement is consistent and free from error." [14] The classical test theory (CTT) guides the establishment of reliability in current measurement scales.[15] The concept of classical test theory introduces that a respondent's observed score on a test are determined by the true score and by measurement error.[14-16] There are two types of measurement error: systematic and random errors.[14, 16] Systematic errors are predictable errors, and it consistently overestimates or underestimates the true score.[14, 16] Random errors are unpredictable factors, such as patient fatigue or mistakenly conducting the measures.[14, 16] If a measure that has little or no random error, the observed score would be close to the true score, and the measurement becomes more reliable.[15] There are four types of reliability: test-retest reliability, rater reliability, alternate forms reliability, and internal consistency.[14]

Test-retest reliability indicates obtaining the same results over repeated measuring occasions on the identical test on the same subjects. The tests are usually repeated on separate days, and they should be close enough to avoid the change of true score and far enough to prevent the learning effect. In clinical measurement, the rater is considered a source of measurement error. Specifically, rater reliability includes intra- and inter-rater reliability. Intra-rater reliability indicates having stable results of measurement by the same rater across two or more testing trials of the same group of participants.[14] When rater skills are associated with the accuracy of a measurement, intra-rater reliability and test-retest reliability could be considered the same estimate.[14] On the other hand, the inter-rater reliability represents the stability between two or more raters on the same subjects.[14] It can be well-assessed in a single session while all the raters measure the response simultaneously.

Another type of reliability is alternate forms reliability. It refers to the consistency of different versions of the same tests, such as professional licensing exams or different models of hand dynamometers. The last type of reliability is internal consistency, and it represents that measurement reflects various aspects of the same characteristics, and it presents the homogeneity throughout the measurement. For example, the Fugl-Meyer motor assessment scale measures people's motor impairment post-stroke,[17] and it only contains the tests of motor function without measuring their psychological function.

If a measure has less measurement error, it is more reliable. Once the reliability is established, researchers can have confidence that the change of observed score reflects the change of true score in stead of affecting by errors. Additionally, the standard error of measurement (SEM) will be known. The SEM can be calculated with the reliability coefficient and the standard deviation of the observed scores, and the SEM gives the measurement errors in absolute values.[15, 18] The SEM can be calculated using the equation, $SEM = s.d. \times \sqrt{1 - ICC}$.[15, 18] Additionally, the SEM is a common way to estimate the minimal detectable difference (MDD), which is the smallest amount of observed score change above a threshold of error and could be considered as true score change.[14] The MDD can be calculated using the equation, $MDC = 1.96 \times SEM \times \sqrt{2}$, which 1.96 represents the 95% confidence level and $\sqrt{2}$ accounts for error introduced by using measures from two testing days.[15, 19]

If the test is reliable, it should show the consistency between separate measuring occasions. Statistically, researchers commonly evaluate the reliability of an outcome measure by calculating the intra-class correlation coefficient (ICC) as it reflects both correlation and agreement. The well-known guideline of reporting reliability levels is listed as coefficients below 0.5 indicating poor reliability, between 0.5 to 0.75 representing moderate reliability, 0.75 to 0.9 showing good reliability, and 0.9 to 1 suggesting excellent reliability.[14] While it is rare to have 1 in reliability coefficients, 0.9 may be an acceptable reliability coefficient for diagnosis.[14] However, a moderate to good reliability may be an acceptable coefficient for functional measurements.

1.3.2 Validity

Validity of the measurement assures that "a test is measuring what it is intended to measure." [14] There are four types of measurement validity: face validity, content validity, criterion-related validity, and construct validity.

Face validity evaluates if the measurement appears to test what it is intended to measure.[14] It is the weakest evidence of validity because it is estimated based on people's opinions or intuitions. Content validity reflects that all the characteristics of the interested variable are covered in the measurement, and it is established based on experts' review.[14] For example, content validity of clinical measures of walking balance in people post-stroke can be found by measuring the extent to which clinical measures contain functional tasks associated with community-level walking in the opinion of physiotherapists who treat walking balance clinically.[13]

Criterion-related validity indicates that an established or gold standard measurement can be used as a reference for another measurement that aims to measure the same criterion. For example, the optimal method to quantify the energy cost during the exercise is by measuring the oxygen consumption rate, and we could verify the measures of heart rate by comparing the results.[14] If the values of heart rate and oxygen consumption rate correlate highly, we could say heart rate is a valid indicator of energy cost.[14] The purpose of examining the criterion-related validity explores an untested tool to replace the previous measurement due to the expense costs, ease of conduct, or practical reasons.

Lastly, construct validity represents how the assessment measures an intangible concept. Researchers use different approaches to support the concept's theoretical framework because the concept or construct is hard to define or measure. One of the construct validations is exploring convergence or discrimination characteristics by determining how the measurement relates to other tests. The convergent validity represents that the results of two different measures will highly correlate if they are believed to reflect a similar concept.[14] For example, both the Berg balance scale (BBS) and the Community Balance and Mobility Scale (CB&M) are believed to measure people's balance capacity, so we could expect the values retrieved from these two scales will correlate highly. By contrast, the discriminant validity shows that the results of two scales will have low or no correlation if they are believed to indicate different or unrelated characteristics.[14] For example, the scores of BBS are expected to have a lower correlation with the Beck depression scale because they measure different concepts.

As mentioned above, the typical way to validate a measurement is by examining the relationships among the results from different or similar measurement scales. The correlation coefficients below 0.25 indicating little or no relationship, between 0.25 to 0.50 representing a fair relationship, 0.50 to 0.75 showing moderate to a good relationship, and 0.75 to 1.00 suggesting a good to excellent relationship.[14]

1.4 Clinical measurement of balance and mobility post-stroke

Physiotherapists need effective and practical measurements to make clinical decisions and rehabilitation goals setting. There are various assessments of measuring balance and mobility post-stroke, and they have different pros and cons while performing or interpreting clinically. Although the concept of balance intensity may be debatable and vague to quantify, the acceptable guideline to test balance capacity is by having people performing balance tasks with increasing levels of challenge.[13, 20] If the subjects can perform difficult or challenging tasks, clinicians consider them having a higher level of balance capacity. Clinicians use many clinical measurements to evaluate balance and mobility in people post-stroke. The following section is not an exhaustive list but represents clinical measures commonly used and relevant to the current thesis.

The Berg balance scale (BBS) has been identified as the most widely used balance measurement tool in elderly and stroke rehabilitation.[21] BBS is a fourteen-item scale, and it intends to measure subjects' static and dynamic aspects of balance,[21] such as sitting to standing, standing unsupported with eyes closed, etc.[21, 22] The maximum score of BBS is 56, and the higher score indicates higher functional balance capacity. One of the advantages of applying BBS is the ease to conduct; the required space and equipment are easy to achieve (i.e., chair, stopwatch, and ruler), and it involves minimal training for clinicians to administer.[21] It also takes around ten to fifteen minutes to conduct the whole assessment.[21] Therefore, BBS can be appropriate for inpatient rehabilitation and help guide clinical approaches in the initial stage of stroke recovery. However, BBS has been shown to have ceiling effects in people post-stroke living in community.[21, 23] It might intend to measure the balance and mobility in a relatively lower end of the mobility spectrum.

Of the BBS items, the Functional Reach Test (FRT) and tandem stance (TS) can be conducted independently. The functional reach test (FRT) is a test to assess the ability of standing postural control towards the limits of stability.[24] For the standardized test procedure, patients are asked to stand against the wall, raise their non-affected arm to their shoulder height, and reach forward as far as possible without stepping to maintain balance. In a standardized clinical setting, clinicians usually place a yardstick or ruler on the wall at the subject's shoulder height level. During the assessment, subjects' fingers should not touch the ruler or lean against the wall while reaching forward. The further a participant can reach forward without losing balance indicates the higher level of standing balance capacity.[24, 25] Studies had found excellent test-retest reliability (ICC = 0.92) and inter-rater reliability (ICC = 0.98) among healthy people from 20- to 87-year-old,[24] and the good inter-rater reliability (ICC = 0.73) for healthy older adults and 0.79 for older adults with a disability living in communities.[25]

The tandem stance test retrieved from the BBS could also be tested on its own. This item is inline with the tandem Romberg stance test.[26] The Romberg stance test is a clinical measure of static standing balance of maintaining a heel-to-toe position with weight distributed equally on both feet.[22, 26] In BBS, subjects are asked to place one foot directly in front of the other and hold the tandem stance position for up to thirty seconds.[22] The scale is rated from 0 to 4, with 4 indicating 'able to place foot tandem independently and hold thirty seconds' and 0 showing 'loses balance while stepping or standing.' [22] The TS retrieved from BBS shows good to excellent reliability (ICC = 0.88 to 0.92) for older adults performed in-person.[22]

Compared to BBS, the Community Balance and Mobility Scale (CB&M) could be more appropriate to measure a higher level of balance capacity.[13] The CB&M was initially developed by physiotherapists and occupational therapists who worked in the neurorehabilitation field. The intent of creating the CB&M was to help guide the decision-making for people to walk safely in the community. The CB&M has been shown to be reliable and valid when used to measure balance abilities in people with stroke.[19] It includes different aspects of challenging posture and movement.[27] There are thirteen items included in CB&M, such as unilateral stance, walking while looking to the side, running with a controlled stop.[27] Some tasks are multitasking, such as asking people to walk forward while looking to one side, as it mimics the context of window shopping.[27] Some items involve complex motor skills, such as lateral dodging using cross-over side steps, and they demand higher precision and timing to perform the task.[27] Therefore, compared to BBS, CB&M could be used to challenge people's walking balance at a higher level of intensity that is more reflective of complete independence in the community.

