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Use of a Telerehabilitation Delivery System for Fall Risk Screening

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The Use of a Telerehabilitation Delivery System
for Fall Risk Screening

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Signature Page

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Abstract

Problem: The Centers for Disease Control and Prevention indicates that falls are the "leading cause of injury death and the most common cause of nonfatal injuries and hospital admission for trauma among people ages 65 and older."[1] Falls can have significant economic consequences to the individual and payer sources. To address these consequences, telerehabilitation was hypothesized to be a suitable supplement for fall screening efforts. Several sources concluded that support for synchronous telerehab was underdeveloped in the literature. **Purpose:** The purpose of this study was to explore the acceptability, feasibility, reliability, and validity of telehealth-delivered fall screening among community-dwelling older adults. **Procedures:** This investigation implemented an experimental, quantitative, cross-sectional design employing both pretest-posttest control group and quasi-experimental static group comparisons using non-probability sampling. This study assembled a panel of experts to provide content validation for a survey tool developed to quantify an older adult's behavioral intension to use and attitudes towards a telerehabilitation delivery system. Seven fall screening tools were investigated for agreement among remote and face-to-face raters, and for comparison with the face-to-face reference standard (Mini-BEST). **Results:** All three null hypotheses were rejected. Results indicate that a telerehabilitation delivery system is a reliable and valid method of screening and determining fall risk in community-dwelling older adults. This study produced a content validated, internally consistent survey instrument designed to determine attitudes and beliefs about telerehabilitation. An experimental design was able to demonstrate a positive significant change in 4 of 7 survey constructs among the intervention group after exposure to telerehabilitation as compared to post-test controls. Overall, no significant difference was calculated between face-to-face or telerehab raters, and both environments produced equivalency with scoring, fall risk classification, and ability to discern fallers from non-fallers. Results from the telerehab STEADI fall risk conclusions were calculated to be concurrently valid with the face-to-face reference standard screening tool, the Mini-BEST. **Conclusions:** This investigation expanded the array of remote healthcare delivery options for clinicians and clients. Further investigation in residential and community settings are recommended.

Keywords: Telerehabilitation, Elderly falls, Telehealth, Technology acceptance

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CHAPTER ONE: INTRODUCTION

Introduction

Telehealth is defined as the delivery of health-related services and information via telecommunications technologies.[2] Telehealth services can refer to the provision of synchronous (real-time) or asynchronous (store-and-forward) services that bridge a remote site (provider) with an originating site (recipient). The scope of telehealth applications in the literature ranges from distance consultations provided by specialists, robotic surgeries, and education and training of healthcare practitioners to the monitoring and education of patients.[3-7] Under telehealth, clinical and medical services provided by telecommunication are known as telemedicine while rehabilitation services delivered by telecommunication are known as telerehabilitation. Telerehabilitation or “telerehab” is an evolving subcategory of telemedicine, and one that directly relates to this investigation. Broadly speaking, the practice of telerehab can refer to any remote assessment, monitoring, or intervention performed by a licensed occupational therapist, physical therapist, or speech-language pathologist.[2]

Falls among the elderly have become a national and international public health crisis. Each year, the U.S. spends billions of dollars treating the sequelae of injurious falls. Overall, the U.S. lacks a sustainable model for the provision of cost-effective healthcare services to older adults. Furthermore, elderly adults who cannot access health care services because they are homebound, without transportation, and/or live in rural areas are at a distinct disadvantage compared to those who do. Although not specific to the remote fall screening of older adults, a systematic review by Kairy et al concluded that evidence does exist in support of the effective-ness and efficacy of telerehabilitation.[8] Several sources, however, concluded that support for synchronous telerehab by a physical therapist was underdeveloped in the literature.[2,9-11] A foundational 2012 American Physical Therapy Association (APTA) publication by Lee and Harada identified 117 articles related to telerehabilitation and physical therapy. These authors stated that the majority of the articles were conceptual or descriptive in nature, and few studies investigated the reliability, validity, or cost-effectiveness of telehealth-delivered physical therapy.[2] A panel of experts who presented at a 2013 APTA conference reported that a PubMed search of "telerehabilitation" in the title or abstract revealed 165 articles within 58 unique journals. The majority of the panelists categorized articles reviewed as opinion/discussion/review or technical. Nonetheless, the number of randomized clinical trial (RCT) publications in telerehab have trended upward since 2010.[10] Despite the limited evidence of telemedicine's long term efficacy and universal acceptance by end-users, the field of telemedicine has experienced tremendous growth in the 21st century. The American Telemedicine Association (ATA) indicated there are now approximately 200 telemedicine networks in the United States (U.S.). The ATA further estimated these networks correspond to nearly 3,500 medical and healthcare institutions throughout the country.[12] Although telehealth is hypothesized to be a cost-effective alternative or supplement to traditional face-to-face healthcare, further evidence is still needed to support its clinical application.

Problem Statement and Purpose

1. While telehealth delivery systems have demonstrated the potential to assist with the screening for and the prevention of elderly falls, its validity and reliability in doing so has not yet been established.
2. While telehealth may be an option for some individuals, little is known about the attitudes and beliefs of older adults with regard to receiving telecommunications-aided healthcare services and whether or not those attitudes and beliefs would be influenced by

a telerehab experience. Older adults, as end users, may not be receptive to the use of real-time telehealth delivery systems.

3. Each year, the U.S. spends billions of dollars treating the sequelae of injurious falls, and the U.S. lacks a sustainable model for the provision of cost-effective healthcare services to older adults. Telehealth services may provide solutions to this, but research-based supportive evidence is lacking.

Purpose: The purpose of this study was to explore the acceptability, feasibility, reliability, and validity of telehealth-delivered fall risk and mobility screening in an older adult population.

Relevance and Significance

The cost of healthcare has a tremendous impact on the United States economy. It is estimated that healthcare represents approximately 19% of our gross domestic product. Rising healthcare costs are partly attributed to a shift in population demographic with older adults representing the largest consumer group of healthcare services.[13] Falls among the elderly have become a national and international public health crisis. The World Health Organization (WHO) reported that the frequency of falling increases with advancing age and frailty levels.[14] In the United States (U.S.), the Centers for Disease Control and Prevention (CDC) listed older adult falls as a high priority area of research. In fact, the CDC indicates that falls are the leading cause of injury death and the most common cause of nonfatal inquiries and hospital admission for trauma among people ages 65 and older.[1]

Falls can have significant economic consequences. The total direct cost of all non-fatal fall injuries in the U.S. for people 65 and older increased from $19 billion in the year 2000 to $31 billion in the year 2015.[15,16] Projections prior to the Balanced Budget Act of 1997 highlighted the potential financial toll of falls on the U.S. healthcare system to be $54.9 billion based on population aging and cost amortization by the year 2020.[17] Although these financial projections pre-date the Patient Protection and Affordable Care Act (ACA) of 2010, national health expenditures (NHE) as a percent of Gross Domestic Product (GDP), were projected to continue to rise. NHE as a percent of GDP was projected to be 20.8% under the pre-ACA laws, whereas NHE was projected to rise to at least 20.9% GDP by 2019 under the ACA laws.[18] The Centers for Medicare and Medicaid Services (CMS) should explore creative options to curb the rising costs of caring for the elderly.[17] Remote consultations have the potential to meet this need.

Healthcare research and public policy recently began to focus on the prevention of elderly falls, in part because the Census Bureau projects the elderly population to grow and reach 80 million by the year 2050.[18] Examples of elderly falls gaining greater national attention are 1) a March 2014 search of the PubMed database revealed 2845 search results from key words “fall prevention” and “elderly” when filtered from 2004 to 2014,[19] and 2) the CDC developed a multi-factorial fall prevention toolkit, the Stopping Elderly Accidents, Deaths & Injuries (STEADI).[20] Telerehab has the potential to reach older adults who reside in geographically or medically underserved regions and to provide a cheaper alternative to the traditional medical model. Finkelstein et al reported a 20-54% savings when comparing face-to-face and virtual monitoring of patients who possessed cardiac and pulmonary diseases.[21] Using a similar population, De San Miguel et al demonstrated an average annual cost savings of $2,931 as a result of reduced incidence of emergency department access and hospitalizations among clients who consented to and received telehealth monitoring.[22] Screening tools have the potential to also benefit older adults who are not geographically displaced or medically underserved.

According to the National Council on Aging, it was estimated that over 1 million older adults attend over 11,000 senior citizen centers across the U.S.[23] Furthermore, a 2002 ABC News poll estimated that 60% of all adults age 65 and older attend church or gather in a place or religious worship each week.[24] These two statistics support the idea that fall screening initiatives can potentially be implemented in multiple sites, and providers can gain access to a larger population of older adults in the community compared to the traditional medical referral and appointment model.

Research supports the hypothesis that preventative health behaviors are influenced if individuals at risk believe the behaviors can have serious consequences, if they regard themselves as susceptible to these behaviors, and if they perceive no inconveniences or unpleasant barriers for action.[25] Psycho-behavioral models have been applied to conditions such as obesity to better understand patterns of patient behavior.[26] However, research has shown that knowledge of a health risk was insufficient to change patterns of health behaviors or motivations to participate.[25,26] Social Cognitive Theory (SCT) supports the impact of one's environment and the individual person as determinants of behavior. Based upon this brief description of SCT, the influence of peers including the impact of patterns and schedules such as health screening activities that are available at a senior citizen center, for example, are likely to positively influence preventive health behaviors of individuals and small groups of community-dwelling adults.[26]

Baranowski et al further discussed the social marketing method of promoting positive changes in health behaviors rather than trying to understand preventative health behaviors. A focus of social marketing offered members of a group (i.e. older adults attending gatherings at a community center) a package of benefits and availability of resources that minimize barriers to performing desired behaviors such as participating in fall-risk screening examinations from a licensed physical therapist. As this telerehabilitation study proposal exemplifies, the primary benefits of social marketing is on members of the target group (older adults) rather than the marketers (remote clinicians).[27]

Social isolation and homebound status are linked with geriatric depression and elevated fall risks.[28,29] Social support systems can mitigate geriatric depression, and depression was negatively correlated with health-promoting behaviors in older adults.[30] Telerehabilitation has the potential to improve access to rehabilitation service providers. Telemedicine systems have been shown to benefit older adults by increasing peer support interactions, providing access to older adults in rural communities, reducing the cost of health care, increasing exercise, reducing pain and depression, and perhaps most important, improving functional independence.[13] Overall, the literature supported a theoretical screening model that older adults are more likely to participate in fall risk screening exams when among peer groups and when integrated into locations and events where they normally congregate.

As previously stated, the foundational purpose of this dissertation was to explore the acceptability, feasibility, reliability, and validity of telehealth-delivered fall risk and mobility screening in an older adult population. By definition, acceptable care is healthcare that is accessible and meets patient preferences.[31] Is it possible that performing medical screening activities in locations where groups of older adults routinely gather was not only acceptable to the client but also feasible for the provider? This question is fundamental to the public health problem addressed in problem statement number 3 (*Each year, the U.S. spends billions of dollars treating the sequelae of injurious falls, and the U.S. lacks a sustainable model for the provision of cost-effective healthcare services to older adults*). The Cambridge Dictionary defines feasible as possible, reasonable, or likely.[32] Because healthcare screening is not usually reimbursed by CMS, telerehabilitation services to Medicare beneficiaries are pro-bono unless an alternative cash-based payment is arranged. Although healthcare providers have ethical duties to provide pro-bono services, these non-reimbursed services must also be reasonable to the provider. That being said, a clinician may consider telehealth more reasonable, and therefore, feasible if he or she can perform some services remotely to eliminate time and costs associated with driving to clients[33] and potentially canceling clients at their office or clinic. These provider attitudes were supported in the literature. Perceived usefulness is a significant predictor of provider intention to use telehealth technologies.[34] What was not clear in the literature was an older adult's perceived usefulness of a telerehabilitation delivery system and how exposure to a fall screening session impacts baseline attitudes and beliefs regarding this technology application.

To prevent falls, healthcare providers need reliable and valid methods from which they can detect one's fall risk in advance of an injury. Furthermore, healthcare providers need access to older adults who, by nature of their age, are at an elevated risk for falls compared to those under age 65.[35,36] Valid fall screening tools should demonstrate strong psychometric properties to minimize false negative rates while also maximizing true positive rates.[37] There are several valid and reliable fall screening tools for clinicians to consider. Among the more commonly used standardized tools are the Berg Balance Scale (BBS), Balance Evaluation Systems Test (BESTest), Dynamic Gait Index (DGI), Tinetti Performance Oriented Mobility Assessment (POMA), and Timed-Up and Go Test (TUG). For providers to implement these standardized screening tools and theoretically reduce the rates of and expenses associated with elderly falls, older adults need greater access to clinicians who are trained in these specialties.

Telemedicine has been shown to enhance provider contact with older adults who reside in rural communities.[13] To that end, methods of fall screening selected by healthcare providers should be acceptable to care recipients. As Stronge et al agreed, it would be an oversight to select advancing technologies such as telemedicine without first considering the needs of end-users.[13] Telehealth delivery systems, if acceptable to the end-user, have the potential to provide older adults greater access to licensed physical therapists. Providers have a fiduciary duty to select tests and measures that are safe, potentially effective, and are reasonable for a given health condition or risk factor. Not all commonly-used fall screening tools can be safely administered by a remote healthcare provider. Some tests and measures require equipment that is not readily available at originating sites. The appropriateness and potential generalizability of standardized fall screening tools to a telerehab delivery system is outlined in Chapter 2.

Fall risk screening or early detection is an important process in preserving the functional independence of older adults.[38] Loss of independence with ambulation, activities of daily living, and transfers leads to long-term medical, social, and economic consequences.[38] Loss of functional independence may lead to institutionalization where fall rates double as compared to rates among community dwelling older adults.[39] When fall rates rise, costs associated with follow-up medical care also rise.[16,36] As previously mentioned, there is a battery of screening and outcome measurement tools available for healthcare providers to categorize an older adult's fall risk. Newly developed, revised, and classically-used screening and outcome tools are readily critiqued and referenced in the healthcare literature, various American Physical Therapy Association (APTA) taskforces (Stroke EDGE [Evaluation Database to Guide Effectiveness], MS EDGE, Geri EDGE, etc.), Clinical Practice Guideline workgroups, and APTA Section programming at national conferences.[40] What was not known was if these tools can be safely and effectively generalized to a telerehabilitation delivery system.

In summary, our healthcare system is in need of cost-effective supplements to traditional face-to-face care. Lack of recognized need for preventive health screenings, lack of transportation, medical staffing shortages, geographic and financial barriers including reimbursement have all been cited as barriers to consistent access to traditional face-to-face healthcare.[41] Given these well-known barriers to care, a potential benefit to current and future telehealth applications is access to care.[33,42] In general, older adults who reside in rural areas are more likely to lack access to comprehensive healthcare. Americans who reside in rural regions are also more likely to lack health insurance and have higher rates of chronic diseases, disability, and subsequent risk factors associated with injurious falls.[41,43] Statistical evidence indicates that healthcare access and overall health outcome disparities exist between residents of rural versus urban regions within the U.S. These health and wellness statistics are further impaired for those individuals who are categorized as rural, homebound, and elderly.[28,43,44] Despite these regional disparities, groups of older adults are likely to gather at community centers or places of worship similar to their urban counterparts. To help meet societal needs, numerous medical specialties such as telepsychiatry, teledermatology, teleopthamology, telenursing, and teledentistry have evolved and are developing evidenced-based practice guidelines to assist with cost, access, and health disparity barriers.[45-53] Physical therapists provide valuable services that restore health and function but are often underutilized for prevention and wellness services. Access to physical therapy services is a key component in preventing recurrent and injurious falls in the elderly. The potential benefit and role of a remote physical therapist and end-user acceptance in the evolving field of "telerehabilitation" needs further investigation.[2,13,54]

Practical Application of the Findings

This investigation was consistent with legislative directives outlined in the Patient Protection and Affordable Care Act (PPACA) of 2010. The PPACA directs the new Center for Medicare and Medicaid Innovation (CMI) to explore, as care models, how to facilitate care at the inpatient, home health, and integrated healthcare levels.[55] An example of an integrated healthcare model is an Accountable Care Organization (ACO). The Centers for Medicare and Medicaid Services (CMS) defines an ACO as groups of doctors, hospitals, and other health care providers who come together voluntarily to give coordinated high quality care to the Medicare patients they serve.[56] Since the major public health goals of an ACO are timely, coordinated care while also preventing medical errors and avoiding unnecessary duplication of services, telerehabilitation delivery systems may be instrumental to this integrated care model where quality care and cost savings are the focus. Regardless of these potential applications, research about telerehabilitation has evolved but remains underdeveloped.[10]

Studies such as this investigation may provide important information to further telehealth advocacy efforts and evidenced-based knowledge for consideration by clinicians and payers. Results of this investigation could lead to future opportunities for prospective, physical therapist-led collaborative research, as well as interprofessional recognition of physical therapists as primary care practitioners. Actualizing this recognition was key to the APTA's previous vision: Vision 2020.[57] The lack of reimbursement for telehealth services by a physical therapist,[58] regardless of the originating site, is in conflict with the APTA's new vision statement (*transforming society by optimizing movement to improve the human experience*)[57] and position statement on the use of telehealth in physical therapy practice.[59] Currently, the American Physical Therapy Association (APTA) does not provide telehealth practice guidelines for clinicians in the *Guide to Physical Therapy Practice*.[60]

The establishment of outcome-based telerehab care models could be a first step to convincing legislators to reimburse physical therapists for remote services, and therefore, motivate healthcare organizations to invest capital into building and staffing synchronous telemonitoring systems. This could assist the estimated 46.1million Americans who have limited access to healthcare services because they reside in areas considered rural,[61] and the 50+ million Americans who are either uninsured or underinsured.[41,62] Because these individuals are unable to consistently access licensed healthcare providers, routine assessments such as physical exams and likely balance screens are not performed to medical standards.[41] Research data also indicates that despite the volume of face-to-face healthcare expenses that occur in the United States, fall incidence is underreported by older adults.[63,64] Furthermore, primary care physicians are not evaluating or managing fall risks at the frequency that is needed to reduce this public health dilemma.[65] Fortinsky et al investigated the extent to which healthcare providers addressed evidenced-based fall risk factors and barriers to the healthcare interventions in response to identified fall risks. Results indicate that 82-85% of patients who presented with gait, transfer, and/or balance disorders received direct interventions, but only 58-61% of patients with foot, footwear, sensory, or perceptive disorders received direct interventions. Patient compliance was reported as the most common barrier to direct interventions, but lack of Medicare reimbursement and availability of healthcare providers were also cited as common barriers to direct fall risk interventions.[66] No comparable investigations were discovered in the telehealth literature.

Neither the CDC nor the American Geriatrics Society/British Geriatrics Society (AGS/BGS) Clinical Practice Guidelines specify the frequency of fall risk screening examinations. However, the CDC Stopping Elderly Accidents, Deaths & Injuries (STEADI) initiative provides an Algorithm for Fall Risk Assessment and Intervention that infers people 65 and older should receive a fall screening exam at least annually or upon report of a fall incident.[20] This algorithm is available on the CDC website. Regardless of the timeframe from which fall screening examinations such as the STEADI are conducted, telerehabilitation is a resource worthy of investigation so that older adults potentially have greater access to healthcare providers such as physical therapists.