Walking speed is also relevant to walking balance and individuals' functioning in the community. One of the commonly used methods is calculating how long it would take for people to walk in three to thirty metres at their comfortable speed.[28] The average walking speed for healthy elderly is around 1.34 and 1.24 metres per second for 60 to 69-year-old men and women, respectively.[28] Additionally, a slower walking speed is associated with difficulty living in the community, such as needing help to cross an intersection safely. When people are asked to walk faster, the walking task also becomes more challenging to maintaining balance than walking at their usual speed.

Together with walking speed, the Timed Up and Go test (TUG) also measures transferring and turning as parts of the timed walking performance measurement. It has been used commonly to measure people's functional mobility.[29] Subjects are asked to stand up from a chair, walk three metres with their comfortable walking speed, turn around, walk three metres back, and sit down. The requirement of space and equipment to perform TUG is low, and it requires less training for a clinician to measure people's mobility. Besides, TUG can be used as a fall prediction tool for the elderly, with the cut-off point at 13.5 seconds as increased risks of falling.[30] The TUG has been shown to have a high degree of test-retest reliability in people with chronic stroke, with ICC estimated as 0.94 to 0.96 for people post-stroke living in the community.[18, 31] Additionally, the SEM of the TUG was 1.14 seconds in people following stroke.[18] Therefore, TUG is a widely used clinical measurement in stroke rehabilitation.

The five-times sit-to-stance test is used to assess the transfer from sitting to standing, and it has been widely used as a predictor of falls, dependence of activities of daily livings, and evaluating lower-extremity strength for older adults.[32 33] Participants are asked to stand up and sit down independently for five repetitions without using armrests. A stopwatch is used to measure the time, and the timing starts once given the instruction 'go' and ends when the participant's buttocks touch the chair after the fifth repetition. The faster performance (measured in seconds) is associated with a better level of lower-extremity strength and balance abilities.[33] It was shown that 5-times STS has excellent intra-rater reliability, interrater reliability, and test-retest reliability with ICC ranging from 0.971 to 0.999 in people with chronic stroke.[34] The 5-times STS has also been shown to have a significant and strong negative correlation with the muscle strength of both affected and unaffected knee flexors of people with stroke.[34] Healthy adults aged 60- to 69-year-old takes about 8 seconds to complete the 5-times STS,[35] and the SEM for 5-times STS is 0.68 seconds for hospitalized elders.[36] The faster to complete the task, measured in seconds, indicates the stronger muscle strength in lower extremities.

Another well-known sit-to-stance task is the thirty-seconds sit-to-stance test (30-sec STS), and it is used to assess lower extremity muscle strength and balance capacity.[37, 38] Participants are asked to perform standing up and sitting down independently as many repetitions as possible over thirty seconds. Compared to the 5-times STS, which is a measure of the amount of time in transfer, the 30-sec STS measures the number of stances a person could do in thirty seconds. It can be used with people with various functional levels, with scores commonly ranging from 0 to 20 or higher repetitions within the required time.[38] A good to excellent test-retest reliability was found (ICC = 0.84 to 0.92) for community-dwelling older adults.[38] For healthy adults aged 60- to 69-year-old , the average is 13 repetitions over the 30 seconds, and the SEM is 1 repetition.[38]

Another aspect to impact walking balance can be endurance, which can be represented by walking in relatively extended period of time. The Six-minute Walk Test (6MWT) has been widely used clinically to measure physical endurance and functional capacity in older adults or people with stroke.[39, 40] The instruction of 6MWT asks subjects to walk independently and as far as they could over the six minutes with or without walking aids. They are allowed to stop or rest during the evaluation. The healthy older adults aged more than 60-year-old have been shown to walk for 499 metres over the 6 minutes.[41] The longer distance walked indicates a higher level of endurance and walking ability.[40] The 6MWT has shown good to excellent test-retest reliability in people post-stroke[40, 42]

1.5 Impacts of the COVID-19 pandemic

Due to the outbreak of the coronavirus disease of 2019 (COVID-19), many surgical or outpatient services were forced to cease.[43] Clinicians needed to provide treatments with the heightened transmission precautious procedures for both infected or noninfected patients.[43] In addition, clinicians aimed to reduce the infection risk by shortening the hospitalization stay and discharging patients once they were stable and basic functional levels achieved.[44] During this time, patients discharged early to private homes may have greater medical complexity and a higher chance of readmissions than before the pandemic.[44] Additionally, home-visit or community-based physiotherapy sessions were considered non-essential visits. They were also suggested to be delayed or cancelled to protect those vulnerable or high-risk groups of older adults.[44] This further challenged the provision of rehabilitation services.

In Canada, about 60% of stroke patients are referred to outpatient stroke rehabilitation services after discharge from hospital.[45] Most patients need regular visits to outpatient services or community exercise programs to help achieve their rehabilitation goals. Therefore, because of the outbreak of COVID-19, there was a sudden emerging need for having an alternative way for those patients to receive rehabilitation services. This immediate need has shaped the direction of my inquiry into clinical rehabilitation of balance and mobility post-stroke in the current environment.

1.6 Virtual rehabilitation care

Virtual rehabilitation, formerly referred to as tele-rehabilitation, is an emerging alternative way to provide rehabilitation services.[46, 47] It can be referred to the delivery of healthcare services using information and communication technology.[48, 49] It includes using telecommunication devices to provide intervention, consultation, or supervision by rehabilitation practitioners, such as physiotherapists, occupational therapists, and speech therapists.[47, 50]

Quite often, virtual rehabilitation has been associated with remote monitoring and applying wireless sensors to monitor vital signs, such as electrocardiogram, oxygen saturation, or blood pressure.[51] Piotrowicz and colleagues applied home-based tele-monitored cardiac rehabilitation for heart failure patients,[52] and it was found to have similar improvements in quality of life as outpatient-based standard cardiac rehabilitation for patients with heart failure.[52] In another aspect, virtual rehabilitation incorporates virtual reality technology to support exercise programs or training.[53, 54] Piron and colleagues provided motor tasks via a virtual reality-based system, which generates a virtual reality environment for patients to conduct arm movement tasks and video-conferencing for people with stroke.[54] They found that combining virtual reality technology, stroke patients improved their upper extremity motor function after one-month treatment.[54] The application of virtual health in the clinical field is broad, we only focus on delivering rehabilitation programs over video-conferencing in this thesis.

People with disabilities perceived many benefits of virtual rehabilitation. The most common benefit reported by people is its convenience.[55] Virtual healthcare service is convenient for people to save time required to travel to appointments, especially for those who lived in remote and rural areas. Some people would prefer having a video consult due to physical discomfort or expense associated with travel.[55] However, accessibility may be one concern for some patients to receive virtual healthcare services.[55] Some people, older adults in particular, may not have experience regarding using the device properly or may not have a proper internet connection in their home. These are the most common challenges regarding virtual healthcare services.

Virtual rehabilitation has been explored for use with people affected by neurological, cardiac, or musculoskeletal diseases to examine its effects on motor function recovery.[53] A systematic review and meta-analysis study found inconclusive findings on the effect of virtual rehabilitation for people with neurological diseases, indicating similar outcomes in virtual rehabilitation and conventional in-person rehabilitation program with respect to improving motor function.[53] Although evidence has been found to be weak in this field, more studies need to be conducted to answer questions regarding the effectiveness of virtual rehabilitation as it remains an important alternative way of delivering conventional rehabilitation.[53]

1.7 Stroke rehabilitation and virtual care

Due to advancements in technology, virtual rehabilitation can be used as an alternative way for stroke patients to receive health care. A systematic review and a meta-analysis study explored the effectiveness of virtual rehabilitation interventions in patients with stroke, compared with conventional in-person rehabilitation treatment.[46, 50] Many studies had shown that virtual rehabilitation interventions could improve motor function or independence in the activity of daily livings in patients with stroke.[46, 50] Studies also found that the virtual intervention had similar outcomes to conventional rehabilitation in improving upper extremity motor function, mobility and balance, and independence in activity of daily livings for stroke patients.[50]

Some studies explored the effects of virtual health care on balance and mobility in patients with stroke.[56, 57] Chen and colleagues applied home-based virtual rehabilitation intervention in improving physical function for people with sub-acute stroke.[56] During their twelve-week intervention, participants received physical exercise over video conferencing one hour a time, twice a day for five days. It included Bobath and proprioceptive neuromuscular facilitation techniques, physical exercise programs, and occupational therapy. They also combined neuromuscular electrical stimulation and electromyographic biofeedback technology as a part of the intervention for twenty minutes per day (equipment provided for in-home use), and the physical activities included stretching, standing balance training, and walking training. They found that people who received home-based virtual intervention improved their balance function and independence in activities of daily livings at post-intervention and twelve-week follow-up.[56] Another study conducted by Lin et al. (2014) applied virtual rehabilitation in people with chronic stroke and living in long-term care facilities.[57] Their intervention protocol for the experiment group included video-conferencing for balance intervention, wireless sensors for vital sign monitor (i.e., heart rate, oxygen saturation, and blood pressure), and 3D animation interactive games with touch screen control while sitting or standing. After a four-week program, they found that people with chronic stroke improved their balance capacity and self-care independence.[57] Also, there was no difference between the experiment group and the in-person traditional intervention group.[57]

It is important to note that even though studies have investigated the effects of virtual rehabilitation using information and communication technology in patients with stroke, all of these studies conducted in-person baseline and post-intervention evaluations of their primary and secondary outcomes in a standard clinical setting.[46, 50] The importance of exploring the utility of conducting clinical assessments over video-conferencing platforms as alternate assessment approaches could meet this need for virtual rehabilitation. This would ensure that the rehabilitation services could be fully completed over video-conferencing, including evaluation and treatment.

1.8 Method of assessments used in the current study of virtual rehabilitation care

Assessment drives treatment goals and approaches in rehabilitation, and there are many solutions to collect data under the umbrella term of virtual healthcare services. Some people apply devices or sensors to conduct remote assessments to monitor patients' progress, and some researchers incorporate virtual reality as their primary research interests. However, it may not be easy for most clinical physiotherapists to apply these sensors or monitor virtual reality platforms. One possible way to follow-up on their clients' progress is by making telephone calls or setting video-conferencing appointments. It is interesting to explore how physiotherapists can assess balance and mobility for people post-stroke in a client's home environment over video-conferencing technology.

The feasibility of evaluating people's movements via communication technology has been explored in a clinical setting.[58, 59] Durfee et al. (2007) asked healthy adults to perform TUG and two items from BBS (i.e., sit-to-stand and forward reach) with two independent assessors involved in each evaluation: one assessor conducted an in-person examination in a standardized clinical environment, and the other rater evaluated the same outcome while viewing the performance over real-time video in a different room.[58] The results showed no difference between two raters in evaluating the same subject in a standardized setting in-person or over a video-conferencing platform.[58] It could suggest that clinicians could make an accurate clinical decision under this circumstance, within the standardized evaluation environment using the appropriate video-based platform. However, this study did not address the participant performing the assessment task without the presence of an in-person assessor.

In another systematic review, Mani and colleagues explored the reliability and validity of video-based physiotherapy assessments for musculoskeletal disorders.[59] However, even though the results showed that video captured (recorded or real-time) physiotherapy assessments were possible for people with musculoskeletal disorders, all participant assessments were still conducted in clinical settings (i.e., the assessor and participants were in different rooms of the clinic).[59] Additionally, most of the studies applied a virtual platform (i.e., eHAB) to help to conduct the clinical measurements, such as range-of-motion.[59] Currently, most clinicians are unlikely to have access to these platforms and are limited to using these techniques to conduct clinical measurements in patients' homes. Though it could be feasible and accurate to conduct a remote evaluation of balance and mobility, it is important to consider safety of the participant performing the task independently in their homes. It is crucial to understand how clinicians can adapt clinical measurements to conduct these remotely via video-conferencing with patients in a home-based environment.

A review study explored the utility of conducting remote and home-based exercise testing in chronic respiratory disease.[60] Hollan et al. (2020) had reviewed 84 studies that conducted functional exercise tests in the home setting and/or remotely in people with chronic respiratory disease. Among its included studies, only eight studies had used exercise tests at home (i.e., 5 times sit-to-stance, TUG, etc.). However, all of their home assessments involved either a researcher or a clinician in-person during the evaluation. The results also showed that sit-to-stand, TUG, and step tests were feasible, reliable, and valid measures of balance and mobility when they are applied in a home setting.

To date, no studies have conducted clinical assessments of balance and mobility in a home-based setting via video-conferencing technology with people following stroke.[46, 50] It's unclear how feasible, reliable, or valid the clinical assessments can be when clinicians perform virtual evaluations neither in-person nor in standardized clinical settings.

1.9 Research purpose

The purpose of this study is to develop an approach to remotely assess the balance and mobility of ambulatory people with stroke living in the community. This study aims to explore: 1) the test-retest reliability of administering walking and balance function assessments via video conferencing platforms for patients with stroke, 2) convergent validity of remotely conducting walking and balance assessments compared to in-person assessments, and 3) the feasibility of conducting clinical walking and balance capacity assessments in home-based settings for patients with stroke without supervision.

1.10 Research hypothesis

The utility of clinical measures of balance and mobility in people post-stroke conducted in-person is well-established. Therefore, the current thesis hypothesizes that 1) the results of modified virtual assessments will show excellent reliability between testing days, 2) the results of virtual assessments will show moderate to strong relationships with in-person assessments of balance and mobility, and 3) it will be feasible to conduct walking and balance assessment via video-conferencing with people post-stroke in their homes without clinician's in-person supervision.

Chapter 2: The reliability and validity of conducting balance and walking assessments in people post-stroke for virtual rehabilitation care

2.1 Background

Stroke is the leading cause of neurological disability in adults worldwide, and individuals with stroke with hemiparesis commonly experience motor impairment and reduced mobility during daily activities.[7] Furthermore, people post-stroke are at increased risk of falls, which commonly results in lower levels of physical activity, and increased risk of hip fracture, or even death.[9] Improving mobility and walking balance continue to be the most common rehabilitation goal throughout the stroke recovery trajectory.[2, 6] However, due to the outbreak of COVID-19 pandemic, many rehabilitation services were delayed or cancelled to protect vulnerable people, including adults and older adults post-stroke.[43] Many stroke survivors were not receiving the assessments and therapies they needed to help with their recovery.[61]

Virtual rehabilitation care, formerly referred to as tele-rehabilitation, has gained increasing interest as an alternative way for patients to receive rehabilitation or health care.[47] It can be referred to the delivery of healthcare services using information and communication technology.[48, 49] It may include assessment, delivery of the intervention, consultation, and monitoring over communication technologies.[47] Virtual rehabilitation interventions have been shown to improve motor function and independence in activities of daily living in people with stroke.[46, 50] However, instead of conducting virtual clinical assessments over video-conferencing platforms, all virtual rehabilitation studies to date have conducted participant assessments and collected all physical outcome measures in-person in standard clinical settings for people following stroke.[46, 50]

There has been extensive evaluation of the reliability and validity of existing functional measurements of balance and mobility that are commonly used during typical in-person assessment conditions, including using outcome measures such as the Berg Balance Scale (BBS) and the Time Up and Go test (TUG).[22, 24, 29, 31] Considering patients' needs of receiving virtual rehabilitation, it is important to consider administering analogous clinical assessments via the same virtual platforms. It raises the question of whether it is feasible, reliable, and valid to perform physical assessments of balance and functional mobility with stroke patients without a clinician's in-person supervision. This study aimed to explore: (1) test-retest reliability, (2) convergent validity, and (3) feasibility of virtual assessments as measures of walking and balance function in individual post-stroke over video-conferencing platforms.

2.2 Methods

2.2.1 Study design

This study used a cross-sectional design with 2 assessment visits over video-conferencing platforms, separated by up to 7 days.

2.2.2 Participants

Participants were recruited from a cohort of 28 people with chronic stroke (>1-year post-stroke) who had previously participated in a study that measured their mobility and balance abilities in-person in a clinical setting prior to the pandemic.[62] The original purpose of the in-person measurements was to determine the reliability and validity of the Rate of Perceived Stability scale in people with stroke. The inclusion criteria for the current study were: (1) older than 20 years of age, (2) having chronic stroke (≥ 1-year), (3) living in the community, (4) medically stable, (5) able to walk 10 meters independently with or without a walking aid indoors, (6) able to provide informed consent, and (7) having access to a telephone, computer, or device that had an internet connection and a webcam. The exclusion criteria were: (1) other active medical conditions impacting mobility, such as cardiac, respiratory, or neurological disease other than stroke, (2) requirement of close supervision in previous study, or (3) changes in health status between in-person and virtual assessments. All participants were contacted by email and phone, and they were able to provide email and verbal consent.

2.2.3 In-person assessments

Participants' clinical characteristics measured included the severity of lower extremity impairment as measured by the Chedoke McMaster Stroke Assessment (CMSA),[63] and balance confidence as measured by Activities-specific Balance Confidence scale (ABC).[64] Three in-person balance and mobility assessment scales were performed in a standardized clinical setting before the tele-rehab assessment visits:

2.2.3.1 Self-selected walking speed

Participants were instructed to walk 8 metres at their comfortable walking speed. They were asked to perform the task three times, and the mean self-paced walking speed (m/s) was calculated.

2.2.3.2 Community balance and mobility scale (CB&M)

The CB&M consists of 13 tasks to evaluate people's mobility and balance abilities (e.g., performing step-ups on a stair, tandem walking).[23, 65] The maximum score of CB&M is 96, with a higher score representing better mobility and balance capacity.[23, 65] It has been shown to be reliable and valid measure of functional balance and mobility in people post-stroke.[23, 65]

2.2.3.3 Six-minute walking test (6MWT)

The 6MWT has been validated as a measure of people's endurance of walking in people post-stroke, and it is widely used in stroke rehabilitation.[40, 42] Participants were asked to walk as far as possible within six minutes at a safe walking speed. Distance (in metres) was the primary outcome of this test, and the longer distances they walked represented a better walking endurance.[40, 42]

2.2.4 Virtual assessment experiment protocol

Virtual assessments were initiated approximately 6 months following the completion of the previous study that measured balance and mobility in-person.[62] Three sessions were conducted via the online video-conferencing platform, Zoom. The orientation session (first session) included orienting the participant to the Zoom platform, collecting emergency contact information, and preparing the evaluation environment (i.e., identifying the 3-metre route for conducting TUG in the participant's home, ensuring the safety of environment, optimizing the camera view). In the assessment session 1, the physiotherapist collected participants' medical history, social history, and medications since they completed the previous study, and conducted virtual assessments of balance and mobility over video-conferencing. In the assessment session

2, all the virtual assessments were administered again by the same physiotherapist. These two assessment sessions were conducted within one week of each other.