While simultaneously considering the client's attitudes and beliefs about telehealth, ongoing advancements in digital and wireless communication technologies in combination with focused healthcare specialties, telehealth delivery systems have the potential to bridge communication between individuals in need and healthcare professionals. Telerehabilitation, and more specifically, synchronous, community-based remote physical therapy applications, need further investigation prior to being integrated into clinical or *pro bono* practice. While the telerehab literature base continues to expand, the majority of publications lack external validity and more research is needed to support the efficacy of this alternative modality.[30]

Barriers and Issues

The major barriers to the development and research of telehealth practice patterns for allied health professions such as physical therapy are technology, reimbursement, patient safety, and the attitudes and beliefs of potential end-users. Real-time telecommunication technologies have demonstrated inconsistent quality of voice and video transmission. This inconsistency inhibited communication and observation abilities.[11,67] Communication is essential for meaningful client and provider interactions. In fact, a goal outlined in the United States' "Healthy People 2020" document was to *increase the proportion of persons who report that their health care providers have satisfactory communication skills* (HC/HIT-2). Additionally, movement-based assessments are essential to most physical therapist-led client interactions.[66] A 2011 study by Shaw et al, however, reported that transmission of wireless video was insufficient for consistent and safe application to the treatment of urban, post-operative total knee arthroplasty patients. These investigators observed inconsistent video quality to support consistent and effective observation of home exercises such as heel slides and straight leg raises.[11,67] To the contrary, other telerehab researchers have reported "satisfactory" audio and visual quality to conduct physical therapy-related interventions.[68] Trevor Russell, PT, PhD, is largely regarded as the world's leading researcher on telerehabilitation. Dr. Russell reported visual quality outcomes from telerehab care recipients measured on a visual analogue scale from 4/10 (centimeters)[30] to 6.6/10.[68] Ongoing upgrades in cellular bandwidth from 3G to 4G should enable healthcare professionals to more reliably apply adjunctive healthcare practice concepts such as telehealth applications with their consenting, community-based clients.[11]

The second pre-existing barrier to the investigation and development of telerehabilitation delivery systems is service reimbursement.[43] Under Medicare Part B, the Medicare physician fee schedule lacks a reimbursable Current Procedural Terminology (CPT) code for the remote monitoring and provision of physical therapy services. Furthermore, physical therapists are not listed as eligible providers for the delivery of telehealth services to Medicare beneficiaries.[69] Provider eligibility is limited to physicians, nurse practitioners, physician assistants, nurse midwives, clinical psychologists, clinical social workers, and clinical nurse specialists. Furthermore, the originating site or the site of the Medicare beneficiary must be at a physician or practitioner office, critical access or regular hospital, rural health clinic, a federally qualified health center, skilled nursing facility, community mental health center, or a hospital-based renal dialysis center.[58] These reimbursement guidelines are for synchronous provider/patient interactions. Medicare does not provide reimbursement for store-and-forward or asynchronous telehealth services to any providers.[69] However, reductions in Medicare Part A reimbursement for skilled services in traditional geriatric settings such as in-home, assisted living, and skilled nursing facilities is creating demand from both providers and payers of care for more cost-effective supplements to traditional face-to-face community health services. Because Medicare Part A service reimbursement is bundled and/or episodic in nature, this creates opportunities for providers to more creatively case manage their clients with asynchronous or synchronous telehealth. As Russell et al stated, however, telerehabilitation is still a relatively unproven modality[30] and research, such as this proposal, is needed to support any potential changes with Medicare reimbursement laws. Some legislators have responded to these expressed needs and recognize the potential cost savings and health benefits associated with telehealth delivery systems. Multiple bills in support of advancing telehealth reimbursement have been introduced in the United States Congress and/or Senate over the past 5-7 years, but all have remained stagnant in committees with no further activity.[70]

The next major barrier to the provision of telerehab services is patient safety. Face-to-face assessments and interventions provide physical therapists the ability to use themselves and/or support personnel to employ specific guarding and positioning techniques to reduce injury risks to their patients. Although the physical therapist can request the assistance of a friend or relative during a telerehab session, these volunteers likely lack the training and experience of the physical therapist and their staff. The clinician has an ethical responsibility to determine which tests and measures are safe to implement remotely.

Another component of patient safety relates to the use of real-time vs. store-and-forward technologies. A common store-and-forward application is the collection and assessment of biometric data. For example, data such as vital signs including body weight can be monitored via asynchronous technology after data was uploaded by the end user (patient/client). If this data indicates a deterioration in a patient’s health status (such as occurs with an exacerbation of congestive heart failure), this potential emergency could not be recognized until a licensed professional logs into their computer to analyze this uploaded and stored data. Delays between data collection, uploading data, and analysis of data could compromise patient safety, thereby also increasing the liability of the provider(s).

A final component of patient safety relates to licensure.[43] Jurisdictional law, and in situations when healthcare professionals are asked to provide consultation to a patient who resides in a different state, licensure portability are topics integral to the successful expansion of telehealth services. In physical therapy practice, we do not have uniform standards for licensure of telehealth practice written into state laws. Currently, face-to-face and distance consultations are treated the same in all but two states.[10] Without expanded portability provisions, a licensed physical therapist is unable to evaluate or treat a client across state borders regardless of proximity or circumstance. Because the role of a state practice act is to protect its population, a lack of licensure portability with uniform standards contradicts this purpose and could, therefore, potentially harm a potential recipient of remote healthcare. Principle 3C of the APTA's Code of Ethics charges physical therapists to be accountable for making sound scope of practice judgments.[71] Physical therapists may need to refer a patient to a peer or another healthcare professional who possesses greater expertise in a given specialty or condition. The closest peer to whom the evaluating physical therapist could have referred a patient may be across state borders. In addition to safety concerns, the lack of physical therapist licensure portability creates an access barrier for potential care recipients who reside near state borders.[43] For an older adult who experienced a recent fall or was experiencing an acute onset of gait instability, the timeliest method of accessing a healthcare provider may be via a telerehabilitation delivery system. As previously mentioned, access barriers contribute to inferior health outcomes among those who resided in rural regions of the U.S.

The last barrier, and one that is central to this investigation, is the perception and acceptance of older adults to technologically-delivered healthcare. A 2003 study that surveyed 350 adults over age 60 reported that only 22.4% stated using a computer in the previous year.[72] Several articles outline differences in attitudes and usage of technology among older adults as compared to other age groups.[73-75] Although 21st century advancements in telecommunication technologies have produced favorable healthcare-related applications, consistent end-user acceptance and legitimacy of the service remains in question.[34,76,77] No surveys currently exist to determine the attitudes, beliefs, and the overall willingness of clients to use healthcare-related technologies such as telerehabilitation. Furthermore, it has yet to be determined what the impact of a telerehabilitation (measurement of change) experience had on baseline attitudes, beliefs, and willingness to use healthcare-related technologies in an older adult population. This study is the first of its kind to measure baseline and post-telerehab change in perceived usefulness of telerehabilitation technologies in older adults.

Research Questions / Hypotheses

Table 1. Research Questions and Hypotheses

Research Questions	Null Hypotheses (H_0)	Alternative Hypotheses (H_A)
1. What effect does exposure to a telerehabilitation delivery system have on underlying attitudes and beliefs of older adults about the perceived usefulness of this healthcare delivery option?	• There is no difference in attitudes and beliefs of older adults exposed to this investigation's real-time telerehabilitation application and older adults in the control group.	• Participation in a real-time telerehab application will influence an older adult's attitudes and beliefs about the perceived usefulness of this healthcare delivery option when compared to a control group.
2. Are fall risk screening conclusions that are derived remotely equivalent to other reference standard (Mini-BEST) face-to-face screening tools?	• Conclusions from the remote STEADI fall risk screening tool will not be equivalent to conclusions from the face-to-face Mini-BEST fall screening tool.	• Fall risk conclusions from a remote rater implementing the STEADI will be equivalent to fall risk conclusions from a face-to-face rater implementing the Mini-BEST.

3. Are outcomes of fall screening measures that are performed remotely consistent with those performed face-to-face?	• Remote scoring and fall risk categorization of the Timed Up and Go Test, 30-second Chair Rise, Four-Stage Balance, Performance-Oriented Mobility Assessment Gait (POMA-G) Tool, 4-meter Walk Test, Functional Reach Test, and STEADI algorithm will not be equivalent to face-to-face raters.	• Remote scoring and fall risk categorization of the Timed Up and Go Test, 30-second Chair Rise, Four-Stage Balance, Performance-Oriented Mobility Assessment Gait (POMA-G) Tool, 4-meter Walk Test, Functional Reach Test, and STEADI algorithm will be equivalent to face-to-face raters.

For this study's purposes, the terms "telehealth" and "telerehab" were operationally defined as technologies that use *real-time* (synchronous) videoconferencing systems transmitted either via a wired or wireless internet connection for purposes related to connecting medical professionals with potential or actual patient/clients. The terms telehealth and telerehab did not include *store-and-forward* (asynchronous) methods of data collection or video analysis.

Operational Definition of Terms

Asynchronous / Store-and-Forward Telehealth Services: the content data of the service was prepared, stored, and then forwarded to the clinician providing the consultative service. Originating and remote sites do not view content in real-time.

Bandwidth: the amount of information that can be carried over a transmission line per second; recorded in kilobits per second (Kbps) or megabits per second (Mbps).

Community-dwelling: adults age 65 and older who reside in a house, apartment, condominium, group home, or assisted living facility, and were able to come to Midwestern University for testing.

Fall: when a person descends abruptly due to the force of gravity and strikes a surface at the same or lower level (CDC).

Injurious fall: physical injuries that result as a direct consequence of a fall and subsequently require the consumption of medical resources.

Inter-environment: the degree of agreement and comparison between face-to-face and remote rater locations.

Originating Site: the site where the recipient of the telehealth or telerehab service is located.

Perceived Ease of Use: the degree to which a person believes that using a particular system would be free from effort.

Perceived Usefulness: the degree which a person believes that using a particular system would help him/her attain gains.

Remote Site: the site where the provider of the telehealth or telerehab service is located.

Rural: geographical displacement from metropolitan territories; population is fewer than 500 per square mile.

Synchronous Telehealth Services: real-time audio and/or video streamed service. Video and audio data travel simultaneously to both the remote and originating sites.

Telehealth: technologies that use *real-time* videoconferencing systems transmitted either via a wired or wireless internet connection for purposes related to connecting medical professionals with potential or actual patient/clients.

Telemedicine: the exchange of medical information from one site to another via electronic communications to improve a patient's health status.

Telemedicine Network: a consortium of healthcare facilities who combine resources to link healthcare providers with patients in need through a telehealth platform.

Telerehabilitation: rehabilitation services through the use of real-time audio and video telehealth technologies; in the larger realm of telehealth, “telerehab” is the integration of tele-communication technology to support rehabilitation services.

Summary

The long-term goal of this study was to explore alternatives to traditional face-to-face fall risk screening that could potentially reduce the prevalence and financial impact of geriatric falls. This was achieved by investigating the reliability and validity of telerehab applications designed to improve access to and costs associated with fall-risk screening of community-dwelling older adults. The foundation of this research, which was a step forward in attainment of the stated long-term goal, was to determine the generalizability of the CDC’s STEADI and other commonly used tests to quantify mobility, balance, and lower extremity strength to current telecommunication technologies. It was the central hypothesis of this study that the scoring of the standardized tests and fall risk conclusions determined by a remote rater would equal scoring and conclusions performed by a face-to-face rater. This hypothesis was formulated on the basis of the simplicity and safety with administering the STEADI, 4-meter Walk Test, TUG, POMA-G, 30-second Chair Rise, and 4-Stage-Balance Tests remotely as compared to other screening tools such as the DGI, BERG, and BESTests, for example. The conceptual framework, hypotheses, and methods of this proposal are supported by foundational published literature on telerehab from Russell et al, published fall prevention guidelines from the American and British Geriatrics Societies, and fall prevention guidelines recently adopted by the CDC.

CHAPTER TWO: LITERATURE REVIEW

Introduction

The scope of telemedicine applications in the literature ranges from distance consultations provided by specialists, robotic surgeries, and education and training of healthcare practitioners to the monitoring and education of patients.[3-7] In the latter part of the 20th century, researchers considered the possibilities of (asynchronous) transmission of diagnostic and clinical information via analog telephone lines. Twenty-first century advancements in telecommunication and robotics have led to the investigation and application of these (synchronous) tools within an operating room. The literature reflected benefits such as robotic-aided telesurgical applications using laparoscopic techniques, teleradiography to minimize radiation exposure to humans, and telementoring initiatives among physicians.[6] Because these healthcare procedures require tremendous precision and accuracy, healthcare providers such as physical therapists can now view telemedicine as a potential supplement or alternative to traditional face-to-face care. One such telemedicine application is fall screening of older adults. The use of a telemedicine system to connect with older adults regarding fall prevention activities would be more specifically classified as telerehabilitation or telerehab because physical therapists are rehabilitation providers.

As a result of their financial impact,[16] elderly falls are receiving greater attention from the United States government.[15,20,39] There are a plethora of screening and outcome measures for consideration by clinicians to quantify fall risk, and no single tool can be recommended for all settings and with all sub-populations.[78] Most of the literature recognizes that elderly fall risk was multi-factorial in etiology.[35,79] The STEADI toolkit is a recent initiative put forth by the Centers for Disease Control and Prevention (CDC). Although not rigorously researched as a collective toolkit, the STEADI is an evidenced-based resource to guide and encourage healthcare providers to appraise and classify fall risk.[20]

The physical therapy profession is well-trained in the screening and treatment of older adults. However, it is in the early stages of exploring telerehabilitation and its feasibility, acceptability, reliability, and validity when used in a community-dwelling, older adult population. Prior telerehab investigations have focused on post-acute practice settings and relate to cardiopulmonary, integumentary, musculoskeletal, and neuromuscular physical therapy practice patterns.[50,68,80-82]

To maximize its potential benefits and safety, technology must be accepted by both healthcare recipients and providers. The attitudes and beliefs of older adults towards the integration of telerehabilitation delivery systems has been in question because of the limited use of computers by older adults.[72] The Technology Acceptance Model suggests that two specific constructs, perceived ease of use and perceived usefulness, determine one's behavioral intention to use technology.[83] If receptive to its implementation into health related services, the older adult may be afforded a longer life span and an ability to remain independent by *aging in place*.[84]

Historical Overview of the Theory and Research Literature

The telecommunications age commenced in the late 19th century when Alexander Graham Bell summoned his assistant, Thomas Watson, from another room stating, "Watson, come here; I want you."[80] From these primitive roots, the telephone developed into an important tool for physician consultation. Over the course of the 20th century, healthcare professionals including those serving in the military realized the benefit of telecommunications as a supplement to traditional face-to-face assessment. Telecommunications are frequently used as a method to triage complex injuries such as traumatic brain injuries (TBI) that occur on the field of battle.[10,85]

With changes in healthcare reimbursement and the influence of Health Maintenance Organizations (HMO's) in the 1980s and 1990s, the practice of "telephone medicine" evolved into an important cost-containing mode of healthcare delivery. In fact, Dr. Anna Reisman, author of the book "Telephone Medicine," estimated that approximately 25% of all internist consultations are performed via phone.[86] Dr. Reisman further indicates that telephone consultation has been instrumental in reducing emergency room utilization.[86] This projection was further complimented by telehealth initiatives that aim towards timely and evidenced-based emergency department utilization upon onset of ischemic stroke symptoms.[87] The technological ability to transmit video data that coincides with traditional telephonic audio data transmission has enhanced telemedicine's contribution to international disaster relief efforts, national healthcare systems in Australia and Canada, distance medical education, robotic surgery, and medical consultation during recent U.S. supported wars in the Middle East. There is a growing body of published literature, as well as interest within the APTA, attempting to integrate telehealth or "telerehab" into physical therapy practice.[10]

The telemedicine concept was first introduced to Americans in an April 1924 issue of *Radio News.* This newspaper edition featured a drawing of a physician viewing his patient on a "radio screen."[80,88] In 1951, the first cross-state demonstration of telemedicine occurred at the New York World's Fair, and six years later, Albert Jutras initiated tele-radiology in Montreal, Canada.[88] This was followed in 1959 by a Nebraska Psychiatric Institute tele-education and tele-psychiatry program offered in conjunction with the University of Nebraska.[88] By the 1960s, the National Aeronautics and Space Administration (NASA) was using "biotelemetry" to monitor astronauts. Biotelemetry was defined by NASA as “a means of transmitting biomedical or physiological data from a remote location to a location that had the capability to interpret the data and affect decision making.”[80,88] These biotelemetry investigations have had profound effects on today’s healthcare delivery system. NASA’s biotelemetry data collection was very similar to store-and-forward telehealth technologies utilized by today’s home health agencies to monitor heart rate, body temperature, oxygen saturation, blood pressure, body weight, and occasionally electrocardiogram as a supplement to nursing assessments. Investments into store-and-forward procedures are increasing in popularity and frequency of use among home health providers as a result of federal outcome measurement initiatives. For example, a home health client may be provided a blood pressure and heart rate monitor that uploads vital sign data through a computer Bluetooth connection three times a day in an effort to prevent rehospitalizations. However, most contemporary telehealth applications are described for the field of medicine without appreciation for the unique needs of the rehabilitation professional and their clients.[43]

The financial sequela of elderly falls are burdening the U.S. Medicare Trust fund.[89] This financial strain is also realized by taxpayers who subsidize socialized medical benefits. It is logical to conclude that patients who have multiple, chronic medical conditions consume greater financial resources. Keehan et al confirms the added resource consumption in the elderly and states that “as age advances, treating progressively more severe and complex medical conditions was reflected in the mix of services.”[89] The need for more efficient and effective outcome-focused care, ongoing healthcare staffing shortages in rural and demographically underserved areas, and multi-factorial access barriers all contribute to the demand for alternatives and/or supplements to traditional face-to-face patient encounters. Whether it was government incentives, pay for performance programs, wellness screening initiatives, or the need for chronic disease management, a confluence of factors are driving telehealth into the discussion on how to reorganize mainstream healthcare delivery.[90] Telerehab may potentially compliment many other face-to-face and remote interprofessional practice initiatives.

The Theory and Research Literature Specific to the Topic

The Institute of Medicine identifies the use of information technology as a central factor to the enhancement of healthcare quality in the United States.[91] The older adult demographic represents a large percentage of the health-related expenses consumed in the United States,[62,92] and therefore, theoretically could benefit the most from telemedicine and telerehabilitation solutions.[54,93] Other than potential limitations with vision, hearing, and in-home space limitations,[93] a major challenge is that this targeted end-user population has less understanding of new, innovative, and technology-driven healthcare concepts and solutions compared with their younger counterparts.[54,94] To maximize its potential and safety, technology must be accepted by both healthcare recipients and providers.