2.2.5 Modification of walking, balance, and mobility outcome measures for use in virtual assessments

Clinical outcome measures used commonly in stroke rehabilitation to assess walking balance and mobility, that have been validated, proven reliable, and used standardized scoring instructions and could be scored without the clinician's physical testing (i.e., manual muscle testing) were considered for inclusion. Modifications of assessment procedures for use over virtual platforms were made based on the team's clinical judgment with participant safety as the priority. The licensed physiotherapist who assessed participants was part of the study team and contributed to developing the standardized evaluation manual to help modify existing walking, balance, and mobility outcome measures in virtual assessments. Importantly, as participants were not excluded if they lived alone, modifications could not rely on a person or caregiver supervising the participants while performing the tasks. Finally, modifications considered the repeatability of set-up and conducting the assessments in people's home environment. All modifications of the measures were piloted for exploration of initial feasibility. The following 5 clinical outcome measures were modified and included for evaluation as virtual assessments of mobility and balance.

2.2.5.1 Five-times sit-to-stand (5-times STS)

The 5-times STS has been widely used as a predictor of falls, dependence in activities of daily livings, and evaluating lower-extremity strength for older adults.[32, 33] The 5-times STS has excellent reliability (ICC=0.971 to 0.999) and strong correlation with the muscle strength of both affected and unaffected knee flexors in people with stroke.[34] People were asked to stand up and sit down independently for five repetitions as fast as they could without the use of the chair arms.[32, 33] However, participants were allowed to use the armrest if needed, and this information was recorded as a deviation from the intended measure. They were instructed to use a dining chair as these chairs are most likely to be optimal height and are commonly seen in a home. The webcam angle was aimed at the participant’s trunk while sitting (start position) and ensured the participant’s hips could be viewed in standing to identify when full standing (end position) was reached. One repetition was performed to ensure the physiotherapist could observe the full range of motion in standing up to sitting down. A stopwatch was used to measure the time, and it started once given the instruction ‘go’ and ended once participant’s buttocks touched the chair after the fifth repetition. Time to complete 5 repetitions (in seconds) was the primary outcome of this test. A faster speed of completion of repetitions indicates a higher level of lower-extremity strength and balance ability.[32, 33]

2.2.5.2 Functional reach test (FRT)

The functional reach test is an item in the BBS that tests people’s standing balance.[22] Reliability and validity of the BBS have been established in patients with stroke.[66, 67] Participants were asked to stand beside the wall, raise their non-affected arm to their shoulder height, and reach forward as far as possible without stepping to maintain balance and to not lean against the wall for balance. Instead of having a yardstick attached to the wall (as in the original measure), we modified the procedure by using sticky notes or pieces of tape at the initial (standing upright) and final position (maximum reach) to help to evaluate the reaching distance on a clear wall.

Participants were asked to measure the distance between the initial and final position and report their distance reached (in inches) to the physiotherapist. The webcam angle was aimed at the participant's upper trunk while standing to try and capture the start and finish position of the participant's hand and observe the reaching technique. Performance was measured using scores from the BBS ranging from 0 to 4, with higher scores reflecting a further distance reached and a higher level of standing balance capacity.[22, 24]

2.2.5.3 Tandem stance (TS)

The TS test, a measure of standing balance, was completed with reference to the measurement of TS in the BBS.[22] Participants were asked to place one foot directly in front of the other and hold the tandem stance position for up to 30 seconds. Measurement followed the BBS scoring from 0 to 4, with 4 indicating "Able to place foot tandem independently and hold 30 seconds" and 0 indicating "Loses balance while stepping or standing."[22] During the TS test, standing close to the wall and having a chair was suggested for the participants to protect them if they lost balance. The physiotherapist first asked the participant to place one foot entirely ahead of the other but not in line (score 3 in BBS) for safety reasons.[22] If the participants could complete score 3, they would be instructed to perform feet inline, heel-to-toe tandem stance.[22] The optimal webcam angle would be aimed at the participant's feet to ensure tandem stance is achieved and alignment maintained. However, due to limitations in computer camera view or the difficulty of adjusting webcam angle (e.g., with a desktop computer), it was anticipated that the camera would have to be aimed at participants' upper trunk. Therefore, participants were asked to report on the position of their feet.

2.2.5.4 Timed up and go test (TUG)

The TUG is used to assess people's timed-functional mobility, and it has been widely used in stroke rehabilitation.[29, 31] High test-retest reliability (ICC=0.94 to 0.96) and moderate to high validity of the TUG as a measure of mobility have been established in people following stroke.[29, 31] To perform the TUG, participants were asked to stand up from a chair, walk 3 metres, turn around, return to the chair, and sit down. We discussed with participants the best location in their homes during the initial set-up that allowed for a 3-metre walkway without a tripping hazard. The webcam angle was aimed at the participant's trunk while sitting as the starting and ending position, and it allowed the physiotherapist to time and score the TUG. Time (measured in seconds) is the primary outcome of this test; shorter time indicates a higher level of functional mobility[29, 31]

2.2.5.5 Thirty-second sit-to-stand (30-sec STS)

The 30-sec STS measures subjects' lower extremity muscle strength and balance capacity.[37, 38] A good to excellent test-retest reliability was found (ICC=0.84 to 0.92) for community-dwelling older adults.[38] Participants were asked to stand up and sit down independently as many repetitions as possible over 30 seconds. The webcam angle was aimed at the participant's trunk while sitting and hips while standing to ensure the physiotherapist could count complete sit to stand repetitions. Participants were allowed to use the armrest if they felt uncomfortable rising independently. The total number of completed repetitions was the primary outcome of the test; the more repetitions a person did within the required time indicates better lower extremity muscle strength and balance capacity.[37, 38]

2.2.6 Feasibility

Feasibility was assessed by the time taken for each session, completion rate, technical issues, adverse events, and oral feedback provided by participants. Feedback was gathered directly following each assessment, with the participant and the physiotherapist conducting the assessment separately. The questions were: (1) Is there anything we could have done to make virtual evaluation easier for you, (2) Did you feel unsafe during the assessment, (3) Do you think you would be scored the same if the physiotherapist was in-person, and (4) Do you have any additional feedback regarding how the physiotherapist conducted the session today?

2.2.7 Statistical analysis

Both participants' demographic and clinical characteristics are presented using descriptive statistics. Test-retest reliability of virtual assessments was calculated using the intraclass correlation coefficients ($ICC_{(2,1)}$) with a corresponding 95% confidence interval using a two-way mixed model for the absolute agreement.[68] The ICC between 0.5 to 0.75 represents moderate reliability, 0.75 to 0.9 shows good reliability, and 0.9 to 1 suggests excellent reliability.[68] The standard error of measurement (SEM) was calculated using the standard deviation of all observed scores and the ICC. The minimal detectable change (MDC) was calculated as the indicator of the smallest change in real improvement.

Spearman rank order correlation coefficients were calculated as measures of convergent validity among the results of in-person and virtual assessments. The correlation coefficient between 0.25 to 0.50 represents a fair relationship, 0.50 to 0.75 shows moderate to a good relationship, and 0.75 to 1.00 suggests a good to excellent relationship.[14] All statistical analyses were carried out using SPSS 19, and the significance level was set at *P* less than 0.05. Subjective feedback provided by the participants was recorded and reviewed, and procedural or technical challenges were tabulated.

2.3 Results

Figure 2.1 shows the flowchart of participant recruitment. Of the 28 participants cohort initially recruited for the in-person assessments, 21 were eligible and agreed to participate in this study. Of the 7 people who were not eligible for the virtual assessments, two people were excluded because of requirements of close supervision during the in-person assessment (participant's balance and motor recovery – partial CB&M: 4/80, CMSA-foot: 2/7, leg: 3/7; CB&M: 5/80, CMSA-foot: 3/7, leg: 3/7), two participants were excluded due to the change of health status since they participated in in-person assessment, two participants didn't have appropriate internet access, and one participant was out of country.

Figure 2.1 Flowchart of screening and recruitment.

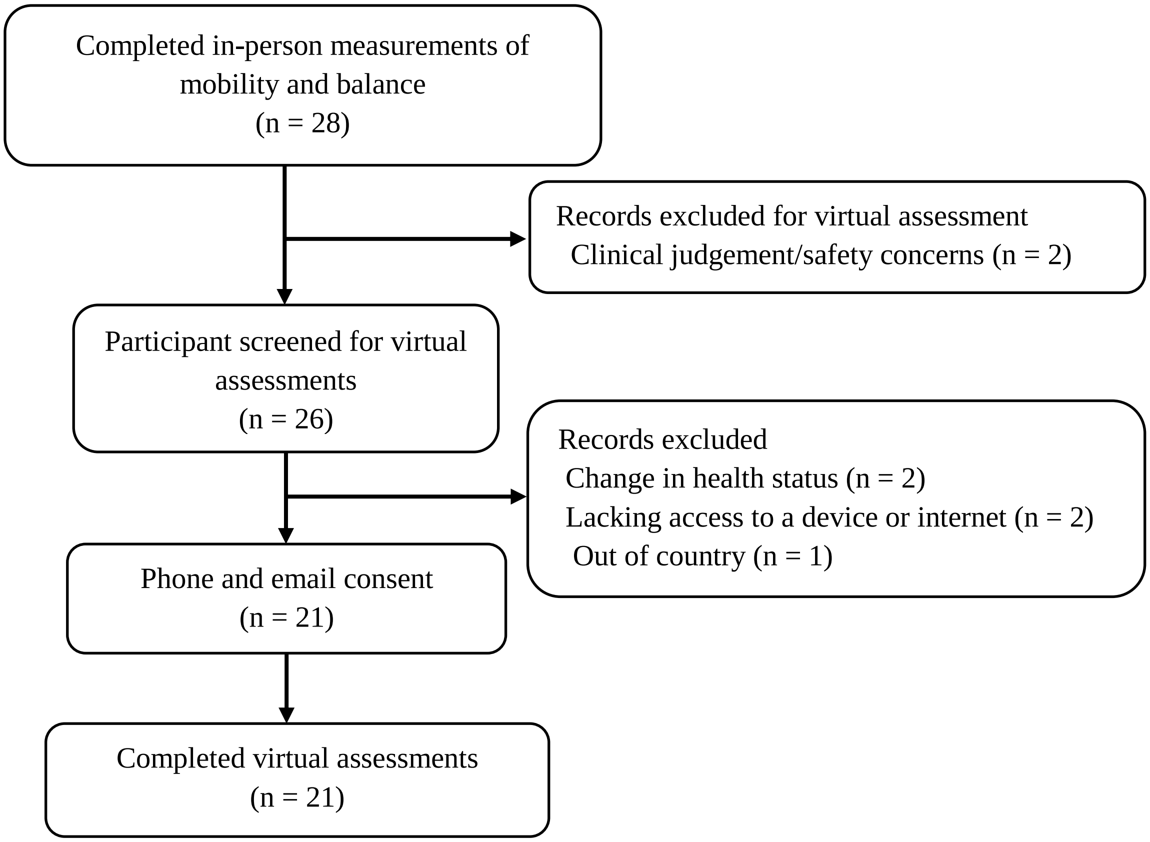

Table 2.1 summarizes the characteristics of 21 participants with chronic stroke who participated in both the in-person and virtual assessments. Ten males and 11 females participated (64.4±10.3 years). The mean Foot- and Leg-Chedoke McMaster Stroke Assessment was 4-5/7, which indicates mild to moderate motor impairments of the paretic leg.

Table 2.1 Demographic and clinical characteristics of participants

Variables	**All participants (n=21)**
Age (yr)	64.43 ± 10.34 (39 - 80)
Time since stroke (yr)	9.06 ± 5.11 (1.7 – 19.6)
Sex	10 Males, 11 Females
CMSA – foot (/7)	4.80 ± 1.99 (2 - 7)
CMSA – leg (/7)	5.95 ± 1.05 (4 - 7)

Walking speed (m/s)	0.82 ± 0.27 (0.44 – 1.21)
CB&M (/80)	30.90 ± 13.32 (11 - 60)
6MWT (m)	329.66 ± 116.13 (127.19 – 567.72)
ABC score (/100)	77.79 ± 15.53 (50 - 100)

Note: Values are mean ± standard deviations (minimum to maximum), or number. Abbreviation: yr: years; s: seconds; m: metres; CMSA: Chedoke McMaster Stroke Assessment; CB&M: Community balance and mobility scale – 11 of 13 items completed for this study; 6MWT: six-minute walking test; ABC: activity of balance confidence scale.

Table 2.2 presents the results of the test-retest reliability of the virtual assessments. The TUG and 30-sec STS had excellent test-retest reliability ($ICC_{(2,1)}$= 0.97 and 0.90 respectively). The 5-times STS had good test-retest reliability ($ICC_{(2,1)}$ = 0.77), and FRT and TS had moderate test-retest reliability ($ICC_{(2,1)}$ = 0.54 and 0.50 respectively). The SEM and MDC values are presented in Table 2.2 addressing day-to-day agreement.

Table 2.2 ICCs for test-retest reliability of virtual assessments.

Assessments	**Day1** [a]	**Day2** [a]	**$ICC_{(2,1)}$**	**95% CI**	**p-value**	**SEM**	**MDC**
5-times STS (/s)	13.56±3.38	12.80±2.93	0.77	0.509 - 0.897	< 0.001	1.53	4.23
FRT (/4)	3.70±0.47	3.71±0.46	0.54	0.123 - 0.789	0.007	0.31	0.87
TS (/4)	3.62±0.74	3.67±0.58	0.50	0.092 - 0.765	0.010	0.46	1.28
TUG (/s)	15.62±6.21	14.81±6.42	0.97	0.901 - 0.988	< 0.001	1.12	3.10
30-sec STS (/rep)	13.00±3.85	13.10±3.69	0.90	0.775 - 0.959	< 0.001	1.17	3.23

Abbreviation: ICC: Intra-class correlation coefficient; CI: confidence interval; SEM: standard error of measurement; MDC: minimal detectable change; 5-times STS: 5-times sit-to-stand; FRT: functional reach test; TS: tandem stance; TUG: timed up and go test; 30-sec STS: 30-seconds sit-to-stand; s: seconds; rep: repetitions.
[a]: Values are mean ± standard deviations

Table 2.3 shows the convergent validity of virtual assessments. The virtual TUG had a good to excellent relationship with in-person walking speed and 6MWT (ρ = -0.82 and -0.85 respectively, P<0.001) and a moderate to good negative relationship with in-person CB&M (ρ = -0.71, P<0.001). The virtual 5-times STS showed a moderate to good relationship with the three in-person CB&M, gait speed and 6MWT (ρ = -0.55 to -0.58, P<0.05). Similarly, the 30-sec STS showed a moderate to good positive relationship with the three in-person assessments (ρ = 0.58 to 0.72, P<0.001). However, the FRT and TS performed during the virtual assessments did not relate significantly with any of the in-person assessments. The Appendix A shows the Scatterplot Matrix of virtual assessments and in-person assessments.

Table 2.3 Correlations between virtual assessments and in-person assessments

		Virtual assessments				
		5-times STS (s)	**FRT (/4)**	**TS (/4)**	**TUG (s)**	**30-sec STS (rep)**
In-person assessments	**Walking speed (m/s)**	-0.57**	-0.05	0.13	-0.82**	0.58**
	CB&M (/80)	-0.55*	0.01	0.38	-0.71**	0.71**
	6MWT (m)	-0.59**	0.15	0.12	-0.85**	0.72**

Abbreviation: 5-times STS: 5-times sit-to-stand; FRT: functional reach test; TS: tandem stance; TUG: timed up and go test; 30-sec STS: 30-seconds sit-to-stand; CB&M: community balance and mobility scale; 6MWT: 6-minute walking test; sec: seconds; m: metres; rep: repetitions. **p-value <0.01; *p-value <0.05.

Table 2.4 presents feasibility aspects. There were no adverse events but some technical problems occurred during the evaluation. Among all the tasks, there was one participant did not complete FRT in the first virtual assessment session. Overall, the orientation session required between 7 and 37 minutes for participants. This range is reflective of the varied level of participant comfort with video-conferencing platforms and preparation of the assessment area in their homes. The first virtual assessment session required between 18 to 39 minutes which was almost twice the amount of time as the second assessment. Technical challenges were reported by 8 participants; 3 participants had internet connection difficulty, 3 participants had trouble navigating the platform, and 2 participants experienced both internet and video platform navigation challenges. Table 4 also summarizes the verbal feedback shared by participants. Generally, participants reported that the orientation helped them familiarize themselves with the set-up and video-conferencing platform, and that the physiotherapist's explicit instruction and demonstration during the assessments assisted with clarity. Most participants felt safe performing the tasks, and most participants reported they would perform the tasks in the same way with or without the physiotherapist's in-person supervision.

Table 2.4 Summary of virtual assessment session and verbal feedback

Variable		Value
Rate	Recruitment rate	21/28
	Task completion rate	104/105
Time	Orientation session (min)	21.33 ± 8.83 (7 – 37)
	Assessment session day 1 (min)	28.00 ± 6.86 (18 – 39)
	Assessment session day 2 (min)	14.67 ± 4.68 (9 – 26)
Adverse events	Falls	0
Technical challenges	Difficulty of internet connection	3/21
	Difficulty of navigating the platform	3/21
	Both difficulties of Internet connection and navigating the platform	2/21

Note: Twenty-one participants performed five balance and mobility assessments; a total of 105 measurements were conducted.
Values are mean ± SD (minimum to maximum), or the number/sample
Abbreviation: min: minutes

Verbal feedback from participants

Question	Numbers of responses	Sample answers

Q1	No (21)	"Orientation session helps me aware of what I need to do." – VA02 "The tasks are easy, so does the set-up." – VA11
Q2	Safe at all times (14)	"Because the challenges of tasks weren't beyond my capacities." – VA03
	Unstable (4)	"I felt unbalance on the tandem stance, but I felt safe" – VA15
	Unsafe (3)	"Only during the tandem stance, I feel unsafe when I performed that task." – VA12
Q3	Yes (17)	"No difference between doing with or without her (physiotherapist) present." – VA05 "Because I can see the demonstration, I can understand the instructions easily." – VA19
	Unsure/No (4)	"Maybe the same, but would feel more secure if PT was there with me." – VA12
Q4	Clear instructions	"Instruction was good, and I can understand all. It's straightforward, no problems" – VA10
	Well demonstrate	"Clear in giving instruction; it's nice to show me what I need to do. She (physiotherapist) explains everything in a great job." – VA19
	Willing to explain many times	"She (physiotherapist) explains the tasks well, but I can only understand some tasks after she explains it twice." – VA12

Q1: Is there anything we could have done to make virtual evaluation easier for you?
Q2: Did you feel unsafe during the assessment?
Q3: Do you think you would be scored the same if the physiotherapist was with you?
Q4: Do you have any feedback on how the physiotherapist conduct the session today?