Literature Related to Technology Acceptance Theories

Like end-user recipients of technology-driven healthcare, the intention of healthcare providers to use technology applications is vital to the success of its implementation.[95] Among office-based physicians who have adopted electronic health records (EHRs), most report that the use of technology has enhanced patient care.[94] The Technology Acceptance Model (TAM) has been used to investigate acceptance of physicians towards telemedicine. While other studies have adopted the TAM to examine attitudes and acceptance of employees and acceptance of prospective patients as end-users, a 1999 study by Hu et al focused on the provider as the end-user.[34] Consistent with the perspective of Hu et al, Duyck et al investigated user acceptance by radiologists and technologists to study behavior intention and perceived voluntariness. The authors reported that providers make technology acceptance decisions independent from their superiors, and focus on usefulness rather than ease of use when determining behavioral intention.[96] In other words, employees value meaning and purpose behind changes as more important facilitating conditions than the mechanics of navigating and use of a new system. By definition, *perceived usefulness* is the degree to which one perceives a change would enhance their job performance whereas *perceived ease of use* is the degree to which an individual believes that a change would be free from physical or mental effort.[97]

Advancements in technology have the potential to promote wellness, independence, and ability to "age in place" among older adult clients.[98,99] Aging in place is a concept that focuses on maintaining health and independence in the community rather than succumbing to or relying on frequent healthcare services including institutional support for instrumental and standard activities of daily living (ADL's). More specific to this study, home and community-based telerehabilitation services have the potential to decrease healthcare costs[21,100-102] and enhance quality of life by enabling older adults to live independently.[54,103,104] "Smart home" technology devices have also been investigated for perceived impact on quality of life and implemented on trial bases for health status and mobility monitoring.[99,105,106] Several sources confirm differences in attitudes and usage of technology among older adults as compared to other age groups.[73-75,94,107,108] Selwyn et al examined the frequency and location of use and reasons for non-use of computers in an older adult population. These authors reported that less than 25% of their England-based sample of 352 older adults indicated using a computer in the previous year. The majority of computer use took place in the home, and participants cited low relevance to daily life as reasons for non-use.[72] Similarly, a United States-based study from Carpenter and Buday indicated that approximately one-third (36%) of 324 residents of retirement communities were actively using computers. Barriers to more frequent computer use included cost, complexity, ergonomic impediments, and a lack of interest, whereas younger retirees with more education, fewer functional impairments, and greater social resources were more likely to use computers.[109] However, computer use is only one indicator of the attitudes and beliefs of older adults towards technology. A 2017 survey conducted by the Pew Research Center indicates that while one-third of older adults have never used the internet, the percentage of Americans age 65 and older who own a smartphone has increased from 18% in 2013 to 42% in 2017. Furthermore, half of older Americans now have a broadband connection at their home.[110]

Inexperience with using computers can impede the potential benefits of technology-aided healthcare. The United States Agency for Healthcare Research and Quality (AHRQ) identifies drivers and barriers related to the successful implementation of consumer health-related technologies. The most frequent driver identified in the literature was perceived health benefits and the most frequent barriers are lack of perceived benefit, inconvenience, and cumbersome data entry.[43,111] Other sources cite privacy[94,112] and cost[102] concerns. Consistent with hypothesis 1 (*There is no difference in attitudes and beliefs of older adults exposed to this investigation's real-time telerehabilitation application and older adults in the control group*), the ultimate impact of telerehab delivery systems to screen for elderly fall risk will be determined by receptiveness of potential end-users towards technologically-delivered physical therapy. Just as was the case with traditional face-to-face healthcare, patients must accept recommended healthcare services for it to be effective. Therefore, the alternative hypothesis that an older adult's exposure to telerehab improved this population's attitudes and beliefs about technologically-delivered healthcare was tested via a pre- and post-test written survey.

Technology is a vital component of most industries and has seen continuous growth within healthcare delivery since the turn of the 21st century. However, computer technology's early roots began in the 1970-1980s with research to understand how Management Information Systems (MIS) could gain acceptance by end-users.[97] MIS was meant to revolutionize the efficiency and management capacity of large businesses. At the forefront of this research was the Massachusetts Institute of Technology (MIT) and Fred Davis, creator of the Technology Acceptance Model (TAM). In simple terms, the TAM was developed to explain computer-usage behavior.[34] Research and development of the TAM was based upon an earlier model of behavioral intention titled, Theory of Reasoned Action (TRA). Fishbein and Ajzen's TRA model focuses on attitude and subjective norms as a method of predicting social behavior.[97,113] The TRA proposes that behavioral intention could be determined by considering both the attitude (sum of beliefs about a particular behavior weighed by evaluations of these beliefs) that a person has towards the action or behavior, and the subjective norm (influence of one's social environment on behavioral intentions) associated with the action or behavior in question.

Fishbein and Ajzen's TRA model operationally defines attitude as a person's positive or negative feelings about performing the actual behavior. Behavioral intention measures a person's strength of intention to perform an action or behavior. This is ultimately what predicts compliance with and carryover of medical recommendations. The TRA model suggests that an attitude towards behavior intention can be measured as the sum product of subjective norms and attitude.[113,114] Simply stated, an individual's voluntary behavior is predicted by attitudes towards that behavior and how the individual thinks other people would view the performed behavior.[114] The TRA provides a useful model that can help to explain and predict the actual behavior of an individual.

Davis took the TRA model and adapted it to the context of user acceptance of a MIS.[113] The research questions central to Dr. Davis' research were 1) What are the major motivational variables that mediate between system characteristics and actual use of computer-based systems by end-users in organizational settings?; 2) How are these variables causally related to one another, to system characteristics, and to user behavior?; and 3) How can user motivation be measured prior to organizational implementation in order to evaluate the relative likelihood of user acceptance for proposed new systems?[97] At the foundation of Davis' pioneering research was a theoretical base that beliefs determine attitudes, that attitudes (along with societal norm) determine intentions, and that intentions determine actual behaviors. Davis' interest focuses on whether baseline beliefs have a direct effect on intentions and/or behavior.[97(p110)] Operational constructs of perceived usefulness (the degree which a person believes that using a particular system would enhance his or her job performance) and perceived ease of use (the degree to which a person believes that using a particular system would be free from effort) are central to his research questions. For perceived usefulness, 13 items (job difficulty, control over work, job performance, addresses my needs, saves me time, work more quickly, critical to my job, accomplish more work, cut unproductive time, effectiveness, quality of work, increase productivity, makes job easier) were clustered into three categories: information related to job effectiveness, productivity, and importance of the system to the job. For perceived ease of use, the 13 items scales (confusion, error prone, frustrating, dependence on user manual, mental effort, error recovery, rigid & inflexible, controllable, unexpected behavior, cumbersome, understandable, ease of remembering, provides guidance) were again clustered into three sub-categories: physical effort, mental effort, and how easy the system was to learn. This framework was the start to what future researchers tested with healthcare technologies. In the end, Davis was able to systematically prove that end-user beliefs and perceptions did in fact have a direct influence on behavior.[97] In essence, the TAM suggests that two specific beliefs, perceived ease of use and perceived usefulness, determine one's behavioral intention to use technology.[83] The TAM was a valid motivational model for user acceptance and a solid base from which to guide future applications and end-user investigations.[97(p232)]

The TAM represents opportunities to quantify pre- and post-use behavioral intentions. Davis' original pre- and post-test perceived usefulness and perceived ease of use questionnaires are listed in Appendix A.[97(pp84-85)] Each construct was tested with 14 Likert scale items and measured on a seven-point scale (1 strongly agree, 7 strongly disagree). Examples of Davis' original validated scales relating to *perceived usefulness* are 1) my job would be difficult to perform without electronic mail, 2) using electronic mail gives me greater control over my work, 3) using electronic mail improves my job performance, and 4) the electronic mail system addresses my job-related needs. Examples of original validated items relating to *perceived ease of use* are 1) I often become confused when I use the electronic mail system, 2) I make errors frequently when using electronic mail, 3) interacting with the electronic mail system was often frustrating, and 4) I need to consult the user manual often when using electronic mail.[97] Through subsequent investigations, Davis' scales for both constructs were refined to 10 items and then to a more reliable ($r = 0.97$) six-item questionnaire.[113]

Davis' work did not end after completion of his doctoral dissertation. Venkatesh and Davis concluded that each of the two scales should be administered separately because mixing items from the two constructs, perceived usefulness and perceived ease of use, confused respondents.[113] Although Davis' work was focused on employment settings, his two principle constructs (perceived ease of use and perceived usefulness) continue to be integral to contemporary research on the attitudes and beliefs of older adults and providers towards healthcare technologies.[34,54,115,116] Despite some weakness with the TAM and some criticism for Davis' research,[113] the literature supports conclusions that the TAM is a reliable and valid motivational model for potential users of technologies,[34,97] and can be applied to prospective older adult users of telerehabilitation delivery systems.[54,115]

While Davis's TAM has its benefits, the TAM has also been criticized for weaknesses.[113,117] Despite the TAM being the most internationally cited technology acceptance model, Chutter states that research on the TAM's conceptual model lacks sufficient rigor and relevance. Chutter cites a publication from Lee et al that claims that the TAM has attracted more easy and quick research such that less attention has been given to the real problem of technology acceptance.[113] Furthermore, Venkatesh and Davis collaboratively identified some limitations in explaining the reasons a person would perceive a given system useful, and therefore, proposed some additional variables such as experience, voluntariness, subjective norm, image, job relevance, output quality, and result demonstrability. Their study integrated end-user perceptions pre-implementation, one-month post-implementation, and three months post-implementation. Their revised model became known as the TAM2.[113] In an attempt to further enhance the TAM, computer self-efficacy, perceptions of external control, computer anxiety, and computer playfulness were proposed as anchors to Davis' perceived ease of use construct.[83]

As an enhancement of Davis' original and subsequent revisions of the TAM, Venkatesh et al set forth to "unify" the major theories of technology acceptance.[118] In what was named the Unified Theory of Acceptance and Use of Technology (UTAUT) model, Venkatesh et al reviewed and consolidated major constructs from eight previous models that attempted to explain and predict system usage and/or behavior. Development and validation of the UTAUT was performed from review of the theory of reasoned action (TRA), TAM, motivational model, theory of planned behavior, the combined theory of planned behavior/TAM, model of personal computer use, diffusion of innovations theory, and social cognitive theory.[118] Development of the UTAUT (n=645) appears to have been a collaborative initiative as Davis was a co-author of *User Acceptance of Information Technology: Toward a Unified View* published in 2003.[118] Referencing data from these eight acceptance theories and testing them over six months across four organizations, Venkatesh et al created and empirically validated the UTAUT. This new model has strong statistical support for three direct intention of use constructs (performance expectancy, effort expectancy, social influence) and two direct determinants of use behavior (intention and facilitating conditions). Significant moderating influences of experience, voluntariness, gender, and age have been confirmed as integral features of the UTAUT. In its conclusion, the UTAUT was able to account for 70% of the variance in usage intention of end-users. This was a substantial improvement over the 17-53% prediction of MIS use explained by the eight other models tested by Venkatesh et al.[118] Both the TAM and UTAUT have been criticized for overlooking specific biophysical (cognitive and physical decline) and psychological (social isolation, fear of illness) factors related to aging which may predict or explain behavior related to use of healthcare technologies.[119] Despite the limitations of the TAM, Davis' Technology Acceptance Model was the most widely applied model of end user acceptance and usage.[83,113]

The literature suggests that older adults may not be receptive to telerehabilitation services. In addition to drivers and barriers cited by the AHRQ, computer literacy,[94,107] privacy,[54] and generational preferences[54,72,102] are commonly cited as potential barriers and biases against the adoption of computers or "smart" devices by older adults. The female gender has been shown to have a greater affinity towards telecommunications technologies;[73] however, most other research simply speaks only theoretically about traditional gender roles and age in predicting attitudes and intention to use MIS.[118]

In contrast to publications citing limited interest in and use of computers among older adults, several publications indicate otherwise. Demiris et al piloted a focus group of older adults to explore “smart home” technologies. Smart home technologies were operationally defined as advanced technologies aimed at prevention and detection of falls, emergency help, and monitoring of physiologic parameters. Demiris et al reported that the 15-member focus group had an overall positive attitude towards devices and sensors in their homes but expressed concerns about the user-friendliness of devices and training needed for use of installed devices.[99] This was consistent with Davis’ perceived ease of use construct and effort and performance expectancy constructs of the UTAUT.[97,118] In a related study, Coughlin et al performed a market investigation into the perceptions of smart home technologies in older adults. This investigation was more robust in that researchers sampled seniors from 10 states in the northeast United States. They concluded that participants were in support of technologic advances that maintain health and wellness.[120] Similar to the study by Demiris et al, older adults expressed concerns with the usability of these smart home applications but also brought forth issues of reliability, trust, privacy, stigma, accessibility, and affordability.[99,120] Although not explicitly stated, findings reported by Coughlin et al are consistent with Davis’ perceived ease of use and perceived usefulness constructs and the UTAUT’s facilitating conditions determinant of behavior.[97,118] Cimperman et al also described and tested similar “context-specific” factors such as computer anxiety, perceived security, self-efficacy, and physician’s opinion.[54]

While appearing to have face validity, neither self-efficacy nor anxiety are included in the UTAUT because both have been found to be indirect determinants of intention fully mediated by perceived ease of use. Physician opinion, however, was a social influence which was concluded to be a valid measure of intention to use for inclusion in the UTAUT.[118] While potential frustrations and usability concerns have also been brought forth by a cohort of 30 Midwest older adults, Heinz et al concluded that older adults are willing and eager to adopt new technologies when usefulness and usability outweigh feelings of inadequacy.[98] Consistent with Coughlin et al, Heinz et al reported that older adults are enthusiastic about new forms of technology that could assist them to maintain their independence and quality of life.[98,120] This conclusion speaks to the need to appraise Davis' perceived usefulness construct prior to introducing older adults to health related technologies.[97] Although these publications dispute the many biases associated with older adults and their acceptance of health-related technologies, "smart home" technology publications such as the one from Coughlin et al may have biased methodologies and conclusions based upon author acknowledgements of private grant funding.

Three recent publications specifically investigated the attitudes and beliefs of older adults towards a telehealth delivery system. These findings were instrumental to supporting hypothesis 1 of this investigation (*There is no difference of attitudes and beliefs towards technologically delivered healthcare between older adults exposed to this investigation's real-time telerehabilitation application and those in the control group*). All three investigations integrated behavior intent constructs from the Technology Acceptance Model (TAM). Two publications cite quantitative statistical methods and one investigation used mixed-methods focus group interviews to drive conclusions.

Wade et al investigated the usefulness and ease-of-use of asynchronous telehealth services in a frail elderly population. These Australia-based authors created a Likert-style scale based upon the TAM. The eight-item scale demonstrated excellent internal consistency (0.92-0.95) and was administered to both patients and caregivers in a pre-/post-test design. While the exact technological platform was not described by the authors, this investigation primarily measured biometric data via store-and-forward methods. The author's primary research question centers around the relationship between the degree to which equipment was free from effort (perceived usefulness) and assisted a client (perceived ease of use), and long-term patient compliance with in-home telehealth. Wade was able to demonstrate that perceived ease of use at pre-test and with usage periods had a positive statistically significant relationship with future compliance ($p = 0.02$).[115] The Likert scale developed by Wade et al serves as a guide to test null hypothesis 1 (H_0). Each Likert scale item was reported on a five-point scale (1 strongly agree, 5 strongly disagree). The authors combined both TAM constructs into one questionnaire that was administered to the care recipient (n=42) and caregiver (n=19) when available.

Wade's Likert scale items relating to perceived usefulness were 1) using the telehealth equipment will improve access to regular testing of my health condition, 2) using the telehealth equipment will make it easier to do regular testing, 3) using telehealth equipment will save time in having regular testing, and 4) I will find the telehealth equipment useful in my regular testing. Wade's Likert scales relating to perceived ease of use were 1) learning to operate the telehealth equipment will be easy for me, 2) my interaction with the telehealth equipment will be clear and understandable, 3) it will be easy for me to become skillful at using the telehealth equipment, and 4) I will find the telehealth equipment easy to use. Wade et al reported no statistical difference in TAM responses between participants with and without caregivers or between caregivers and care recipients. There was, however, significant improvement ($p<.05$) between pre-training and actual usage means for the telehealth-led transitional care program. The combination of pre-usage, perceived usefulness, and ease of use accounted for a non-significant 17% of the variance in the usage compliance rate ($R^2 = 0.17$). The "perceived ease of use" of the telehealth equipment increased significantly from pre-telehealth training and usage to post-transitional care program ($p = 0.001$). There was no change in the "perceived usefulness" of the equipment. "Perceived ease of use," at pre-training and usage, had a moderate positive relationship with future compliance ($r = 0.40$; $p = 0.02$). Telehealth acceptance constructs "ease of use" and "usefulness," at pre-telehealth training and usage, were nearly significant as a predictor of future usage compliance ($p = 0.06$).[115]

The second quantitative study to specifically look at the attitudes and beliefs of older adults towards a telehealth delivery system was a Taiwan-based study by Jen et al. These investigators integrated the TAM and the Theory of Planned Behavior (TPB) to predict the likelihood that families would adopt mobile healthcare services (MHS).[102] The underlying theory behind this prediction model was the TPB's focus on normative and control factors. As previously outlined, the TAM, in part, focuses on system design and was useful as a guide to design efforts. The research model from Jen et al explained 64% of families' intent to adopt MHS for their elderly loved ones. Least squares regression analysis found perceived usefulness ($R^2 = 0.338$) and attitude ($R^2 = 0.581$) to be the primary factors in predicting behavior intention ($R^2 = 0.641$). Although the authors specifically state that their MHS adoption model only generalizes to social structures based on Confucian values, results of this study affirm that *attitude* was the most important factor in determining the behavioral intention to adopt MHS.[102]

In the studies by Wade et al and Jen et al investigating the acceptance of telehealth by older adults and/or their families, the UTAUT model was not used.

In a 2013 publication by Cimperman et al, seven predictors that play a role in the perceptions of older adults towards home telemedicine services were identified.[54] This qualitative and quantitative investigation utilized 12 focus groups (n=87) consisting of community-dwelling older adults from both urban and rural parts of Slovenia. Cimperman et al combined constructs from Davis' TAM and Venkatesh's UTAUT. As previously outlined, the UTAUT successfully analyzed acceptance of computer technologies among healthy individuals, general internet users, and healthcare professionals.[111] Evidence has shown that the UTAUT demonstrates a substantial improvement over other technology acceptance models such as the TAM, explaining 69% of the variance in behavior intention, which as Davis hypothesized,[97] was the most common indicator of acceptance.[111]

Using the root constructs of perceived usefulness and perceived ease of use of the TAM and root constructs perceived usefulness, effort expectancy, social influence, and facilitating conditions of the UTAUT, Cimperman et al assessed the usefulness of home telemedicine system functionalities. Each of 12 focus groups were conducted in community centers and each consisted of 6-12 retired participants (n=87; age 55-75; 65 women, 22 men). Participants were first given an overview of home telehealth services to introduce concepts while attempting not to influence their attitudes. All participants were also asked to complete a seven-point Likert scale questionnaire prior to the focused group sessions.