The feedback provided by the assessing physiotherapist aligned well with the feedback from participants. Specifically, the physiotherapist identified: 1) the importance of the initial session to orient the participant to the platform and identify the evaluation set-up in their home settings, 2) using the safety check-in list to build the clinical comfort in challenge people's balance and mobility remotely, 3) it was critical for the participant to watch the task demonstration by the PT prior to performing it, and 4) the importance of not talking to participants while they focused on performing the timed task to prevent interruption or shifting participant attention to the video-conferencing device. With respect to the safety of each task, the PT identified that performing the FRT raised the most concern for potential loss of balance of a participant during the assessment. The assessment booklet and safety check-in list are listed on **Appendix B**.

2.4 Discussion

This study is the first to explore the reliability, validity, and feasibility of performing clinical assessments of balance and mobility in people with stroke via video-conferencing platforms representative of virtual assessments. We found that the TUG, 30-sec STS, and 5-times STS showed good-to-excellent test-retest reliability and moderate-to-good convergent validity when performed in virtual assessments with people with mild to moderate chronic stroke in their own homes. Completing these assessments was feasible for those able to participate; however, clinical judgment of safety to perform tasks without supervision limited the enrollment of two participants, and lack of access to required technology limited the enrollment of a further two participants in the study.

Our results are aligned with previously established findings that the TUG and sit-to-stance tasks show good to excellent test-retest reliability, low SEM values, and convergent validity in people with stroke during the in-person assessments.[18, 31, 34, 38] Our results extend these findings to using these outcome measures during virtual assessments. For sit-to-stand tasks, the requirement for a good evaluation is the ability to see them sitting down and standing up fully. All participants could successfully set the webcam angle to capture their upper trunk while sitting and their hips while standing. These outcome measures require minimal effort for participants to rearrange their environment or optimize webcam angles when using video-conferencing platforms. Similarly, for the TUG, timing the beginning and end of the test was based on the physiotherapist seeing the sit to stand movement that initiates the test and the stand to sit that ends the test. Even though the physiotherapist could not observe the 3-metre turning point due to the limited webcam angle, participants could follow the instruction and reproduce the task well once they identified a landmark associated with the end of the 3-metre walking route in their home. Additionally, it is encouraging to note the strong relationship between the performance scores of the TUG and the 30-sec STS via video-conferencing and the CB&M and 6MWT measured in-person.

Conversely, we found low test-retest reliability and convergent validity in the FRT and TS tests measured in virtual assessments. Under in-person administration, these measures have been shown to have excellent test-retest reliability.[22, 25, 66, 67] Specifically for the FRT, one possible explanation of this discrepancy would be different strategies used by participants to reach as far as they could between days (e.g., rotation through the trunk, contact with the wall), or the accuracy of participant measurement between start and finish positions. Because of the restricted observation view, the physiotherapist was not confident that they could verify the participant’s approach to reaching did not change between days. Similarly, during the TS measurement, the physiotherapist could not view participants' feet during most assessments as participants could not re-position their cameras (e.g., using tablets with limited camera angles, difficulty maneuvering computer or webcam with one paretic arm). Therefore, practical reasons and indirect challenges of optimally using technology potentially limits the reliability of FRT and TS clinical measures via the video-conferencing platform.

It is important to note that our study recruited a convenience sample of participants that completed in-person balance and mobility assessments in our lab. Two participants were excluded from this group as the assessing clinician did not feel comfortable challenging their balance capacity remotely without in-person supervision. Safety is an essential consideration regarding the feasibility of assessment over virtual conferencing platforms, and safety protocols and in-person supervision to conduct balance assessments in patients' homes are required. Additionally, two participants did not have access to technology to participate in the evaluation via video-conferencing. This speaks to the challenges of ensuring all people deemed appropriate for virtual rehabilitation have access to the required technology. Based on participants' walking speed and 6MWT, the walking function of the current sample is in-line with that of community dwelling people with chronic stroke, and additionally would be classified as a lower level of walking function compared to healthy older adults.[28, 41] The balance confidence levels of the study sample, as measured by ABC, were similar to healthy older adults.[69]

Replication of the in-person CB&M and 6MWT was not considered practical or safe to perform via video-conferencing due to the nature of the tasks (potential challenge to balance or risk of fall) and required space and time. The modified clinical measures used in the virtual assessment were chosen based on the research team's clinical judgement regarding safety of participants to perform these tasks without stand-by supervision. Accordingly, measures of balance and mobility in a virtual setting present with a lower level of challenge to balance than is feasible during in-person settings.

Of those who were able to participate in the virtual assessment, the task completion rate was high, and only one participant had trouble understanding the instructions of FRT. During the virtual assessments, there were no adverse events, and most participants reported feeling safe while being guided through the assessment over video-conferencing. Therefore, the evaluated balance and mobility assessments performed via video-conferencing appear feasible for ambulatory people with stroke living in the community. However, it is important to note that extra time was needed to facilitate the virtual assessments from a feasibility perspective. For example, the initial orientation session was required prior to the first virtual assessment to familiarize participants with video-conferencing, address technical challenges, and arrange their space for optimized assessments. Also, the virtual assessment session 1 was almost twice as long as the session 2 due to time required for the assessor to explain and demonstrate the tasks and for participants to arrange their environment (i.e., moving the chair to the 3-metre turning point of TUG or moving the laptop around to adjust the webcam angle as able)." It is suggested that additional time is required to facilitate the virtual assessments conducted via video-conferencing platforms.

2.5 Limitations

Conducting clinical measurement of balance and mobility over video-conferencing platforms poses limitations based on participant safety and available in-home space and equipment. We developed an assessment protocol to optimize the outcome measures. However, limitations such as the participants' inabilities to adjust webcam angles may have contributed to poor results of the FRT and TS measures. Future studies need to explore technology that could address the challenges of using technology for people with stroke, including manipulating the equipment or webcam with upper extremity impairment. It also highlighted the needs of future investigation into development of other platforms to optimize the way clinicians can connect with patients and visualize their performances. Additionally, this current study's sample size was small and included people with chronic stroke who had good insight and understanding of their mobility and balance abilities. Future studies could explore the feasibility of conducting clinical balance and mobility assessments in a larger sub-acute stroke population while they are currently receiving formal rehabilitation following stroke, comparing the in-person assessments to the same virtual assessments.

2.6 Conclusion

The TUG, 5-times sit-to-stand and 30-second sit-to-stand performed over video-conferencing platforms are feasible, reliable, and valid mobility measures in ambulatory people post-stroke. These findings support the use of these measures over video-conferencing platforms without clinician's in-person supervision. Standardized assessment instructions and the safety protocol are required when challenging patients' balance and mobility during virtual assessments.

Chapter 3: Conclusion and General Direction

3.1 Summary of the findings

This study aimed to explore the reliability, validity, and feasibility of existing clinical measures of mobility and balance modified for use during assessment of people with stroke over video-conferencing platforms. We found that performing the TUG, 5-times STS and 30-second STS were reliable and valid measures of balance and mobility when carried out over a video-conferencing platform with people with mild to moderate chronic stroke in their own homes. The modified clinical measures of the FRT and TS demonstrated low reliability and validity if performed and measured over the virtual platforms. This study is the first to date to explore clinical assessments of balance and mobility in people with stroke remotely. This present study also highlighted the main consideration regarding administering clinical assessments over virtual platforms, which is how to implement those clinical balance and mobility measures over video-conferencing platforms.

3.2 Implementing clinical assessments of balance and mobility via the video-conferencing platform

In the present study, the assessor was well-trained in conducting clinical assessments over video-conferencing as the physiotherapist was a member of the research team that developed the modifications of the outcome measures and the methodological approach to instructing participants during the assessment via the video-conferencing platform. There were four main considerations of successfully planning the approach to evaluating over the virtual platform; 1) understanding the video-conferencing platform, 2) optimizing technology hosting the platform,

3) optimizing individual adjustments of people's home settings, and 4) safety while doing remote balance and mobility assessments.

3.2.1 Understanding the video-conferencing platform

The research team decided to use Zoom as the video-conferencing platform due to its convenience among all other platforms. The interface is intuitive to follow, and it doesn't require users to register an account in advance to join a meeting. By clicking the link set to their emails, participants can access the website without downloading and installing the app. The user platform is also easy to navigate. In terms of data security, by the time of developing the study design, UBC had a campus-wide license for Zoom as a platform to provide video-conferencing. The data is stored in Canada and followed the policy under the Freedom of Information and Protection of Privacy Act (FIPPA).