Cimperman's Likert scales covered a broad scope of potential telemedicine applications from E-prescription as the highest rated function (mean 6.01) to E-triage after hospital discharge as the lowest rated function (mean 4.68). Other home telemedicine system functionality scales were online referrals for examination and laboratory testing, communication with personal doctors, update about recent changes or received medical reports, overview of waiting lists, access to information such as vaccination records when traveling, access to general health information such as published articles, e-pharmacy, communication with other users who have similar problems, access to personal health record, access to second medical opinion, and home monitoring of vital signs using the computer. Authors reported that perceived usefulness, effort expectancy, and facilitating conditions were all consistently mentioned during focused group interviews. Costs were mentioned as the most important facilitating condition with technical support being secondary. Other qualitative themes reported were data security, physician approval, and a preference towards tablets over standard personal computers. Self-efficacy and computer anxiety were minimally reported themes of the interviews.

Although one of the focuses of this investigation is on the attitudes and beliefs of older adults towards telerehabilitation delivery systems, Cimperman et al made practical recommendations to gain end-user acceptance. For example, using visual reminders to reassure care recipients that the computer platform was secure and trustworthy, and providing a thorough orientation on the functions of a system prior to administering the questionnaire may give providers insight into end-user preferences.[54] It was notable that none of the three articles that investigated the attitudes and beliefs of older adults using standardized acceptance models such as the TAM focused on synchronous connections of providers with end-users for health screening purposes. Results from this dissertation will be a unique contribution to the literature base because it is the first of its kind to examine the perceived usefulness of a telerehabilitation delivery system for the purpose of examining fall risk in older adults. This investigation also addresses conclusions from Peek et al who stated that quantitative post-implementation data is "scarce" in the literature.[119]

Falls are often sentinel events that mark the beginning of functional decline in older adults.[99] Falls are associated with poorer overall functioning and early admission to long-term care facilities.[79] Use of technologies aimed at preventing elderly falls is receiving greater consideration by providers and researchers. This concept was central to hypotheses 2 and 3 of this investigation. Hawley-Hague et al published a systematic review aimed specifically at the perception of older adults towards fall prevention, detection, or monitoring technologies.[121] This publication identified 76 potentially relevant papers but included only 21 publications in their review. Hawley-Hague et al suggest that intrinsic factors related to attitudes around control, independence, perceived need, and requirements for safety are important prerequisites to motivate an older adult to use and continue use of technologies. They conclude that attitudes and beliefs surrounding fall technologies are influenced by positive messages and ensuring that technology platforms are simple, reliable, effective, and tailored to meet individual needs.[121] This message is similar to Davis' perceived ease of use construct.

A 2014 systematic review by Peek et al focused specifically on factors influencing acceptance of technology for aging in place.[119] This publication examined 2,841 articles on the topic but found that only 16 met their inclusion criteria. Peek et al concluded that technology acceptance was influenced by 27 factors divided into 6 themes: 1) concerns with technology (costs, privacy, usability); 2) expected benefits of technology (increased safety, perceived usefulness); 3) need for technology (perceived need and subjective health status); 4) alternatives to technology (help from family or spouse); 5) social influence (influence of friends, family, professional caregivers); and 6) characteristics of older adults (desire to age in place).[119] Many of these factors are congruent with validated findings in the UTAUT model.[118] Interestingly, Peek et al notes that 14 of the 16 included articles lacked the use of an existing technology acceptance framework or model. Furthermore and central to the need for testing of research question 1 of this investigation, Peek et al concluded that quantitative post-implementation data was “scarce” in the literature.[119] Despite using a technology acceptance model framework, Cimperman et al also echoed the statement by Peek et al in stating that that their qualitative research should be considered more exploratory rather than confirmatory, and that further research should take a more quantitative approach to analyze the categorical acceptance constructs on community-dwelling adults.[54]

A comprehensive review of the literature confirms that the Technology Acceptance Model (TAM) is the most recognized and cited model for determining end-user behavioral intentions. It was essential for anyone interested in user acceptance of technology to have an understanding of the TAM. While the TAM and the more contemporary acceptance model UTAUT both include the predictive construct of perceived ease of system use, this dissertation focused on the perceived usefulness construct. The purpose of research question 1 was not to test a specific telerehab delivery system or software platform, but rather to measure the pre- and post-exposure attitudes of older adults toward a fall screening activity. This was supported by Venkatesh’s work in that the focus was on measuring how perceptions form and change over time once the end-user has participated in a synchronous telerehab session.[83] According to Davis, perceived usefulness was more directly correlated ($r = 0.65$) with attitude towards use than perceived ease of use ($r = 0.12$) (pg. 109-110). In fact, Davis’s original work found that the influence of ease of use on attitude was insignificant.[97] More specifically, regression analysis concluded that usefulness exerted more than twice as much direct influence on use than did attitude, and usefulness exerted 3 times as much influence on attitude as did ease of use.[97] Despite Pramuka and Roosmalen's contradictory emphasis on usability and ease of use for telerehabilitation end-users,[43] these findings from the TAM support the decision to use a general teleconferencing system as the medium for synchronous appraisal of fall screening tools while also appraising perceived usefulness feedback from participants.

To control for confounding variables that could potentially bias an end-user, a laptop computer with a standard, non-touch screen Windows display was used in this investigation. This methodological decision was supported by Cimperman et al who reported that a tablet was viewed more favorably by focus groups.[54] It has been inconsistently reported that females are more likely to use computers than age-matched males,[122] but most findings speak generally about the impact of traditional gender roles.[118] While this is not a proposed exclusion criteria, participants with prior experience using or observing synchronous or asynchronous telehealth systems may also have an impact on this investigation's outcomes because of their perceived ease of use that develops from familiarity and prior training.

Conclusions from Cimperman et al parallel the UTAUT and serve as the basis for the development of a tool which will quantify baseline and potential changes in attitudes and beliefs towards telerehabilitation services in an older adult population. Despite being a European-based study, results from Cimperman et al are more directly generalizable to this investigation than investigations previously outlined that used the TAM as the foundation of their investigations. Using Cimperman's four major acceptance predictor categories, perceived usefulness, effort expectancy, social influence, and facilitating conditions,[54] this investigation developed Likert scales items for each construct in the survey instrument which was tested for content and face validity by a panel of experts. Four Likert scale questions from Wade et al that pertain to the perceived usefulness construct also served as an evidenced-based guide to this investigation. Phrasing is consistent with items from Davis' validated TAM model. Methodology for the development of this Likert scale questionnaire is described in Chapter 3.

Literature Related to Elderly Falls

The Clinical Guidance Statement (CGS) from the APTA's Academy of Geriatric Physical Therapy states that physical therapists should play a role in questioning older adults about the presence, frequency, and circumstances surrounding falls and in the screening for balance impairments and gait abnormalities.[35] There are a battery of fall risk screening and outcome measures available for healthcare providers to employ. However, few screening and outcome tools are tested in more than one setting and among all diagnostic categories or across varying levels of risk.[35,78] No single fall risk screening tool is recommended for implementation in all settings of healthcare or for all subpopulations with each care delivery setting,[78] and there is limited research in support of specific guiding questions and standardized assessment tools to guide effective and efficient screens.[35] In summary, there lacks one uniform gold standard or criterion measure clearly identified by the literature for the face-to-face screening of fall risk among community dwelling older adults. In the absence of an undisputed gold standard, Portney and Watkins recommend use of a "reference standard" when attempting to establish concurrent validity.[37] The Balance Evaluation Systems Tests (BESTests) are the most robust, validated tools available and will serve as the reference standard to evaluate concurrent validity (research question 2) in the absence of universal agreement on a fall screening gold standard. This investigation has attempted to provide reference standards for the integration of fall risk screening into telerehabilitation delivery systems. Chapter 4 will provide reliability and validity data that will compare outcomes from face-to-face and telerehab raters.

Selecting the most appropriate screening or outcome measurement tool(s) is impeded by the lack of consistency in methods of reporting and interpreting comparative psychometric properties of fall risk assessment tools. Prior to analyzing each tool for their psychometric properties and for their appropriateness to a telehealth application, one must first distinguish a screening tool from an outcome measure. A valid *screening* tool should be able to stratify risk and be sensitive enough to confirm the presence/absence of a condition or risk status. In other words, a valid and reliable screening tool provides clinicians, who start with a heterogeneous population, the ability to narrow to a more homogeneous population based upon use of a screening application(s). A valid *outcome* measurement tool not only confirms the presence of a condition or risk, but should be sensitive to change over time.[123] Some tools are interchangeable as screens and outcome measures because their statistical properties confirm responsiveness over repeated measures, thus, demonstrating the ability to accurately re-delineate risk and demonstrate outcomes that result from physical therapy interventions.

Screening tools will be considered for their reliability and validity as well as projected safety with telerehab implementation. Criteria for establishing cut-off points for high predictive likelihood varies in the literature, but sensitivity should be at least 70-80% and specificity should be at least 70-75% according to Perell et al and Oliver et al.[78] Statistical measures such as minimal clinical important difference (MCID), minimal detectable change (MDC), and floor/ceiling effects are not relevant to selection of this study’s fall screening tools. As previously outlined, the purposes and relevance of psychometric properties which represent screening tools differ from those of outcome measurement tools.

In a 2007 systematic review, Scott et al examined 38 fall risk quantification tools comprised of either a multifactorial assessment tool (MAT) or functional mobility assessment

(FMA) across four settings. Of the 38 available tools cited in this publication, only 11 were multi-factorial in nature with five of the 11 (45%) investigated in the community. However, 23 of the 27 (85%) remaining functional tools were tested among community-dwelling elders. Some tools, such as the Functional Reach and Berg Balance Tests, have been investigated in three different settings. A MAT was operationally defined as an assessment which covers a wide range of fall risk factors whereas a FMA covers the physiologic and functional domains of postural stability including strength, balance, gait, and reaction times. Some tools are designed purely as mechanisms to discriminate high-risk falls from other populations, while other tools allow for customizing interventions based on assessment findings. Specific to the community setting and this investigation, Scott et al identified 23 distinct tools across 14 studies, but only seven studies reported sensitivity and specificity data. This systematic review reflects a wide range of sensitivity values (14-94%) and specificity values (38-100%).[78] These reports are congruent with the APTA's CGS conclusions that there was a need for evidenced-based guidelines to describe predictive performance and feasibility of fall risk screening tools.[35] All studies reported by Scott et al had interrater reliability >80% with the exception of the Timed Up and Go (TUG). Brauer et al reported a 56% interrater reliability,[78] although this was refuted by systematic review data reported in the Rehabilitation Measures Database which reports excellent reliability with a mean rater difference of 0.04 seconds (n=31) reported by Siggeirsdottir et al.[124,125]

The systematic review published by Scott et al found the following community-based screening tools to be prospectively validated in the literature: the Balance Self Efficacy Scale, Berg Balance Test, Clinical Test Sensory Interaction for Balance (CTSIB), Dynamic Gait Index, Elderly Fall Screening, Fall Risk Screen Test, 5 Minute Walk Test, Five Step Test, Floor Transfer, Functional Reach Test, Geriatric Postural Screening Survey (GPSS), Home

Assessment Profile, Lateral Reach, Maximum Step Length, POMA-b, Postural Stability, Quantitative Gait, Rapid Step, Step Up Test, Tandem Stance, TUG, Tinetti Balance, and 100% Limit of Stability tests.[78] When selecting a fall screening tool, whether it be for a face-to-face or a telerehab assessment, the clinician should consider their client(s). If the purpose is to screen a high-risk population, the tool(s) needed should be efficient and easy to apply yet have good sensitivity and specificity. If the purpose is to reduce fall risk, the tool(s) should be able to reliably assess and identify modifiable risk factors from which interventions can be focused.[78] The latter is consistent with the more comprehensive approach adopted by the Centers for Disease Control and Prevention (CDC) when creating the Stopping Elderly Accidents, Deaths & Injuries toolkit or the STEADI.[20]

Using the definitions from Scott et al, the STEADI is a hybrid tool combining components of a FMA and a MAT. For this dissertation's purposes, the battery of screening tools for community-dwelling older adults has been narrowed down to 10 eligible tools commonly found in the geriatric physical therapy literature, American Physical Therapy Association's Combined Section Meeting Programing, and the general medical literature appraised through the PUBMED database: The Balance Evaluation System's Test (BESTest), Berg Balance Scale, Clinical Test of Sensory Interaction and Balance (CTSIB), Dynamic Gait Index, Functional Reach Test, Gait Speed measurement, Tinetti POMA, Short Physical Performance Battery (SPPB), 30-second Sit to Stand, the TUG, and the STEADI. All of these fall screening tools are FMA with the exception of the STEADI which was a FMA and MAT. Each tool was appraised for its psychometric properties with community-dwelling older adults, as well as its potential feasibility and safe implementation using a telerehabilitation delivery system.

The purpose of this study was to determine the feasibility of performing reliable and valid fall screening via a telerehabilitation delivery system. Because telerehab applications extend traditional telehealth beyond a patient/client interview or professional consultative session, researchers and clinicians have an ethical duty to minimize the safety risks to participants. Not all fall screening tools are appropriate for use when a clinician is conducting the screening exam from a remote location. Despite being extremely comprehensive and sensitive with detecting fallers, the BESTest and its abbreviated versions exemplify screening tools that are not safe to be implemented from a distance. Furthermore, some fall screening tools require equipment that may not consistently be available at the end-user's location. Without the presence of a licensed physical therapist closely guarding for falls and monitoring for adverse symptoms, tasks that are associated with some fall screening tools predispose a participant to falls or osteoporotic fractures; therefore, it is important for facilitators of telerehab to realize that not all face-to-face screening tools or interventions are transferable to remote applications. This theme is further elaborated on within subsequent paragraphs.

Balance Evaluation System's Test (BESTest)

The BESTest is one of the most contemporarily developed and studied tool in the recent literature. The BESTest has excellent psychometric properties and has had several recent modifications to make its time to administer more efficient for clinical use.[126] The original BESTest was modified to "mini"- and "brief"-BESTest versions. The original and mini- versions both require more time to administer than the more recently amended "brief" iteration of the BESTest. The Mini-BEST is a 14-item, 28 point scale as opposed to the Brief-BEST's six-item, 18-point scale.[127] Cut-off scores in the literature are inconsistently reported or not yet published from the creator of the BESTest, the Oregon Health and Science University. Leddy et al report a fall risk cut-off score of 23/32 on the Mini-BEST (sensitivity = 0.96, specificity = 0.47),[128] but King and Horak published a confirmation in 2013 stating that sources such as Leddy et al were incorrectly scoring item numbers 3 and 6, therefore, decreasing the total possible score from 32 to 28.[129] Despite the lack of universally agreed upon cut-off scores for determining fall risk, the clinical utility was strong and O'Hoski et al published normative reference data representing age cohorts per decade for the BESTest, Mini-BEST, and Brief-BEST.[130]

The Brief-BEST was recently developed as another alternative version of the BESTest.[127] Both the mini- and brief- versions are valid and reliable screening and outcome measurement tools. Rater agreement among items from the Mini-BEST with the highest item-selection correlation comprise the more time efficient ("brief") version.[127] The Brief-BEST consists of items for hip abductor strength, functional reach, single-legged stance, lateral push-and-release, standing on foam with eyes closed, and the TUG. In essence, this version has components of several other standardized balance, mobility, and strength tests.

According to Padgett et al, the Brief- and Mini-BEST both have a 72% accuracy of identifying people with or without a neurological diagnosis. Although the authors do not operationally define "neurologic diagnosis," community-dwelling elders who have fallen or have an elevated risk of falling are considered within this classification.[131] The Brief-BEST would be the most compatible of the three BESTest versions for this study because of its diminished number of items requiring under ten minutes to complete, high sensitivity for predicting falls (100%), specificity for predicting non-fallers (100%), and interclass correlations reliability coefficients (ICC) ($\alpha = 0.98$).[127] However, the Brief-BEST was only validated for identifying fallers diagnosed with Parkinson's disease and this tool lacks a clear cut-off point for fall risk.[132] The Mini-BEST has age-related normative scores for ages 50-89 established in a Canadian population and is somewhat more robust than its briefer version.[130] When both sensitivity and specificity are maximized, a cutoff score of 20/32 (63%) was identified for the Mini-BEST (sensitivity = 0.88, specificity = 0.78) and 69% was identified for the BESTest (sensitivity = 0.84, specificity= 0.76). When maximizing sensitivity and LR−, a cutoff score of 23/32 (72%) was identified for the Mini-BESTest (sensitivity = 0.96, specificity = 0.47) and 84% for the BESTest (sensitivity = 1.00, specificity = 0.39).[128] The problem using cut-off score data from Leddy et al was that they miscalculated the total score of the Mini-BEST. The total score was 28 rather than the 32 points from which they based their validity calculations.[129] The normative age reference data, however, established by O'Hoski et al can serve as appropriate cut-off scoring as this publication appropriately scored the Mini-BEST out of 28 possible points. Despite its excellent discriminative validity,[124,130] this fall screening tool is not appropriate for telerehab applications because of safety concerns for participants with administration of the Romberg on foam surface and the lateral push and release items from a remote rater. Furthermore, consistency of forced perturbations would likely be inconsistent with untrained examiners such as a family member serving as a safety assistant during administration of a remote screen. Given these client safety concerns as they relate to this study's target population, the BESTests will not be selected for inclusion in telerehabilitation delivery system applications. However, the robust nature of the BESTests and their excellent validity and reliability metrics lend well to its use as a reference standard comparison for other FMA or MAT screening tools selected for remote implementation.

Berg Balance Scale

Similar to the BESTest, the Berg Balance Scale (BBS) has two versions: the original BBS and the short form BBS (SFBBS). The BBS was a 14-item fall risk prediction tool with normative data for community-dwelling older adults, as well as established fall-risk cut-off scores in the general elderly, individuals with spinal cord injury, and individuals who have suffered a stroke. The SFBBS was a seven-item scale validated only for use in patients who have had a stroke.[124,133,134] Therefore, the SFBBS was not be considered for use in this telehealth study despite its more efficient ten-minute time to administer as compared to the original BBS which requires 15-20 minutes to complete.[133] The BBS has long been considered the "gold standard" of fall screening tools. Berg et al established a cut-off score of 45 for elderly who may be at a greater risk of fall and a score of 56 indicating that the elderly client demonstrated functional balance.[134] Shumway-Cook et al build upon Berg's foundational psychometric data reporting excellent sensitivity (91%) and good specificity (82%), and added an additional cut-off score of 40 indicative of almost a 100% fall risk.[135] The BBS has excellent test-retest reliability (ICC α = 0.91) and intra-rater reliability (ICC α = 0.97) among community dwelling older adults, but the majority of inter-rater reliability, sensitivity, and specificity properties that support the use of the BBS relate to populations outside of the context of this study.[124,136-138] Furthermore, two of the 14-items on the BBS pose a potential safety risk to participants given the remote location of the clinician. The BBS requires the participant to stand with their eyes closed. The second item posing safety concerns is requesting that the client pick up an object from the floor from a standing position. Participation in this activity places research participants at a heightened risk of spinal compression fractures. Because inclusion criteria that screens for existing compression fractures and T/Z scores would be cost- and time-prohibitive, the investigator and an osteoporosis rehabilitation consultant both feel that the risks of asking a potentially osteoporotic participant to pick something off of the floor does not outweigh the potential benefits from their participation in this task.[139] Because the results of this study may potentially influence the care management of elderly who reside in rural territories as a means of accessing preventive healthcare services, it was important to consider that prospective telerehab care recipients may not have received prior bone density screening and/or adhere to pharmacotherapy regimens.[41,140] Given these client safety and psychometric property concerns as they relate to this study's target population, the BBS was not selected for inclusion in this telehealth screening study.

Clinical Test of Sensory Interaction and Balance (CTSIB)

The CTSIB has six components or conditions which progressively challenge an individual's visual, somatosensory, and vestibular systems. This assists clinicians in evaluating the influence that each sensory system potentially has on instability, postural control, and fall risk.[141] Implementation of the CTSIB requires participants to maintain their balance for up to 30 seconds on each of six conditions: firm surface with eyes open, firm surface with eyes closed, firm surface with visual conflict, unstable surface with eyes open, unstable surface with eyes closed, and unstable surface with visual conflict.[141] The CTSIB, also referred to as the "Foam and Dome" test, is a valid fall risk screening test. A modified, briefer version (mCTSIB) of the CTSIB creates an abbreviated method of analyzing functional balance and postural sway by eliminating the visual conflict components. The four conditions of the mCTSIB are eyes open firm surface, eyes closed firm surface, eyes open unstable surface (foam), eyes closed unstable surface (foam). The mCTSIB can be performed with or without computerized analysis, thus making it more applicable to residential or community gathering environments such as a senior or religious center. Eyes open while standing on foam was associated with falling.[142] According to a 1992 study by Anacker and Di Fabio, the CTSIB has excellent test-retest reliability (r = 0.75)[143] but their 1996 published work notes the CTSIB having limited predictive validity (75% fallers, 60% non-fallers) and very low sensitivity (44%) among community-dwelling older adults.[141,143] The mCTSIB can be a cost-effective and efficiently administered screening tool; however, it has limited published utility with accurately screening for fall risk. As was the case with the Mini-BESTest and BBS, safety concerns arise for participants with the administration of the Romberg on a foam surface. Therefore, the CTSIB was not selected for inclusion in this telehealth screening study.

Dynamic Gait Index

The Dynamic Gait Index (DGI) is an eight item fall prediction tool that has been tested in a variety of populations and only requires ten minutes or less to administer. Similar to the BBS, the DGI has well-established cut-off scores and normative data for community-dwelling older adults.[124] Test-retest reliability has not been calculated in the community-dwelling elderly, but standard error of measurement (SEM) was acceptable (1.04) and intrarater reliability (ICC α = 0.89-0.90) as well as interrater reliability (ICC α = 0.82-.092) was good to excellent in this population.[124,138] Because the DGI has several scoring items that involve head turns and change in speed/direction, the DGI has demonstrated excellent validity metrics when implemented in a population with varying degrees of vestibular dysfunction.[144,145] However, sensitivity and specificity has not been calculated for the DGI in a general community-dwelling elderly population.[124] Because predictive validity statistics are not available for the target population of this proposal and because of observation analysis concerns when interfacing the potential challenges of reliable video transmission with scoring this tool, the DGI was not selected for inclusion in this telehealth screening study.[67,124,146]

Functional Reach Test (FRT)

The standing Functional Reach Test (FRT) requires approximately five minutes to administer and requires a yardstick and colored tape. The forward FRT has been tested in community-dwelling elders, and according to Weiner et al, has a cut-off point of less than seven inches as indicative of requiring assistance to leave home, being more restricted with ADL's, and having limited in mobility skills.[147] Thomas et al calculated a 75% sensitivity and 67% specificity in distinguishing fallers from non-fallers among frail elder patients.[148,149] Despite the ease of use and portability of the FRT, most published findings fall below the recommended 70% sensitivity and specificity guidelines from Perell et al and Oliver et al.[78] In contrast with other commonly used and portable screening tests, Thomas et al found the POMA and single leg stance test to be more predictive of prior falls than the FRT.[149] Despite this, the FRT has excellent test-retest reliability (ICC $\alpha = 0.89 - 0.92$) when applied to community-dwelling elders, and according to Weiner et al, has good correlation with gait speed ($r = 0.71$), tandem walk ($r = 0.67$), mobility skills ($r = 0.64$), and one-legged stance ($r = 0.64$).[147] Its ability to be applied to a telerehab delivery system, however, was brought into question because of the limited availability of yard sticks at the point of origin (home or community center) and the ability to accurately measure functional reach without specialized engineering software. As with other tests and measures, the physical therapist would need to plan in advance of fall screening sessions. Clinicians could mail a yard stick or wall-mounted poster to prospective care recipients in advance of screening appointments. Alternatively, clinicians could request that a yard stick be provided by the individual or community center, in addition to a request for a suitable person to guard participants during the fall screen tests. Because of its portability, moderate to good correlation with other highly valid screening tools such as gait speed, and because of its recognition in the healthcare literature, the FRT was selected for inclusion in this telerehab feasibility investigation.

Gait Speed Measurement

Gait speed is a functional "vital sign" indicative of underlying physiological processes and predictive of future health events.[150-152] Vital signs are summary indicators of multiple physiologic system inputs that reflect the overall health of an organism. Additionally, vital signs are characteristic of normal and abnormal ranges and assist physicians with differential diagnoses.[35] Fritz and Lusardi, in a white paper titled *Walking Speed: the Sixth Vital Sign*, promote gait speed as fitting these descriptions.[151] Like blood pressure when examining cardiovascular health, gait speed cannot stand alone as the only predictor or evaluative tool for function.[151,152] However, gait speed is an efficient, standardized screening tool and outcome measure that can be easily reproduced in most clinical settings.

The literature confirms that gait speed data is sensitive, specific, and responsive to change over time. Gait speed, otherwise referred to as walking speed or gait velocity, has excellent utility, reliability, and validity, and is correlated with functional ability, balance, and more serious falling patterns, activities confidence, cognitive status and executive functioning, hospitalization, and mortality.[150-152] Gait speed is normative referenced.[35] In well-functioning older adults, usual gait speed of less than 1.0m/s (2.2mph) identifies persons at higher risk of health-related adverse outcomes.[151] In contrast, the cut-off point of >1.0m/sec was also predictive of independence with activities of daily living (ADLs), reduced hospitalization risk, and an important threshold for effective community ambulation. In fact, healthcare providers can correlate walking speeds >1.2m/sec with an ability to navigate street cross walks, negotiate many stairs, and engage in light yard work, and should consider a client walking at this threshold extremely fit.[151]

To the contrary, another important cut-off point is 0.6m/sec (1.3mph). Individuals whose gait speed was below this threshold are "severely impaired" and likely dependent with ADLs (bathing, dressing, grooming, continence) and instrumental (I)ADLs (managing medications, finances; meal preparation, shopping). Middleton et al reported that gait speed <1.0 m/sec predicts cognitive decline within five years and clients with gait speeds of <0.8m/sec are two times more likely to have frailty if they are 75 years of age or older.[150] Individuals with gait speed that averages between 0.4–0.8m/sec are considered limited community ambulators, and individuals who walk below 0.4m/sec are characterized as homebound and, therefore, labeled household ambulators.[35,151,152]

These cut-off points are strongly associated with rising incidence of falls. To detect gait speed and subsequent fall risk, the most common methods for measurement are the 4 meter, 10 meter, and 6-minute Walk Tests.[153] Some medical publications reference the Timed Up and Go (TUG) Test as a method to appraise gait speed. Because the TUG involves the tasks of arising from a chair, motor planning with turning and then sitting down, it was *not* the most direct measurement of the walking speed construct. The 6-minute Walk Test can be influenced by endurance, and for this study's purposes, would not be as efficient as the 4-meter Walk Test, for example, in quantifying gait speed.[152] Like the FRT, gait speed can be calculated in five minutes or less and has been tested in a wide variety of populations including community-dwelling older adults.[99] Calculation of gait speed appears to be an efficient, meaningful, and safe screening tool to investigate with a telerehabilitation system, and therefore, the 4-meter Walk Test was selected for inclusion in this investigation.

Performance Oriented Mobility Assessment (POMA)

The Tinetti Performance Oriented Mobility Assessment (POMA) is a 16-item fall risk prediction tool that has two sub-tests within it: the POMA Gait (POMA-G) has seven items and the POMA Balance (POMA-B) has nine items. The entire tool requires 10-15 minutes to administer, but the POMA-G requires less than three minutes.[154] Similar to the BBS and DGI, the POMA has cut-off scores for fall risk and also normative data for older adults aged 65-80. General responsiveness of the POMA is adequate to good, with several studies reflecting sensitivity at 64-68% and specificity at 66-78% among older adults without Parkinson's disease or stroke.[64,155] However, the POMA's sensitivity and specificity are improved when the tool is administered on a frailer population.

Sterke et al reported the sensitivity of the total Tinetti POMA (POMA-T) score at 85% and sensitivity for the POMA-B at 70% in an ambulatory nursing home population.[156] Thomas et al further validated this conclusion reporting sensitivity of the POMA-t at 83%, and specificity markedly improved to 72% when administered on frail elders.[149] The non-neurologically impaired population referenced by Sterke et al and Thomas et al are consistent with prior descriptive data for the homebound or community-dwelling elderly.[149,156] Like many other fall risk assessment tools, the POMA's intra- and inter-rater reliability has been calculated in a wide variety of disorders. Intrarater reliability (ICC $\alpha = 0.84$ Thomas et al) and interrater reliability (ICC $\alpha = 0.692 - 0.96$) are good to excellent among older adults, with the greatest amount of variability reported for the POMA-B score.[154,155] One of the major limitations reported in the literature was a high ceiling effect with the POMA. A ceiling effect has also been reported with the DGI and, to a lesser degree, the BBS.[157] However, because the focus of this investigation was on screening applications and not intervention-focused outcome measures, responsiveness over time was not a significant criterion for tool selection. There are potential safety issues with administering the POMA-B via a telerehab delivery system; however, the seven-item POMA-G can serve as an opportunity for the clinician to both observe and quantify gait. Given the portability, good statistical properties when applied as a screening tool, and ease of use and time efficiency with administering the POMA-G, it was selected for inclusion in this investigation.

Short Physical Performance Battery (SPPB)

The short performance battery is a fall screening tool used to quantify lower extremity function in older adults.[158] As with other fall and mobility screening tools, the SPPB has been studied with multiple patient populations including those suffering from stroke. Stookey et al recently reported a significant correlation between the SPPB and the 6-minute Walk Test (r = 0.76) and peak fitness (r = 0.52) indicating that the SPPB may be reflective of longer duration functional mobility performance.[159] This tool has a 12-point summary scale comprised of balance, gait speed, and sit to stand sub-scales. Most data exists in support of the SPPB as an outcome measurement tool given its known MCID (0.54 - 1.34 points) and standard error of measurement (1.42 points). According to Puthoff, decline in SPPB scores have predictive validity among older females who experienced a heart attack, stroke, or hip fracture over a 3-year period.[160] The literature has little information about the sensitivity and specificity of the SPPB as a fall screening tool among community-dwelling older adults, but it has been found to have good discriminative validity in detecting frailty ($R^2 = 0.33$).[161] This tool was not selected for inclusion in this study due to its similarity with other tools selected. The SPPB is further analyzed below in comparison with the STEADI.

Thirty Second Chair Rise

This test was developed by Jones et al to overcome the floor effects of a repetition-limited five-time sit to stand test. The 30-second Sit to Stand Test (30STS) was a lower extremity strength measure that involves counting the number of repetitions that one can stand without using their upper extremities within 30 seconds. Jones et al initially established mean chair rise repetitions for community-dwelling elders at 13.7 (SD 3.2) for men and 12.7 (SD 3.6) for women.[162] In 2013, Riki and Jones established age related cut-off scores among moderately active older adults; these cut-off scores range from 15-16 repetitions among women and men ages 65-69 to nine repetitions for individuals ages 90-94. The 30STS has strong current validity with leg press performance, and therefore, lower extremity strength ($r = 0.77 - 0.78$). Lower extremity weakness is linked to falls in the elderly.[163] The 30STS was selected by the CDC for inclusion in the STEADI fall screening and risk classification algorithm.[64] The 30STS requires under 5 minutes to administer and can easily and safely be reproduced in all practice settings including telerehabilitation.[162]

Timed Up and Go (TUG)

The final FMA tool to be considered for inclusion in this study was the TUG. The TUG is a commonly used screening test for mobility dysfunction and as a predictor of fall risk in the elderly. It is a simple test requiring under three minutes to administer, but provides the examiner information that is reliable and valid.[124,135,164] Despite the context of this test being different from the BBS, DGI, and POMA, the TUG also has cut-off scores and normative reference data for community-dwelling older adults.[124] This tool has excellent reliability with test-retest (ICC $\alpha = 0.97$), intra-rater reliability (ICC $\alpha = 0.92$), and inter-rater reliability (ICC $\alpha = 0.91$).[124] The TUG has been shown to be useful with not only predicting future falls but also frequent "near-falls" in older adults with hip osteoarthritis.[165] Herman et al concluded that the TUG was the appropriate tool for clinical assessment of functional mobility favoring the TUG over the BBS and the DGI. Herman et al further highlighted the applicability of the TUG to healthy community-dwelling older adults and stated that it was related to executive cognitive function.[164] The Rehabilitation Measures Database summarizes the TUG's concurrent validity with other important measures of function in the non-neurologically compromised older adult population. These correlations, as published by Podsiadlo & Richardson, are as follows: gait speed (r = -0.61), the Barthel Index of ADL's (r = 0.78), and the BBS (r = -0.81).[124] Lin et al determined that the TUG has adequate correlation with the Tinetti POMA (r = -0.55 POMA-B, r = -0.53 POMA-G) and walking speed (r = 0.66). Brooks et al reported adequate correlations between the TUG and FRT (r = -0.36) and good correlation between the TUG and two minute walk test (r = -0.68).[124] Consistent with the need to identify fall risk prior to an injurious fall, the TUG was validated for predicting falls within six months after hip fracture (>24 seconds) and predicting a requirement for ambulation aides and dependency in activities of daily living (≥30 seconds).[135]

Because of its ease of use, clinical utility, and strong psychometric properties identified in the literature, the TUG was selected for integration with this remote fall screening investigation. The TUG does not tier fall risks as low, moderate, and high and there is some ambiguity with a clear dichotomous cut-off score for fall risk among community-dwelling elders. However, the TUG enables the clinician to perform an observational transfer and gait analysis, and gain information on general lower extremity functioning.[164] Like the 30STS, the TUG was selected by the CDC for inclusion in the STEADI fall screening and risk classification algorithm.[20] Although deemed reliable and accurate when applied over a telehealth delivery system, Russell et al did not apply the TUG with general community-dwelling older adults nor did they investigate the TUG's relationship with predicting past or future falls when delivered by a remote clinician.[166]

STEADI Algorithm (Stop Elderly Accidents, Deaths, and Injuries)

The prevention of elderly falls has received growing attention from healthcare policy makers and payer sources.[16,167] The STEADI is a hybrid tool combining both FMA and MAT properties defined by Scott et al. In a 2011 summary of the Clinical Practice Guidelines (CPG) established by the American (AGS) and British Geriatrics Societies (BGS), multi-factorial screening, assessment, and interventions are described as vital preventative initiatives required to reach an important public health objective of reducing elderly fall rates.[79]

Over two million older adults are treated in emergency departments for nonfatal fall injuries each year, one out of five falls causes a serious injury such as head trauma or fracture, and direct medical costs for fall injuries total over $28 billion annually.[36] Because less than half of Medicare beneficiaries who fell in the past year spoke to their healthcare provider about it, the Centers for Disease Control and Prevention (CDC) is encouraging all healthcare providers to make fall prevention part of their clinical practice.[20] In fact, the CDC developed the STEADI toolkit from the American and British Geriatric Societies' Clinical Practice Guidelines[79] as a robust initiative for guiding the screening of fall risks and the subsequent education of older adults, their friends, and their families about falls.[20] The goal of this initiative is care planning and prevention.[20] The Stopping Elderly Accidents, Deaths & Injuries or STEADI toolkit and resources is free to both clinicians and care recipients.[20] Psychometric properties for reliability or validity of the STEADI are unpublished and not discoverable on the CDC website. However, the STEADI was adopted based upon evidenced-based Clinical Practice Guidelines published by the AGS and BGS. This provides the STEADI fall screening framework face validity. Because most falls are multi-factorial in etiology, the STEADI was constructed to address both intrinsic and extrinsic risk factors.[20]

The CDC website (cdc.gov/steadi) is designed to be a resource for both providers and consumers. The STEADI toolkit includes an algorithm for screening and categorization of fall risk (Appendix B).[20] This algorithm for evidence-based[35,65,168] risk screening, assessment, and interventions is transparent and readily accessible on the CDC website for providers and recipients of fall risk screening initiatives.[20] The screening process commences with the consumer or patient completing the "Stay Independent" brochure (Figure 1). This brochure includes a 12-item questionnaire with a cut-off score of 4. Two items are weighted at two points (*I have fallen in the past year; I use or have been advised to use a cane or walker to get around safely*), whereas the remaining ten items are weighted at a maximum of one point each for a total of 14 possible points. The CDC has not published reliability or validity statistics on this questionnaire nor is its relationship with the three-tiered fall risk algorithm. However, this component of the algorithm serves as the multi-factorial risk assessment.

Circle "yes" or "no" for each statement below		Why it Matters
Yes(2) No(0)	I have fallen in the past year.	People who have fallen once are likely to fall again.
Yes(2) No(0)	I use or have been advised to use a cane or walker to get around safely.	People who have been advised to use a cane or walker may already be more likely to fall.
Yes(1) No(0)	Sometimes I feel unsteady when I am walking.	Unsteadiness or needing support while walking are signs of poor balance.
Yes(1) No(0)	I steady myself by holding onto to furniture when walking at home.	This is also a sign or poor balance.
Yes(1) No(0)	I need to push with my hands to stand up from a chair.	This is a sign of weak leg muscles, a major reason for falling.
Yes(1) No(0)	I am worried about falling.	People who are worried about falling are more likely to fall.
Yes(1) No(0)	I have some trouble stepping up onto a curb.	This is also a sign of weak leg muscles.
Yes(1) No(0)	I often have to rush to the toilet.	Rushing to the bathroom, especially at night, increases your chance of falling.