3.2.2 Optimizing technology hosting the platform

There were pros and cons of using different devices to host the video-conferencing. For optimal adjustability, the physiotherapist used a laptop to be able to adjust the webcam angle vertically, horizontally or moving close or far from the webcam to change the view when demonstrating the task. We used a room with a clear wall as a background. The headset was not used so that the physiotherapist could hear and speak to participants even with distances (e.g. when they were standing up to demonstrate a task). We ensured that the room was private and without interruption during sessions.

The laptop was the ideal device to perform the virtual assessments. However, not every participant had a laptop computer, and we found different set-up solutions to optimize webcam angles depending on the device. Some participants chose to use a tablet with a stand. Tablets are lighter than laptops and were easier for participants to be move around; however, we found that use of the tablet restricted webcam angles (i.e., to aim at the participant's feet). Therefore, our view was restricted to participant's upper trunk while sitting or standing. One participant used their phone for the assessment. This participant was able to adjust the device to where it was appropriate for the assessment, and creatively used packaging tape to stabilize the phone in a range of positions. This would likely be challenging for many people with stroke, specifically those with significant upper extremity paresis. Finally, for some assessments, participants' partners were present during the call and physically helped to move the devices, either the tablet or the external webcam of the desktop, to film the entire performance. This was beneficial, however, is not available for many people with stroke that live alone (i.e., 50% of our participants).

3.2.3 Optimizing individual adjustments of people's home settings

We modified outcome measures commonly used in the stroke rehabilitation field that had existing scoring instructions, guidelines, and training to perform the assessment. The major focus of modifications was adapting the required equipment and finding the required space in people's homes. For example, initial modification of the functional reach test included instructing participants to stick a piece of paper on the wall and have people hold a pen and draw a line while they reach forward. However, we found it challenging to perform this modification of the functional reach test in the pilot testing (e.g., tape damage to walls, pen on walls with errors).

Therefore, we modified to using sticky notes to indicate the start and finish position of the reach on a clear wall or door to complete the task.

Initial preparation of participants for assessment via video-conferencing is time consuming and involved considerable time to find required space and equipment in an individual's home. This was in addition to time that participants spent to prepare their environment based on instructions sent to them prior to the orientation call. The average time spent in the first Zoom orientation session to prepare the assessment and orient participants to the Zoom platform was 22 minutes, ranging from 7 to 37 minutes. Since it's needed to make individual adjustments to meet the requirement of performing assessments, it highlights that conducting virtual assessments in people's homes likely takes longer than performing those same tasks in a clinical setting that is designed for performing tasks such as these.

3.2.4 Safety while doing remote balance and mobility assessments

Outcome measures were chosen with safety as the main priority in this study. A parallel priority was to not exclude participants who live alone or live with partners who are unable to physically assist the participant. We did not want to rely on an additional person present to ensure participant safety. Operationally, we attached a safety check-in list in our assessment booklet for the examiner to review prior to each assessment. For example, in the safety check-in list, we confirm the participant's emergency contact information, phone number, and current address in case of an emergency event. The assessor ensured every participant had a sturdy chair and wore proper footwear before introducing any assessment task. If participants had to move outside of the webcam angle, we ensured that we could hear each other talking from these required distances. The above safety approaches worked well in the present study and made the examiner comfortable in challenging participants' walking and balance capacity.

3.3 Addressing rehabilitation of balance and walking function following stroke over video-conferencing

An important goal of rehabilitation following stroke is independent mobility. Critical components of this goal are addressing balance capabilities, walking endurance, and lower extremities strength. For optimal patient outcomes, virtual rehabilitation following stroke will need to address each of these aspects.

3.3.1 Balance capabilities

During rehabilitation activities that challenge or aim to train people's balance, protecting people's safety is the priority. In tele-rehabilitation and virtual care studies to date, it is common to note inclusion criteria of having one additional person present with the participant during treatment to ensure the stroke participants' safety when clinicians challenge their balance.[56, 57, 70] For example, three randomized controlled trials had applied balance training over the video-conferencing platform to improve lower extremity motor function or balance capacity for people following stroke.[56, 57, 70] They clearly stated having one caregiver present in the video call as one of the required inclusion criteria to provide standby supervision or program assistance.[56, 57] These inclusion criteria make the clinicians feel more comfortable in delivering virtual health services. However, data from 2016 Canada Census of Population, over 25% of older Canadians live alone.[71] The inclusion criteria of having one caregiver present inevitably rule out some participants who might need extensive rehabilitation services. In our paper, 11 out of 21 participants were performing the tasks alone and completed the assessment alone. The current study provides evidence for potential tasks that can somewhat challenging the balance of people with stroke without standby or hands-on supervision. To illustrate more, we found the TUG had the highest reliability between testing days and highest validity when corelated TUG to in-person assessments. However, the FRT and TS, which are the standing balance measures, didn’t show acceptable reliability and validity. The technical challenges of the FRT and TS require further development of how to implement these measures reliably during virtual assessment.

Gradually progressing the challenge level is another way to ensure stroke participants' safety when clinicians challenge their balance. In the study of Lin et al. (2014), the researchers provide a general guideline for the balance exercise of phase 1 to 4 (i.e., phase 1: static/dynamic sitting balance on a firm surface; phase 4: dynamic standing balance on firm surface.).[57] In our study, it also aligns with the way of how the physiotherapist test people's static standing balance in tandem stance test. This study retrieved the four Likert scale from the Berg Balance Scale to test the participant's static standing balance. The physiotherapist chose a level that she felt comfortable in challenging the participant first. For example, the physiotherapist usually asked participants to perform score 2, taking small steps independently, as their first attempt. After knowing participants were confident in this level, they would process to score 3 or 4 depending on the participant's performance. Understanding how to safely increase the challenge over virtual rehabilitation is an important consideration for future research and will increase the ability of virtual rehab to address balance challenge following stroke.

3.3.2 Walking endurance

There are limited studies that address walking endurance in their virtual rehabilitation interventions for people post-stroke.[56] In the randomized control trial of Chen et al. (2017), the research team applied a virtual platform that integrated EMG triggered neuromuscular stimulation, detecting physiological parameters, and a high-quality video-audio system for stroke survivors to improve their physical function. Both groups received a total of 60 sessions of physical exercise and electromyography-triggered neuromuscular stimulation, and the physical activities included stretching, standing balance training, and walking training. However, the paper didn't mention how they conducted walking training in people's homes, and the implementation components were not discussed in the article.[56] With the lack of established protocol of walking program with people post-stroke over video-conferencing platforms, one research team currently explored the efficacy and effectiveness of TRAIL (TeleRehabilitation with Aims to Improve Lower Extremity Recovery Post-Stroke) in sub-acute stroke to fill the gap of its application in virtual healthcare services.

Assessment of walking endurance was limited in our assessment. Our findings suggest that the TUG and 30-sec STS had the highest level of validity with the in-person 6MWT, which is the measurement of endurance in people post-stroke. Suggesting a relationship, however, these measures are not direct measure of walking endurance. The 6MWT is the most commonly used measure of walking endurance in people following stroke, however, this is difficult to have participants perform 6MWT in their home settings. Clinicians commonly use a straight and flat walkway to perform the tasks.[40, 42] However, it's hard for people to have this indoor setting in their home, especially those living in an apartment. If some participants do have a walkway inside their house, the researchers may not be able to observe the whole walking route or the starting and ending point of the test. In the study of Salbach et al. (2020), the research team developed the iWalkAssess app to help clinicians conduct 6WMT and 10-metre walking tests.[72] It is free to download and easy to install on iOS and Android platforms. It helps researchers to monitor time and administer the task. Unfortunately, it requires an assessor conducting the walking tests in a standardized setting, such as a hospital walkway, and does not lend itself for use in virtual rehab setting. Additionally, it is not designed for stroke survivors to use for self-monitoring. It does not capture distance walked, and it relies on the assessor measuring the lengths of the walking path in advance to calculate the laps during the assessment. Commercially, other smartwatch devices (e.g., Fitbit) might fit the goal of self-monitoring of walking distance. It can measure time and step counts simultaneously, and people could know their rough walking distance after walking for 6 minutes. However, not everyone would be able to afford or want to purchase a smartwatch to have an awareness of these values. Importantly, GPS of smartwatches work better in the outdoor environment than inside any building which may limit its usability for people with stroke (e.g., walking in indoor environments such as malls during inclement weather). Therefore, further study could fill the gap to help people measure their walking endurance without the clinician's in-person supervision.

3.3.3 Lower extremities strength

Clinically strength is measured with hands-on techniques (e.g., MMT, hand-held dynamometry). This is a significant challenge for virtual healthcare services. In the current study we used 30-sec STS as a function measure that would be impacted by lower-extremity strength. Virtual rehabilitation intervention studies in stroke to date have not directly measured muscle strength during as an outcome during the in-person assessment.[50] However, it is common for interventions to include lower-extremity strengthening exercises (e.g., repeated sitting or standing exercises) with a goal of improved walking function. Future research inclusive of strengthening exercises in virtual interventions may benefit from inclusion of outcome measures such as the 30-sec STS as a measure of lower extremity strength.

3.4 Conclusion and future directions

This current thesis is practically driven by modifying and conducting those clinical assessments in response to the outbreak of COVID-19. At the same time, clinicians raised the question of whether they could challenge people's balance and mobility without standby supervision over video-conferencing platforms. The present study attempted to provide evidence of extending virtual rehabilitation and healthcare services to perform remote clinical assessments. Specifically, 5-times STS, TUG, and 30-sec STS showed good-to-excellent test-retest reliability and convergent validity as the balance and mobility measures for people following stroke and could be conducted over video-conferencing platform. It also raised the discussion of the scale of fitting its role in the current field of stroke rehabilitation. With the gradual re-opening plan of institutions and facilities, the further application of this present study could be providing alternative ways of extensive rehabilitation services when in-person services were not applicable, for example, for those living in rural areas and preventing the exhaustion of long commute.