Yes(1) No(0)	I have lost some feeling in my feet.	Numbness in your feet can cause stumbles and lead to falls.
Yes(1) No(0)	I take medicine that sometimes makes me feel light-headed or more tired than usual.	Side effects from medicines can sometimes increase your chance of falling.
Yes(1) No(0)	I take medicine to help me sleep or improve my mood.	These medicines can sometimes increase your chance of falling.
Yes(1) No(0)	I often feel sad or depressed.	Symptoms of depression, such as not feeling well or feeling slowed down, are linked to falls.
TOTAL _______	*Add up the number of points for each "yes" answer. If you scored 4 points or more, you may be at risk of falling. Discuss this brochure with your doctor.*	

Figure 1. "Stay Independent" Brochure Questions

As an alternative to completion of the Stay Independent brochure, providers can simply ask the following key questions: 1) Has the patient fallen in the past year?; 2) Does the patient feel unsteady when standing or walking?; and 3) Does the patient worry about falling? These questions and the CDC brochure are based upon AGS/BGS recommendations.[35,168] If the patient scores $\geq$ 4 on the Stay Independent brochure or answers yes to any of these three key questions, the algorithm suggests that the provider perform or refer the patient to a provider for a Timed Up & Go (TUG), 30-second Chair Rise, and 4-Stage Balance Tests. If the patient scored less than four (4) on the Stay Independent brochure or replied no in response to each of the three questions, the patient is not referred for screening of balance, mobility, or strength and is classified as *low risk*. If the patient scores $\geq$ 4 on the Stay Independent brochure or answers yes to any of these three key questions but no mobility, lower extremity strength, or balance problems were identified through the three standardized screening tools, the older adult was also classified as *low risk* for falls. If mobility/gait (TUG), strength (Chair Rise), or balance (4-Stage Balance) problems are identified through implementation of these screening tools and the patient reports experiencing at least one injurious fall, a multifactorial fall risk assessment is recommended and these older adults are classified as *high risk*.[20,64,167] If gait, strength, or balance problems are identified through implementation of these screening tools, but the patient has not experienced any falls or the patient has no history of injurious falls, then the older adult was classified as *moderate risk*. Whether classified as low, moderate, or high risk, the STEADI's algorithm outlines tiered follow-up interventions, exercise or community fall prevention programs, and/or patient education.[20]

Although the CDC's decision-making algorithm is consistent with the evidence-based guidelines summary from the American Geriatrics Society,[79] the APTA's Academy of Geriatric Physical Therapy and American/British Geriatric Societies do not specifically prescribe specific tests to screen constructs of gait, lower extremity strength, or balance. Their recommendations provide the clinician latitude with selecting the most appropriate tests and measures for quantifying fall risk.[35] The CDC, however, does prescribe tests and measures for screening fall risk. While the CDC has included the TUG, Chair Rise, and 4-Stage Balance tests for provider use, these tools may not be appropriate for all patients and for integration with a telerehab delivery system. Future investigations should investigate whether other screening tools have potential for inclusion in the STEADI toolkit. An element of flexibility when examining the constructs of gait, strength, and balance may be helpful to a telerehabilitation provider, for example, who may need to modify traditional fall screening tools based upon the needs of a remote client. Follow-up research on the STEADI beyond this investigation is recommended.

Although not all CDC resources are directly related to this investigation, the STEADI toolkit includes a comprehensive list of supplemental materials for providers to reference or administer to their patients. These materials are categorized into one of six titles:

1) *Make Fall Prevention Part of Your Practice*. This section includes six provider documents focusing on fall prevention.

2) *Get Background Information about Falls*. This section includes three provider documents focusing on the incidence, significance, and risk factors including medications associated with elderly falls.

3) *Case Studies Featuring Patients at Risk of Falling*. This section provides a case study representing each of the algorithm's three fall risk categories.

4) *Use Validated Tests to Assess Your Patients' Falls Risk Factors*. This section includes forms to perform and record the TUG, 30-second Chair Stand Test, 4-Stage Balance Test, and to measure orthostatic hypotension. This section also includes instructional videos for each of the three screening tools.

5) *Offer Your Patients a Medical Referral*. This section includes a form to refer a patient to a specialist for gait, mobility, or other medical problems that may increase his or her risk of falling.

6) *Offer Your Patients Encouragement, Resources & Referrals*. This section includes brochures to provide to patients about fall risks and provider templates for activities such as recommended community program resources.[20]

The STEADI algorithm evaluates three functional performance domains associated with falls and the history of fall-related injuries. Although each test that screens for gait, lower extremity strength, and balance are individually reliable and valid, Ward et al confirm that the literature lacks evidence about these tests when performed in combination with other assessments such as a falls history or appraisal of self-efficacy (i.e., worrying about falling).[158] The STEADI lacks psychometric data in support of the FMA portion of the algorithm; however, its combination of the TUG, 30-second Chair Rise, and 4-Stage Balance tests closely resembles the Short Physical Performance Battery (SPPB) with the exception of some variation with foot placement on the balance testing. In addition, an eight foot (2.44 meters) walk test is on the SPPB, whereas the TUG is integrated into the STEADI. Both tests provide a timed mobility metric and an opportunity to qualitatively observe functional mobility. The SPPB and each screening test within the STEADI have established cut-points and normative data. The SPPB is predictive of disability and mortality in older adults.[158] Individually, subcomponent tests of the FMA portion of the STEADI algorithm have been researched and psychometrically reported for face-to-face assessments. Unfortunately, no psychometric data was published by the CDC supporting the STEADI's algorithm.

In a 2015 publication, Ward et al hypothesized that combined with fall history and falls self-efficacy, the SPPB and/or its sub-component screening tests would predict injurious falls. In a prospective cohort sample (n=755), those that experienced injurious falls (n=221) over an average follow-up time of 2.43 years was best predicted by fall history, whereas falls efficacy measured by the Falls Efficacy Scale and the SPPB score did not predict injurious falls. Participants with the poorest chair stand performance (>16.7 seconds) had a greater incidence of injurious falls than other predictor variables. A slow chair stand test and history of falls were associated with the highest (46%) incidence of injurious falls over a two-year period compared with other predictor models which included balance tests and gait speed.[158] It was notable that Ward et al reported that having a slow chair stand time without a previous history of falls was associated with a marginally higher incidence of injurious falls but not significantly different from other low risk groups classified by the CDC algorithm.[158] The research examining the predictive nature of the SPPB test by Ward et al was consistent with public health initiatives aimed at reducing the frequency and sequelae of elderly falls. No published research exists examining the relationship between prior falls and the STEADI, nor have the STEADI's screening tools been examined for their predictive validity when implemented as recommended by the CDC.

The STEADI is a new fall screening and fall prevention educational tool. It has not yet been examined for its psychometric properties. Despite this, it was consistent with AGS/BGS recommendations, and, therefore, may be considered the criterion standard for multi-factorial fall screening tools. However, because the STEADI is not yet validated, it will be referred to as a reference standard and not a gold standard. Furthermore, the STEADI includes individually validated tools which assess constructs of gait, strength, and balance, and it closely mirrors integrated tests such as the SPPB which has components that have been proven to have positive predictive validity. Physical therapists, for example, have a plethora of validated screening tools for gait, strength, and balance, and no single fall risk screening tool is recommended for implementation in all settings of healthcare or for all subpopulations within each care delivery setting.[78] Healthcare providers have an ethical obligation to adapt to the individual needs, preferences, and clinical presentation of their clients. The implementation of fall screening services provided by a remote physical therapist may demand additional adaptability, and research was lacking to guide these evidenced-based decisions. For example, a patient with a knee contracture may have difficulty participating in the STEADI's Chair Rise Test. Results on this test may result in a false positive outcome. Modifying a standardized test from its tested protocol could invalidate the outcome and interpretation by the clinician. Therefore, future investigations should ask the question: "What other tests and measures could be substituted while still providing the clinician reliable and meaningful data to complete the STEADI's fall risk algorithm?"

Another example of the need to select alternative tests and measures for the construct of gait could occur if a care recipient was unable to follow directions to complete the TUG, or was unable to properly set-up the test from their originating site. Which combinations of tests and measures that are deemed safe and transferrable to a telerehab delivery system can provide clinicians the most predictive gauge of fall risk measured in combination with the CDC's "Stay Independent" brochure, for example? Based upon the literature and the detailed analysis of other FMA screening tools, the STEADI has the potential to include alternatives to the TUG, Chair Rise, and 4-Stage Balance tests within the screening algorithm. Despite these identified weaknesses of the STEADI when implemented by face-to-face or remote clinicians, the STEADI, as the current reference standard of *multi-factorial* fall screening tools, will be investigated for its feasibility of implementation using a telerehab delivery system as a starting point to answer the research questions outlined in this study.

A review of the physical therapy literature and Rehabilitation Measures Database highlights numerous standardized tools potentially available for use by clinician raters when screening an older adult's fall risk. These tools are often times validated on some, but not all, populations. The goal is to screen patients in advance of an injury. Regardless of the tool(s) selected by clinicians or which discipline implements the screen, standardized screening tools should demonstrate strong psychometric properties to minimize false negative rates, while also maximizing true positive rates.[37] Most tools simply focus on the examination or screen of balance and gait. This is exemplified by classically utilized and referenced tools such as the Berg Balance Test, TUG, and Tinetti POMA.[65] However, the contemporary literature and the most current Clinical Practice Guidelines from the American and British Geriatrics Societies recommend a multi-factorial fall risk assessment.[168] The CDC's STEADI toolkit was developed in response to these guidelines.

Risk factors for falling can further be classified as either intrinsic or extrinsic. Examples of intrinsic risks for falls are lower extremity weakness, poor grip strength, balance deficits, and visual and cognitive impairment. Examples of extrinsic risks for falls are polypharmacy (defined as 4 or more prescription drugs), and environmental factors such as loose carpets, poor lighting, and lack of bathroom safety equipment.[168] Polypharmacy and the prescription of psychotropic and cardiac medication both present as serious intrinsic fall risk factors.[35] The STEADI is the only multi-factorial fall risk screening tool to have received the endorsement from the CDC. Furthermore, the fall risk algorithm published by the CDC and recommendations from the APTA's Academy of Geriatric Physical Therapy include key evidenced-based questions about a patient's 12-month fall history,[20] difficulty with balance or walking,[20,35,64] and worries or anxiety about falling.[20] If a client is determined to have an elevated fall risk, all relevant intrinsic and extrinsic risk factors can be assessed in further detail by the interprofessional healthcare team.

The STEADI is the most contemporarily developed fall risk screening tool, and it incorporates both multi-factorial risk assessments and a classification system. The STEADI is potentially compatible for telerehab delivery systems. As outlined, the CDC integrated three functional screening tools to appraise the lower extremity strength, balance, and mobility of older adults. What is not known is how the TUG, 4-Stage Balance Test, and 30-second Sit to Stand Tests function as a group or compare with other valid and reliable screening tools when implemented individually or bundled together. This matter was central to research question 2 (*Are fall risk screening conclusions that are derived remotely equivalent to other reference standard face-to-face screening tools?*) in appraising the STEADI's concurrent validity when implemented through a telerehab delivery system with what appears to be the current criterion standard of FMA fall screening tools, the BESTests. Central to research question 3 (*Are outcomes of fall screening measures that are performed remotely consistent with those performed face-to-face?*), this study is needed to evaluate interrater consistency and the feasibility of conducting selected fall screening assessments among remote and face-to-face raters. Rater agreement and feasibility is first needed to be established so that the individual tests can be analyzed for potential fit into the STEADI algorithm in future investigations. In addition, inter-environment reliability and rater agreement, and validity metrics examining the relationship with prior and future falls, for example, must be established before clinicians can begin to consider a telerehabilitation delivery system for appraising elderly fall risks. Only one study has been published regarding the reliability and accuracy of fall and mobility screening tools delivered via telehealth. Russell et al recently appraised the use of the TUG, BBS, and functional reach using a proprietary telehealth system investigating the feasibility of examining individuals diagnosed with Parkinson's disease.[166] Although this was ground-breaking research in the field of telerehabilitation, it is well known that individuals with Parkinson's disease are already at elevated fall risk as a result of physical manifestations from the disease process. Furthermore, taped-recorded calculation of these assessments were aided by computer software not accessible to the vast majority of clinicians in the world, and it is not yet available commercially in the U.S.

What is needed is to reach the estimated 50 million people age 65 and older here in the United States[169] who statistically have the greatest risk of injurious falls, loss of independence, and financial impact on the healthcare system.[1,170] To accomplish this access goal, researchers should consider investigating the application of commercially available audiovisual conferencing systems that are simple yet secure, HIPAA compliant, cost-effective, and readily available. Once the feasibility, acceptance, consistency, and accuracy of telerehabilitation among community-dwelling older adults is established in the literature, customization of software such as the one selected by Russell et al may serve a more meaningful clinical role. For now, the investigation methods used by Russell et al are unable to be reproduced, and therefore, render little clinical application and reference to this investigation. Because telehealth is not reimbursable by most third-party payers, including Medicare, when delivered by a physical therapist, elaborate software systems are not likely to be purchased for clinical use. In consideration of these current legislatively-imposed revenue limitations, further research is needed to supplement Russell's preliminary work with older adults.

For providers to implement these standardized screening tools and theoretically reduce the rates of and expenses associated with elderly falls, older adults need greater access to clinicians who are skilled in this area. To that end, methods selected by healthcare providers should be acceptable to recipients of these fall screening initiatives. Telehealth delivery systems, if acceptable to the end-user, have the potential to provide older adults greater access to licensed physical therapists. This investigation has the potential to directly impact elderly fall rates by investigating telerehab as a possible strategy or modality to meet the CDC's call to action directed at healthcare providers.

Summary

A comprehensive review of the literature identified a plethora of commonly used fall screening tools that apply to a variety of patient conditions. Although the contemporary literature did not label any fall screening tests a "gold standard," the robustness of the BESTests and the multi-factorial nature of the STEADI capture these two tests as leading candidates for selection with community-dwelling older adult populations. However, telerehabilitation providers must consider patient safety when implementing readily available and psychometrically valid fall screening tools. For various reasons, this literature analysis has determined that none of the three BESTest versions and several other commonly used tests such as the Berg Balance Scale are safe to be conducted by a remote clinician, and concurrent validity with the normative referenced Mini-BEST needs to be established in order to merit the outcomes of any remote fall screening assessment results.

Current AGS and BGS "best practice" guidelines recommend regular assessment of multi-factorial fall risks by a qualified healthcare provider. Fall risk screens should occur at least annually or following a fall. The STEADI algorithm is unlike other screening tools in that it combines a multi-factorial risk assessment (Stay Independent Brochure) with other commonly used tests for balance, mobility, and lower extremity strength to create an evidenced-based algorithm. It is the only multi-factorial assessment tool which includes standardized functional performance measures, client interview, physiologic contributors to falls, risk stratification, and intervention guidelines. Despite being created by the CDC, the challenge with the STEADI is that no psychometric data on its reliability or validity exists for comparison with face-to-face outcomes. Other limitations with the STEADI are with the somewhat arbitrary selection of component screening tools to appraise mobility/gait, lower extremity strength, and balance, and it lacks the depth of physical performance measures as compared to the BESTests, for example. Despite the lack of statistical data available to support the algorithm, the STEADI will serve an integral role in fulfilling the purposes of this investigation and initiatives promoted by the CDC. In addition to the STEADI, other fall screening tools will also be tested for their feasibility and reliability using a telerehab delivery system. A review of the literature with consideration of the safety of care recipients participating in remote fall risk screening efforts highlights the appropriateness of the following tests for inclusion of this investigation: 4-meter walk test, POMA-G, and FRT. The STEADI already includes the TUG, 4-Stage Balance (single limb, tandem, narrow stride, and narrow stance tests), and the 30STS totaling nine individual tests that were analyzed for their feasibility, rater and environment reliability, and concurrent and predictive validity. Each individual test or a combination of these tests represent potential options for remote clinicians to select when conducting fall risk assessments on community-dwelling older adults.

The literature is void of publications that investigate a synchronous telerehabilitation delivery system on community-dwelling, non-neurologically compromised older adults for the purpose of fall screening. The STEADI algorithm, its toolkit components, and other selected tests are potentially feasible to implement through telerehabilitation. However, older adults, as end users of a telerehab delivery system, may not be receptive to receiving healthcare through these methods. This is despite several studies determining that focus groups of elders were receptive to “smart” technologies that were aimed at maintaining in-home independence or aging in place. The Technology Acceptance Model (TAM) provides a framework by which healthcare providers can determine perceived usefulness and, therefore, behavioral intention and attitude towards use of a technology application by an end-user. Despite a well-established theoretical framework to appraise the acceptance of technology, the literature was void of any surveys that could quantify attitudes and beliefs of older adults towards telerehabilitation delivery systems. Nonetheless, a robust theoretical literature base in the field of technology acceptance provides a solid foundation from which to develop a survey instrument to test hypothesis one.

Davis’ early work in the field of technology adoption and acceptance produced the TAM. Simply, the TAM was developed to explain computer-usage behavior.[34] Research and development of the TAM was based upon an earlier model of behavioral intention titled, the Theory of Reasoned Action (TRA). Behavioral intention is ultimately what predicts compliance with and carryover of medical recommendations.[97] Building on Davis' identification of perceived usefulness and perceived ease of use as root constructs to predict behavioral intention to adopt a technology application, Venkatesh et al reevaluated all major theories of technology acceptance in route to developing and validating the Unified Theory of Acceptance and Use of Technology (UTAUT) model. Development and validation of the UTAUT was performed from a thorough analysis of the theory of reasoned action (TRA), TAM, motivational model, theory of planned behavior, the combined theory of planned behavior/TAM, model of personal computer use, diffusion of innovations theory, and social cognitive theory.[118] Building on published works from Davis, Venkatesh, Wade, and others, Cimperman et al qualitatively and quantitatively investigated seven predictive factors that play a role in the influence the perceptions of older adults towards home telemedicine. Using the root constructs of perceived usefulness and perceived ease of use of from the TAM and root constructs perceived usefulness, effort expectancy, social influence, and facilitating conditions of the UTAUT, Cimperman et al assessed the usefulness of home telemedicine system functionalities.[54] Conclusions from Cimperman et al parallel the UTAUT and served as the basis for the development of this investigation's survey tool designed to quantify baseline and potential changes in attitudes and beliefs towards telerehabilitation services in an older adult population.

A comprehensive review of the technology acceptance literature revealed seven key constructs that served as a foundation to the creation and implementation of a TR survey instrument: *Performance Expectancy / Perceived Usefulness* (Cimperman, Venkatesh 2003, Wade 2012, Davis 1989), *Effort Expectancy* (Cimperman, Venkatesh 2003), *Social Influence*

(Cimperman, Venkatesh 2003), *Facilitating Conditions* (Cimperman, Venkatesh 2003), *Perceived Security* (Cimperman), *Computer Anxiety* (Cimperman), and *Physician's Opinion* (Cimperman). In addition, phrasing of Likert scales are consistent with items from Davis' validated TAM model and published work from Wade et al and Cimperman et al.

CHAPTER THREE: RESEARCH METHODOLOGY

Introduction

The overall goal of this investigation was to determine if telehealth applications provide an acceptable, valid, and reliable method of screening fall risk and mobility status in an older adult population. This chapter outlines the study design, description of participants including sampling methodology, inclusion and exclusion criteria, statistical measurement procedures including a priori sample size projections, and methodology that was used for content validation of a survey and for the procedural collection of clinical data.