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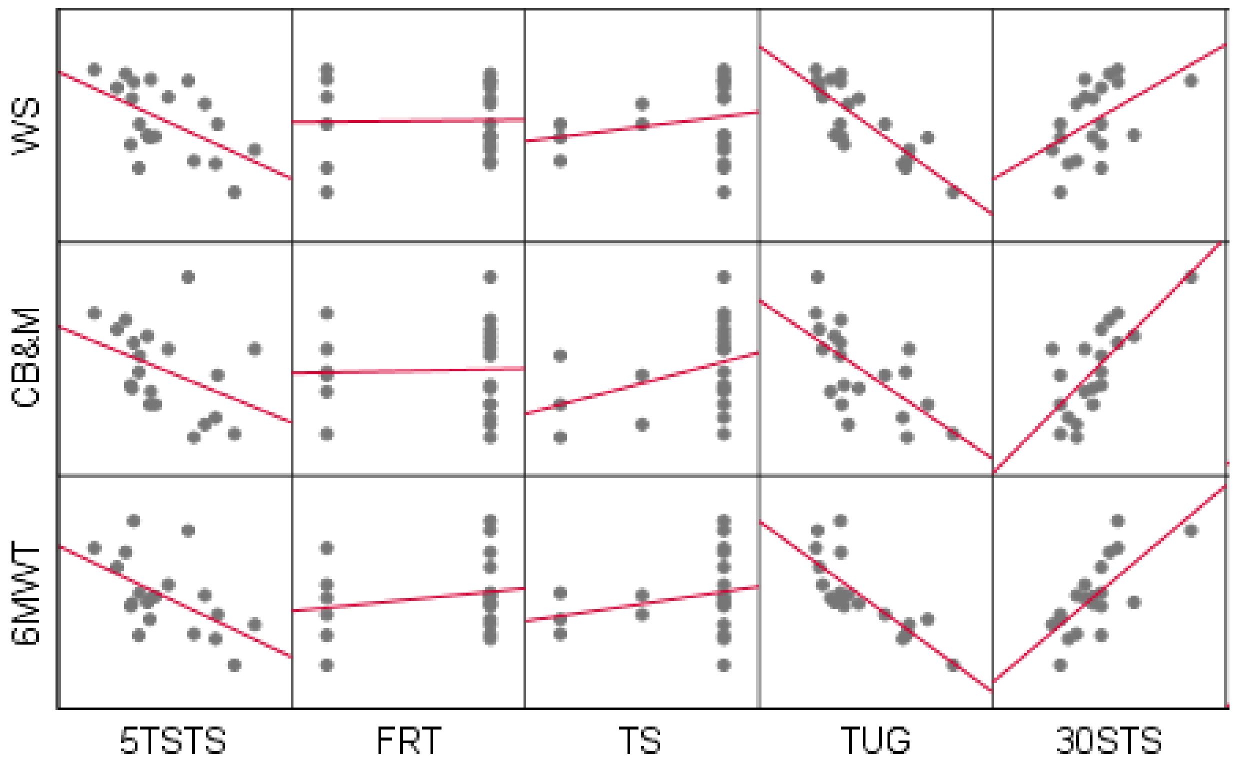
Appendices

Appendix A Scatterplot Matrix of virtual assessments and in-person assessments



Appendix B Virtual Assessment booklet

Assessment instructions: Physiotherapy assessments for balance and mobility delivered over video-conferencing platforms.

Outline of Assessment

Activity	Estimated time
Demographics and History (updates, current status)	15 mins
5-times Sit-to-Stand	5 mins
Functional Reach Test	10 mins
Tandem Stand	10 mins
30-second Sit-to-Stand	5 mins
Timed Up and Go test	10 mins
	Total: 55 mins

B.1 Introduction

Suggested script for assessor:

Thank you for agreeing to participate in this study. The purpose of this study is to examine if it is possible to do these standard physiotherapy tests with people who have had a stroke over video conference instead of in the same room.

I am a registered physiotherapist and will talk you through the tests. Tzu-Hsuan is on the call also and the things she will be doing is: helping to mark down the timing of the tests, act as a back-up in case we have trouble with technology. If there are any technological difficulties that can't be resolved in 5 minutes, we will call you to make an alternate plan.

You will be doing 5 tests throughout this session. The tests involve standing up, standing balance, and walking. You may already be familiar with these tests from the previous study. After each test, you will tell me how stable/unstable you felt doing that task. At the end of the session, I will ask for your feedback about the experience on doing these tasks by videoconferencing.

Part of this study is to figure out how long these tests will take, but I expect it will take roughly 45 minutes.

B.2 Safety Check-in

- [ ] Does the participant have a sturdy chair?
- [ ] Is participant's space clear of tripping hazards?
- [ ] Is participant wearing appropriate footwear?
- [ ] Does participant have gait aid(s) and brace(s) ready for use?
- [ ] Does the participant have their phone close by?
- [ ] Does the participant have a contact number for study staff?
- [ ] Confirm participant's phone number on file. Does participant have an alternate phone number (eg. Landline)?
- [ ] Does the participant have someone in the home or are they alone?
    - Confirm contact information for others in their home, and confirm consent to contact them in case of an emergency

- Confirm address of participant’s current location.
- Ensure participant is aware that they can request a break at any time.
- Ensure participant is aware that they can choose not to do an assessment or end the session at any time.
- Ask participant if they have any questions before we start

B.3 Platform suggestion

Suggest to participant that they might want to change their Zoom screen to ‘speaker view’ instead of gallery view.

B.4 5-times Sit to Stand

Instructions: Sit in the middle of the chair. Place your hands on the opposite shoulder crossed at the wrists. Keep your feet flat on the floor. Keep your arms against your chest. When I say “Go,” stand up to a full standing position and sit down as quickly as you can but at a speed that you feel safe 5 times. First please do one practice for me to show me how you stand up.

Notes for the assessor: Timing starts on the word ‘go’ and ends when the patient’s buttocks touch the chair after the 5^{th} repetition.

B.5 Functional Reach Test

Instructions: Stand with your strong side towards the wall. Have a chair behind you. Lift your arm to shoulder height and mark your starting point with tape/sticky note/pen. Reach as far forward as you can without losing your balance. Keep your feet on the floor. You are not allowed to touch the wall or the ruler as you reach. You can have two practice trials and then I will record the distance that you reach forward.

After the practice attempts: Get your sticky post-it notes or your pieces of tape ready in your strong hand. (or paper on the wall; pen in your hand). We will measure this after we are finished all the other tests.

4: can reach forward confidently more than 10 inches (>25cm)	
3: can reach forward more than 5 inches safely (>12.5cm)	
2: can reach forward more than 2 inches safely (>5cm)	
1: reaches forward but needs supervision	
0: needs help to keep from falling	
SCORE:	/4

B.6 Tandem Stand

Instructions: The final version of this test is to place one foot directly in front of the other, touching heel to toe. You will hold this position for up to 30 seconds.

Talk the participant through the easier options if tandem stand is too difficult, or you are unsure it will be safe for the participant to try. Optional to repeat the test with the other foot in front in the participant does not achieve full score on first attempt.

4: Able to place foot tandem independently and hold 30s	
3: Able to place foot ahead of the other independently & hold 30s	
2: Able to take small step independently and hold 30s	
1: Needs help to step but can hold 15s	
0: Loses balance while stepping or standing	
SCORE:	/4

4 points. feet in line heel to toe

3 points. 1 foot completely ahead of the other but not in line

2 points. 1 foot overlaps the other

B.7 30-second Sit-to-Stand

Instructions: Sit in the middle of the chair. Place your hands on the opposite shoulder crossed at the wrists. Keep your feet flat on the floor. Keep your back straight and keep your arms against your chest. When I say “Go,” rise to a full standing position, then sit fully back down again. Complete as many full stands as possible in 30 seconds.

Note for assessors: in case a participant cannot do ***any*** repetitions of sit to stand without assistants, complete the test and make a note in the ‘comments’ section the amount of UE assistance that was used. Half-way through tell them they are at 15 second mark and give them encouragement (eg. “you are halfway there, good job”).

B.8 Timed Up and Go (TUG)

Instructions: Begin seated in a standard armchair. On the word “go,” get up, walk at a comfortable and safe pace until you cross the line on the floor (3 metres away), turn, return to the chair and sit down.

Notes for assessors: The time (seconds, to first decimal point) from rising from the chair to sitting back down – when their back touches the backrest and leaves the backrest. Assistive device used during this test: Walking pole can be marked as “Cane: Single point”.

Observations for TUG

☐ Slow tentative pace

☐ Loss of balance

☐ Short strides

☐ Little or no arm swing

☐ Steadying self on walls

☐ Shuffling

☐ En bloc turning

☐ Not using assistive device properly

☐ Other/comments:____

____

B.9 Feedback

Ask participant 4 questions:

- Is there anything we could have done to make this easier for you to do these tasks today?
- Did you feel unsafe at any time?
- Do you think you scored the same as you would have scored if I was there in-person?
- Do you have any feedback on how the physiotherapist conduct the session today?