With the exception of the STEADI toolkit, the literature reflects adequate to excellent psychometric properties in support of the Mini-BESTest, TUG, FRT, gait speed, 30-second Chair Rise (30STS), and POMA-G when used for fall risk screening.[124,130,131,148,155,162,164,171,172] This established literature base allowed this investigation to focus on testing the generalizability of these screening tools to a telerehabilitation delivery system. Participant completion of a Fall History Questionnaire distinguished the self-reported fallers from non-fallers.

Research Methods

This study implemented an experimental, quantitative, cross-sectional investigation employing both pretest-posttest control group and quasi-experimental static group comparison designs using non-probability sampling methods. Subjects were randomly assigned to either the control or intervention groups. Once assigned, participants in the intervention group also participated in the quasi-experimental, static group component of this investigation that included fall risk screening (Figure 2).

Control Group

Pre-test TR Survey &
Fall History Questionnaire

Post-test TR Survey

Intervention Group

Telerehabilitation Raters | Face-to-Face Raters

Pre-test Survey &
Fall History Questionnaire

*STEADI
- Stay Independent Brochure Questionnaire
- Timed Up and Go (TUG)
- 30-second Sit to Stand (30STS)
- 4-Stage Balance Test
  - Single Leg Stance
  - Tandem Stance
  - Narrow Stride Stance
  - Narrow Stance

*Functional Reach Test (FRT)
*Tinetti Performance Oriented Mobility Assessment (POMA-G)
*4-Meter Walk Test

*STEADI
- Stay Independent Brochure Questionnaire
- Timed Up and Go (TUG)
- 30-second Sit to Stand (30STS)
- 4-Stage Balance Test
  - Single Leg Stance
  - Tandem Stance
  - Narrow Stride Stance
  - Narrow Stance

*Functional Reach Test (FRT)
*Tinetti Performance Oriented Mobility Assessment (POMA-G)
*4-Meter Walk Test
*Mini-BEST

Post-test TR Survey
6-month Prospective Fall Incidence

Figure 2. Research Design Flow Diagram

Because no validated surveys rooted in the theoretical structure of technology acceptance exist for integration into this study, the investigator created a survey specific to telerehabilitation and tested it for face and content validity. This survey was based upon empirically validated constructs of the Unified Theory of Acceptance and Use of Technology (UTAUT)[54,118] with the goal of measuring an older adult's behavioral intension to use a prospective telerehabilitation delivery system.

Procedures

Upon Institutional Review Board (IRB) approval from Midwestern University in Glendale, Arizona and Nova Southeastern University in Fort Lauderdale, Florida, volunteer participants were recruited from but not limited to local senior citizen centers, libraries, physician offices, and religious congregations in Glendale, Peoria, and Phoenix, Arizona. IRB approval letters are in Appendix C. The locations from which the investigator accessed community-dwelling older adults was generalizable to some medically-underserved older adults who have access to community centers, public libraries, physician services, and worship centers. This study was unable to include a sampling of participants who reside in rural communities. The Phoenix metropolitan area is approximately 2-3 hours from regions of Arizona that are considered rural, and technology barriers with the transmission of real-time video data necessitated that both the face-to-face and remote screening assessments be conducted in a controlled setting for a more reliable and secure internet connection.[10,11,67,146] This study employed a wired Ethernet connection via Category 5 or higher (CAT6) cable at Midwestern University in Glendale, Arizona to ensure connectivity.

This investigation's target population was community-based older adults, and all of the selected fall risk *screening* tools are either valid and reliable or strongly encouraged for use with the general community-dwelling elderly. Participant recruitment was classified as nonprobability purposive sampling as this study focused on a pre-defined population representative of community-dwelling older adults.[173] Assignment of volunteer participants, however, to either the control (survey only) or experimental groups (survey and telerehab fall screening) was largely randomized based upon every other name on the schedule although occasional attendance and punctuality issues with pre-scheduled participant appointments necessitated minimal exceptions to the every other name methodology. For example, if participant cancellations were going to result in a two or more-participant mismatch between control and experimental groups for each data collection day, exceptions were occasionally necessary to promote the goal of an equal number of participants assigned to both groups over the course of numerous data collection dates.

Selecting an appropriate sample size is an important component to minimizing the risk for statistical error and enhancing the power of research initiatives. Factors involved with the accurate calculation of a sample size include power (1-β), effect size, sample variance, and significance criterion (α).[37] An effect size is defined as "an estimate of the magnitude of difference between groups or the effect of an intervention."[37] Because this was a proof-of-concept study, there are no prior effect size estimates available for which to base this study's sample size. Cohen recommends that researchers estimate the effect size according to operational definitions for "small (0.2)," "medium (0.5)," and "large (0.8)."[37] For this investigation, a medium effect size was chosen for the a priori sample size estimation. G*Power 3.1 is a statistical program that assisted the investigator with the calculation of sample sizes in accordance with estimated effect sizes.[174] Based upon G*Power input parameters for power (0.8), alpha (0.05), and medium effect size (0.5), research question 1 (*What effect does exposure to a telerehabilitation delivery system have on underlying attitudes and beliefs of older adults about the perceived usefulness of this healthcare delivery option?*) would employ the F-test analysis of covariance requiring a minimum sample size of 34 (17 in each group). Based upon G*Power input parameters for power (0.8), alpha (0.05), and medium effect size (0.5), research question 2 (*Are fall risk screening conclusions that are derived remotely equivalent to other reference standard (Mini-BEST) face-to-face screening tools?*) would, in part, employ an independent Spearman rho correlation analysis requiring a minimum sample size of 106 (53 in each environment); Research question 3 (*Are outcomes of fall screening measures that are performed remotely consistent with those performed face-to-face?*) would employ intraclass correlation coefficient (ICC) analysis, which is a correlation analysis that does not have strict guideline on sample size requirement.[174] Because sample size projections varied greatly between research questions, a recruitment sample in the middle of 34 and 106 (n=70) was selected for this proof-of-concept investigation. Allowing for 10-15% attrition, the investigator recruited over 80 older adults upon IRB approval. Half of the participants were assigned to the control group (surveys only), and the remaining participants received the telerehabilitation delivery system and gold-standard face-to-face screening tests (surveys + "intervention" participation in fall screening tests). Participants from both groups completed the fall history questionnaire (Appendix D) and were blinded to their assignment until their scheduled date of participation.

Each fall risk screening tool was rated by a team of face-to-face and a team of remote raters. Each rater team was initially proposed to consist of 1) a physical therapist licensed in the state of Arizona with at least two years of experience working with older adults and 2) a 3rd year Doctor of Physical Therapy student with a GPA of at least 3.0 on a 4-point scale. However, unanticipated scheduling challenges necessitated that each rater team consist of a pair of 3rd year DPT student raters. This will be further outlined and analyzed in Chapters 4 and 5.

Rater teams were used for both face-to-face and remote fall screen test administration, but only one rater's data (rater 1) was used to calculate agreement between face-to-face and telerehab environments. However, measurements from rater 2 were used to calculate interrater agreement with rater 1 for each test environment. For screening tests where protocol requires more than one trial, the best score for each rater was selected. This procedure was used for the calculation of inter-environment agreement of fall risk, inter-environment agreement of raw scores, and interrater reliability for each rater environment. Reference of the best time or distance, for example, is consistent with clinical practice. For example, the TUG, 4MWT, FRT, and Four-Stage Balance Tests were each administered twice.

All raters received standardized instructions in the form of YouTube videos and instructions from a physical therapist with 19 years of clinical experience prior to participating in the investigation. The order of the fall screening testing was varied to prevent post-test bias, fatigue, or consistency of effects when completing the TR Survey. For example, the order of the tests that were administered remotely was flipped every 3 subjects and beginning with either the Mini-BEST or telerehab tests, was alternated with every other subject. A standardized instruction and scoring “script” was used by all raters for consistency (Appendix E).

All participants of the control and intervention groups completed baseline and post-test telerehab surveys examining their attitudes and beliefs about their perceived usefulness of a telerehabilitation delivery system. The Fall History Questionnaire and the STEADI’s Stay Independent Brochure questions were administered at baseline to both groups. Participants were scheduled at 45-minute intervals and intervention group participants were assessed simultaneously by face-to-face and remote (telerehab) raters at Midwestern University in Glendale, Arizona (Figure 2).

The telerehab raters were remotely positioned in a designated video-conferencing room and the face-to-face raters were positioned with the participants in a designated room that was at least 250 square feet. The telerehab rater team was located in a different building on campus from the face-to-face teams. The physical layout in the designated face-to-face assessment room facilitated a 20-foot walking path so that raters could adequately observe gait quality and velocity on the POMA-G and 4-meter walk tests (Figure 4).

One of the telehealth raters was designated as the lead clinician (rater 1) and was responsible for providing all standardized instructions to participants. This lead rater was also a 3rd year DPT student. Instructions provided in real-time by a member of the telehealth rater group could potentially strengthen the external validity of this investigation. This will be discussed further in Chapter 5. This consistent “voice” also strengthened this study’s internal validity by eliminating affective variations of instructions and any potential confounding effects that changes with tone of voice and gender, for example, may have had on the participants. All participants received standardized instructions for test administration via a 17” laptop positioned on a table for viewing by participants and face-to-face raters. The position of the laptop table was standardized for all data collection dates by marking the correct position for each screening test with tape of the floor. The webcam used at the originating site was clipped to the top of the laptop. This laptop transmitted both audio and video data from the lead telerehab clinician who was positioned remotely with telerehab rater 2 in a conference room. To maximize the audio quality of verbal instructions and help to compensate for age-related hearing losses with some participants, a high definition (HD) microphone was used by the lead telehealth investigator and the laptop was equipped with HD speakers. Upon entering the fall screening testing room (Figure 4), study participants were verbally instructed that they were to direct questions to the telerehab clinician and were to avoid directing questions to the face-to-face raters and safety assistant. Participants were permitted to approach the laptop computer when necessary for clarity of instructions and communication. This also helped to preserve any human effects natural to a patient/provider relationship.

During the administration of the balance and mobility screening tests, the two face-to-face raters and the second telehealth rater were not permitted to communicate with study participants. Both of the face-to-face raters had the option to remain seated or standing but were consistently positioned within the room for all participant sessions. As depicted in Figure 4, the room set-up, camera angle, and therefore, position of face-to-face raters varied for some tests. For example, the position of the camera/laptop and raters was consistent for the POMA-G and 4MWT but was different from the FRT and TUG. Face-to-face raters were positioned in the room at least five feet away from participants and a minimum of five feet apart to prevent consultation with each other during the fall screening test administration. Likewise, telehealth raters avoided consultation with each other during the collection of data. Both groups of raters were blinded to each other's scoring and results from participant surveys during data collection. Furthermore, raters participating in the nine simultaneous telerehabilitation / face-to-face screening tests and raters who were administering the Mini-BEST were blinded to each other's test results and did not have direct methods of communicating to each other during data collection. Mini-BEST tests were administered off-camera and in a different room from the telerehab test procedures.

Cues and guidance were only permitted from the remotely positioned lead clinician and from a designated safety assistant. The safety assistant was a physical therapy student who had completed introductory coursework including basic guarding and handling techniques in the physical therapy curriculum. This safety assistant successfully completed PTHE 1592 Acute Care Rehabilitation at Midwestern University as a pre-requisite for assisting with this investigation. PTHE 1592 is a first year DPT course that includes curricular objectives for patient guarding, handling skills, and gait and transfer training. It is notable that the Midwestern University IRB would not approve this investigation unless a safety assistant had formal didactic training with guarding techniques. The safety assistant was instructed to avoid providing verbal, visual, or tactile cues to the participants unless it was determined that a participant's inability to follow directions may result in a fall, jeopardize safety to themselves or others, and/or if the lead clinician had repeated the same instructions at least three times.

All face-to-face and remote raters independently recorded scores for each screening tool. Raters were provided pre-printed standardized forms for record keeping (Appendix E). Participant names were printed on each form by the individual raters after the lead clinician confirmed the name and spelling with each participant at the start of each video conferencing session.

Instrumentation

The preliminary draft of the telerehab survey instrument can be referenced in Appendix F, and the final version of the telerehab survey can be referenced in Appendix I. As previously outlined, the root constructs of this survey are fundamental to Davis' original Technology Acceptance Model (TAM)[97] that served as a foundation to many healthcare related technology adoption studies.[30,116,117,175-177] Wade et al incorporated Davis' and Venkatesh's work when developing a survey to gauge feedback from frail elders using asynchronous biometric screening devices. The survey developed by Wade et al most closely resembles the population and purpose of this investigation as compared to other findings in the literature. However, the challenge with referencing existing telehealth investigation questionnaires identified in the literature such as the items developed by Wade et al was that survey item development demonstrated a lack of methodological rigor.[115] Therefore, this investigation developed and content validated a survey tool aimed at quantifying an older adult's behavioral intension to adopt and their attitudes towards a telerehabilitation delivery system.

Methods to Test Research Question 1

An older adult's behavioral intension to adopt and their attitudes towards a telerehabilitation delivery system was measured immediately before and after a telerehabilitation experience for the intervention group, and it was measured at baseline and approximately one month following baseline testing for the control group. This quantification of pre- and post-survey outcomes was instrumental in testing hypothesis one.

The following procedures were followed in the development of this survey instrument:

1) Draft a survey tool rooted in the seven constructs (performance expectancy/perceived usefulness, effort expectancy, social influence, facilitating conditions, perceived security, computer anxiety, physician's opinion) empirically validated by Venkatesh et al and Cimperman et al. Consistent with other investigations on end-user technology acceptance, a larger response scale of 0-7 was adopted.[54,97,175] Some publications have implemented a smaller four to five option scale[178] but including additional response options may capture greater sensitivity to change.
2) Select a panel of experts consisting of at least four to five members. A minimum of two members had to possess extensive employment experience and training in the fields of information technology and/or media production. At least one panelist had to be a licensed physical therapist with board certification as a geriatric clinical specialist (GCS). One member of the panel had to be a community-dwelling older adult age 65 or older who possessed at least a bachelor's degree in any field or science. Each panelist was instructed to provide feedback based upon their independent review of each survey iteration. The primary investigator provided PDF copies of reference articles and operational definitions of each construct deemed critical background information to this

survey's fundamental constructs, a brief description of the purpose of the survey tool including response deadlines, a confidentiality waiver, and a copy of each survey iteration with cumulative comments from the panel in Microsoft Word format (Appendix F).

3) Panelists were requested to review and comment on the survey tool two times to reach consensus with feedback. The first review was a comprehensive appraisal of the survey instrument for relevance and clarity of each item with its corresponding construct. Panelists were encouraged to make relevant editorial or grammatical suggestions. Following this first review, the investigator assembled all suggestions into one document to aid panelists with their second review. In addition to making relevant editorial or grammatical suggestions, each panelist was asked to rate each item as "essential," "useful but not essential," or "not necessary" during this second review. These ratings enabled the investigator to quantify consensus in accordance with Lawshe's conceptual framework[179] and more precisely report outcomes to the content validation process.
4) Once finalized, the survey tool was piloted for relevance, readability, scoring, and general feedback among a focus group of five older adults. Based upon this pilot test, final modifications were made to the survey instrument prior to its implementation with study participants.

Methods to Test Research Question 2

To test the hypotheses related to research question 2, the following methods were employed by the investigator. Two face-to-face raters simultaneously and independently scored participants on the *Mini-BEST* and determined the fall risk based upon risk stratification validated by Padgett et al and Duncan et al.[127,132] A lead clinician provided instructions to each intervention group participant, and a safety assistant actively guarded each participant as they would during a typical physical therapy examination. The second telehealth rater and both face-to-face raters essentially served as a "passive" participant for the purpose of scoring. Although quantitative risk stratification remains in development for the BESTests, O'Hoski et al have recently provided normative reference values for older adults.[130] Age-related normative scores for the Mini-BEST are as follows: age 60-69 was 88% or 24.6/28, age 70-79 was 75% or 21/28, and age 80-89 was 70% or 19.6/28. Age related norms for age 90+ are not established so normative scoring was reduced by 5% to 65% or 18.2.[130] The Mini-BEST is comprised of 14 items totaling a maximum of 28 points. The primary investigator anticipated that the average age of study participants would be between 70-79 years old, so it was projected that the average cut-off score for fall risk would be 21/28.[132]

Because the *STEADI toolkit* was also being tested in this investigation for its feasibility and accuracy when implemented using a telerehabilitation delivery system, the CDC fall risk algorithm (Appendix B) was used to quantify the fall risk of participants. This algorithm has three tiers (low, medium, and high risk), which served as the guide for establishing concurrent validity with the face-to-face Mini-BEST. To accurately complete the algorithm's risk assessment and maximize potential data analysis opportunities, the raters administered questions from the *Stay Independent* Brochure (Figure 1) followed by evaluation of gait (TUG Test), lower extremity strength (30-second Chair Rise Test), and balance (4-Stage Balance Test). This entire STEADI pathway was completed for all members of the experimental group rather than skipping these three functional tests and automatically classifying the client as low risk if a participant scored less than four on the Stay Independent Brochure. To appraise interrater reliability, a two-rater procedure was utilized for remotely completing the functional fall screening components of the STEADI. This is consistent with the two-rater scoring of the Mini-BEST.

The CDC has specific pathways outlined on its risk algorithm (Appendix B). If the participant scores less than a score of four on the Stay Independent brochure and/or no gait, strength, or balance problems are identified by the three screening tools, the participant is classified as “low risk.” If gait, strength, or balance problems were identified and the participant had yet to fall or had experienced a fall without injury, the participant is classified as “moderate risk.” If the participant had identifiable gait, strength, or balance problems and has suffered multiple falls or at least one injurious fall, the participant is classified as “high risk.”[20] Finally, all four face-to-face and remote raters scoring the TUG, 30STS, and Four-Stage Balance components of the STEADI were blinded to results from the Mini-BEST and vice-versa.

All fall screening tests were simultaneously administered to standardize the reliability of audiovisual communication and internet connectivity that has been noted as a limitation to telerehabilitation by Shaw et al and Russell et al.[11,68,81] To that end, a test-retest methodology where each individual rater administers each test may have introduced confounding factors into subsequent comparisons of reliability and validity between face-to-face and remote environments. Approximating participants with remote clinicians maximized accessibility to technical support and clinical personnel, should unanticipated challenges occur. For example, there were several instances in which the investigator contacted information technology personnel for them to observe video or audio pixilation in hopes to trouble shoot in advance of upcoming TR sessions. Methods of isolating face-to-face raters/participants and remote raters was consistent with methodology performed by Russell et al when they compared internet-based rehabilitation post-total knee arthroplasty with traditional face-to-face care.[30] Lastly, standardizing the test location helped to eliminate confounding influences that might occur from ergonomic set up and décor, as well as variations with internet bandwidth availability that has been known to occur within the Phoenix metropolitan area.[67] Minimizing confounding, but realistic, influences on outcomes of this investigation limited its generalizability, but were needed to test proof-of-concept and minimize Type II error rates.

Methods to Test Research Question 3

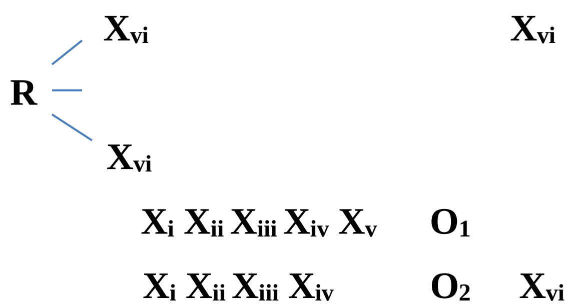
Methods used to test research question 3 were very similar to research question 2. A student physical therapist provided guarding of participants (safety assistant) during all fall screening tests conducted by remote rater 1. This work study student was permitted to don/doff gait belts, ensure proper set-up of equipment, and provide guarding of participants during test administration. As with methods for research question 2, the presence of a non-licensed person for guarding of study participants also symbolized the prospective presence of an able-bodied friend, family member, or community/religious center representative that are recommended for older adults to participate in remote fall screening tests.

In addition to the STEADI, the 4-meter Walk Test (4MWT), Tinetti POMA-gait (POMA-G), and the Functional Reach Test (FRT) were included in the testing of research question 3. Using Fritz and Lusardi's red, yellow, and green flag cut-off speeds, a three-tier fall risk classification was used for statistical analysis: high risk 0.6m/sec or slower, medium risk 0.6 - 1.0m/sec, and low risk 1.0m/sec or higher.[151] Although participants are unlikely to have a zero gait speed based upon inclusion criteria for this investigation, gait speed has a true zero and therefore the test was analyzed on a ratio scale.[37,173] The POMA-G is a seven-item subcomponent of the Tinetti POMA tool measuring each item on a 2- to 3-point ordinal scale. Although cut-off scores are established for the POMA as a whole (POMA-t) and the POMA balance (POMA-B) with community-dwelling older adults and residents of extended care facilities,[64,156] no cut-off scores were discovered in the literature specific to the POMA-G.[154] POMA-t scores ranging from 24-28 are associated with low fall risk, 19-23 are associated with a moderate fall risk, and scores $\leq$18 are associated with a high fall risk.[180] The FRT has established cut-off points for determining fall risk and limitations with ADL independence in older adults. According to Weiner et al and Thomas et al, the cut-off point for "risk" or "limited functional balance" is 7 inches (18.5cm), whereas 10 inches (25.4cm) is considered normal.[147,149,181] The FRT results were measured in units of distance, but a score of zero does not mean that a participant is absent of balance. Therefore, the FRT is considered an interval scale rather than ratio data.[37,173]

The STEADI consists of the Timed Up and Go Test (TUG), 30-second Chair Rise (30STS), and 4-Stage Balance tests. Unlike the TUG, the Chair Rise and 4-Stage Balance tests are ordinal data because repetitions and time intervals within each individual tool are not equivalent.[37] In other words, someone who completes ten repetitions on the chair rise test is not necessarily twice as strong as someone who completes five repetitions, and the difference between seven and five repetitions may not be the same as the difference between four and two repetitions.[173] The 30STS, 4-stage balance, and TUG Tests administered as a group lack psychometric properties much like the three-tiered STEADI algorithm despite its adoption by the CDC. However, established cut-off points do exist for the TUG and 30-second chair rise tests as individual screening tools. Most sources conclude that community-dwelling older adults are correlated with high risk for falls when total time to complete the TUG exceeds 13 or 14 seconds.[135,181,182] However, there are some sources that place the elderly at a high risk of falling with TUG scores greater than 12 seconds.[183] The TUG's cut-off points for delineating fall risk although the literature[181] (13 seconds) differs from the STEADI toolkit[20] (12 seconds). TUG results are measured in units of time and are considered ratio data.[37,173] According to Riki et al, cut-off scores for fall risk and "independence" on the 30STS range from 15 repetitions with ages 65-69, 13-14 repetitions with ages 70-79, and 11-12 repetitions with ages 80-89.[184] The 4-Stage Balance Test is similar to recommended exercises in the *Otego Preventing Falls Program* for older adults, but cumulative risk cut-off scores do not exist for the four stages (feet together, semi-tandem, tandem, and single leg stance).[170] The STEADI toolkit, however, does state that an inability to stand in tandem stance for 10 seconds is indicative of elevated fall risk.[20] Because of variability in the literature, reliability of fall risk (inter-environment agreement) and validity data for the FRT and TUG were calculated using two cut-off points for fall risk. Statistical analyses utilized the following cut-off scores when calculating inter-environment agreement of fall risk and area under the curve data: FRT 7 and 10 inches, 4-meter walk 1.0 m/sec, TUG 12 and 13 seconds, tandem stance 10 seconds, and the 30STS and Mini-BEST based upon published age norms. Gender also plays a role in cut-off scores for the 30STS Test.

All participants were informed of their fall risk based upon scoring and/or general observations made by raters via written letter that can be referenced in Appendix G. Participants who demonstrate an elevated risk of falling were strongly encouraged to follow-up with a licensed physical therapist and his/her primary care physician. Experimental group participants were also provided follow-up recommendations based upon the CDC's STEADI three-tiered risk algorithm.[20] The algorithm and specific recommendations is found in Appendix B and cross-referenced with the fall risk notification letter in Appendix G.

The following graphics schematically represent this investigation's design:



O_1= on-sight raters
O_2= remote (telehealth) raters
X_i= STEADI algorithm assessment including questions
X_{ii}= POMA-G assessment
X_{iii}= gait speed assessment (4-meter walk)
X_{iv}= Functional Reach Test
X_v= Mini-BESTest
X_{vi}= written survey

Figure 3. Research Design Schematic

Inclusion and Exclusion Criteria

***Inclusion criteria*.** Participants must have 1) been at least 65 years of age, 2) been able to follow one-step commands consistently, 3) been able to read and speak English as their primary language, 4) had a primary residence in a house, apartment, assisted living or group home, and 4) had the ability to walk 100' with or without an assistive device.

***Exclusion criteria*.** Individuals were excluded if they 1) had been diagnosed with hemiplegia or paraplegia, 2) were unable to walk without the physical support of another person, 3) required supplemental oxygen on a continuous basis, 4) were unable to access transportation to the testing location(s) on the designated investigation dates, 5) had been hospitalized within the previous14 days, 6) resided in a long-term care or skilled nursing facility, and 7) were unwilling or unable to execute an informed consent form.

Inclusion and exclusion criteria were established to ensure study participants possessed attributes important to the purpose of this study.[173] The reason for the age criterion was that older adults have a higher incidence of falls with increasing age after turning 65 years old.[185,186] As outlined in Chapter 1, the validity of fall screening tools can differ with population variations. For example, the POMA lacks validity when implemented with subjects who have neurological conditions such as multiple sclerosis or late effects from a cerebrovascular accident (i.e. stroke).[124] Therefore, persons with hemi- or paraplegia were excluded from this investigation. Supplemental oxygen was listed as an exclusion criterion as oxygen cords pose liability and safety risks to this investigation and its participants, and unpredictable acute symptoms associated with pulmonary disease could potentially serve as confounding variables affecting the results of this study. Similarly, cognitive deficits in participants who are unable to consistently follow one-step commands could have imposed confounding variables that would impact the results of this study. Older adults who reside in a long-term care facility or skilled nursing facility do not meet the definition of community-dwelling older adults; therefore, this population demographic was excluded from this study's sampling methodologies.

This study initially proposed to employ a wired Ethernet connection via Category 5 (CAT5) or higher cable (CAT6) and not a wireless network connection such as with Wi-Fi or a cellular network unless information technology professionals could attest to the reliability of connection. As discovered by Shaw et al, wireless connectivity has been proven to be unreliable in the Phoenix metropolitan area because of inconsistent access to a 4G bandwidth signal.[11] However, IT professionals were able to integrate a wireless connection using a Wi-Fi signal booster within the data collection laboratory the week data collection commenced. Recommendations from Shaw et al and the need to closely monitor connectivity necessitated that this study take place at Midwestern University in Glendale, Arizona. Requiring participants to individually provide transportation to Midwestern University, as opposed to the primary investigator conducting this investigation in community settings such as a senior center or place of worship, actually lengthened the period of time for achieving an adequate sample size.

Resources Used

Technology-related resources for data collection and analysis include the following:

- *Telehealth Hub Site*: 1) Two, 42" NEC LCD displays, 2) Polycom HD videoconferencing system software, 3) Polycom HD pan-tilt-zoom camera, 4) Dell Optiplex 780 computer, 5) Revolabs HD microphone
- *Telehealth Remote Site*: 1) Dell Mobile Precision M6600 17.3" Full DH, LED laptop computer, 2) Polycom and CMA Desktop software, 3) Logitech HD PRO C920 web-camera, 4) High speed internet with secure bridge connection using CAT5 or higher Ethernet cord.
- Statistics were calculated using IBM SPSS for Windows (versions 19.0 and 22.0).

In an attempt to minimize threats to internal validity, the following resources guided the administration of and rater training in each fall risk screening tool:

- 4-meter Walk Test: https://www.youtube.com/watch?v=vrm4JP7l1Ms
- Performance Oriented Mobility Assessment: https://www.youtube.com/watch?v=7FNn2-i_-og
- Functional Reach Test: https://www.youtube.com/watch?v=jJJELnJk1Nw
- Timed Up and Go Test: https://www.youtube.com/watch?v=BA7Y_oLElGY (STEADI)
- 30-second Chair Rise Test: https://www.youtube.com/watch?v=Ng-UOHjTejY (STEADI)
- 4-Stage Balance Test: https://www.youtube.com/watch?v=3HvMLLIGY6c (STEADI)

Standardized written instructions and scoring sheets are in Appendix E.

The following equipment was used for the administration of the POMA-G, 4-meter Walk, Functional Reach, TUG, 30-second Chair Rise, and 4-Stage Balance Tests:[20,124,130,148,152,162,165,187]

- POMA
    - 15 feet of unobstructed walking path
    - 1 hard, armless chair, 17" in height (POMA-B)
- 4-Meter Walk Test
    - Digital stopwatches for each rater
    - Measuring tape to measure to acceleration, timed, and deceleration zones
    - Colored tape to mark start and stop points
    - 20 feet of unobstructed walking path
- FRT
    - Two wall-mounted, yard sticks (for left and right-handed dominant participants) mounted parallel in reverse direction of each other
    - Colored tape to mark standing position
- TUG
    - Digital stopwatches for each rater
    - 1 hard chair with arm rests, 17" in height
    - 1 cone and colored tape
    - 1 tape measure with tape to mark 10 foot walking path
- 30-second Chair Rise Test
    - Digital stopwatches for each rater
    - A chair with straight back without arm rests 17" in height
- 4-Stage Balance Tests

- Digital stopwatches for each rater
- Two straight back chairs for upper extremity support as needed by participants
- Laminated 8” x 11.5” white paper with enlarged black/white foot positions to supplement the lead rater’s verbal instructions

Figure 4 provides a schematic layout of the telerehab data collection space. The research space had wall-to-wall, low pile carpeting glued onto concrete floors. This floor covering did not appear to impact the outcome of any fall screening tests. Note that the camera / laptop required repositioning on 3 occasions during each TR fall screening session to accommodate the allocated research space.

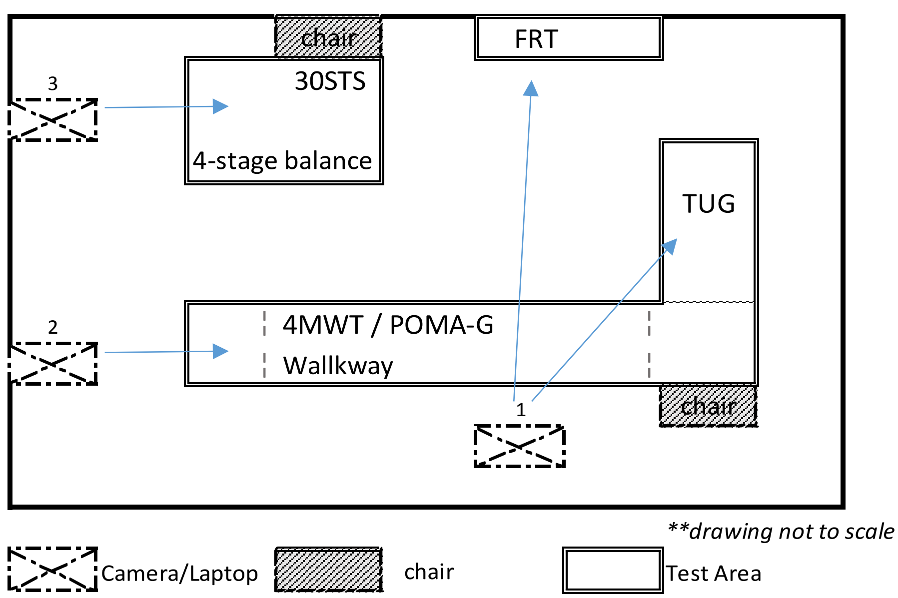


Figure 4. Telerehab Research Space

Data Analysis (Reliability and Validity)

Analysis of covariance (ANCOVA) was used to test the hypothesis that there was no difference in attitudes and beliefs of older adults in the control versus post-test intervention (TR) groups. Pre- and post-test survey results were appraised for internal consistency using Cronbach’s alpha.

Reliability of a telerehabilitation delivery system was determined by calculating 1) Interclass Correlation Coefficients (ICC) to quantify interrater and inter-environment agreement of scores from fall risk screening tools simultaneously measured by face-to-face and remote raters, and 2) Cohen's Kappa to quantify inter-environment agreement of fall risk categorization using dichotomous cut-off scores[188] where applicable for the FRT, TUG, 30STS, Four-Stage Balance, POMA-G, 4MWT, and STEADI toolkit algorithm. To account for the random effects from subjects and to fully appraise the agreement of all four raters, a two-factor random effects model was used to supplement ICC values.

Validity of a telerehabilitation delivery system was determined by calculating 1) receiver operating characteristic (ROC) curves for comparing results from face-to-face and telerehab raters with independent variables from the Fall History Questionnaire (fall history since age 65, 12-month fall history, 12-month emergent care history, fall-related fracture history, and 6-month medication change history all collected at baseline, and a 6-month prospective fall report collected by phone, 2) Correlation data to evaluate the degree of relationships between fall screening tests and the independent variables, and 3) sensitivity and specificity of fall screening tools that have established cut-off values for fall risk and participant's self-reported overall since age 65 and 12-month retrospective fall histories, as well as 6-month prospective fall incidence. Both correlation and ROC analyses were implemented to determine *concurrent validity* by comparing the fall risk conclusions from a remote (telerehab) clinician conducting the STEADI with a face-to-face clinician conducting the psychometrically validated and normative referenced Mini-BEST.[124,131] All statistical measurement for this investigation used a confidence interval of 95% (α=0.05).

CHAPTER FOUR: RESULTS

Introduction

This investigation was able to provide evidence to support the reliability and validity of telerehabilitation for fall risk screening through inferential statistical analysis. Furthermore, the survey instrument was able to quantify positive changes in the attitudes and beliefs of older adults towards technology-aided physical therapy among experimental group participants.

Baseline Data

To most accurately appraise research question 1 (*What effect does exposure to a telerehabilitation delivery system have on underlying attitudes and beliefs of older adults about the perceived usefulness of this healthcare delivery option?*), an experimental design and control group were employed to minimize threats to internal validity. Descriptive statistics were calculated for all 84 participants randomly assigned to one of two groups (experimental n=39, control n=45). Furthermore, a one-way analysis of variance (ANOVA) was used to determine if any statistical differences existed between the sampled experimental and control groups. To that end, age, gender, fall history, fracture history, prior use of emergent care, recent medication changes, assistive device use, place of residence, and baseline scores on the STEADI's Stay Independent Brochure Questionnaire were used as dependent variables for comparison with the grouping (independent or factor) variable. With the exception of self-reported number of falls in the 12-months ($p = 0.012$) prior to participating in this investigation, no significant differences were calculated between members of the experimental and control groups ($p = 0.083$-0.772). The control group had a greater percentage of participants (64.4% or 29/45) reporting no falls in the previous 12-months as compared to participants of the experimental group (43.6% or 17/39). However, this difference in fall rates leveled off somewhat with an insignificant difference in number of falls since age 65 between groups (p = 0.083). Table 2 demonstrates the equivalency of demographics between the control and intervention groups.

Table 2. Baseline Descriptive Statistics and Analysis of Variance Comparing Control and Experimental Groups

Variable	Group (Control n=45 Experimental n=39)	Mean (SD) Range	Description	df	F	p
Age	Experimental	74.6 (6.3) 65-93	-	83	0.705	0.404
	Control	76.0 (8.7) 65-96				
Gender	Experimental	-	19 male 20 female	83	1.009	0.318
	Control		17 male 28 female			
Falls Since Age 65	Experimental	-	0 falls = 10 1 fall = 7 2-3 falls = 9 4-5 falls = 5 5+ falls = 8	83	3.090	0.083
	Control		0 falls = 17 1 fall = 9 2-3 falls = 11 4-5 falls = 4 5+ falls = 4			
Fall-related Fractures	Experimental	-	Yes = 6 No = 33	83	0.084	0.772
	Control		Yes = 7 No = 38			
Falls in Last 12months	Experimental	-	0 falls = 17 1 fall = 10 2-3 falls = 7 4-5 falls = 4 5+ falls = 1	83	6.650	0.012*
	Control		0 falls = 29 1 fall = 11 2-3 falls = 4 4-5 falls = 1 5+ falls = 0			

Emergent Care related to Falls Last 12months	Experimental	-	0 episodes = 32 1 episode = 4 2+ episodes = 3	83	1.393	0.241
	Control		0 episodes = 39 1 episode = 6 2+ episodes = 0			
Medication Changes Last 6months	Experimental	-	Yes = 11 No = 28	83	0.508	0.478
	Control		Yes = 16 No = 29			
Assistive Device Use	Experimental	-	Yes = 8 No = 31	83	0.099	0.754
	Control		Yes = 8 No = 37			
Primary Residence	Experimental	-	House = 29 Apartment = 8 ALF = 1 Group Home = 1	83	0.193	0.662
	Control		House = 31 Apartment = 12 ALF = 0 Group Home = 2			
Score Stay Independent Questionnaire	Experimental	-	Elevated Risk ($\geq$4) = 20 Low Risk = 19	83	0.370	0.545
	Control		Elevated Risk ($\geq$4) = 23 Low Risk = 22			

Research Question 1

The following methods pertain to the data analysis process of research question 1 (*What effect does exposure to a telerehabilitation delivery system have on underlying attitudes and beliefs of older adults about the perceived usefulness of this healthcare delivery option?*). To quantifiably test this hypothesis, a survey instrument was developed to measure the effect, if any, that exposure to a telerehabilitation delivery system has on baseline attitudes and beliefs towards this technology application. As was described in Chapter 3, the telerehabilitation (TR) survey instrument was constructed based upon a thorough review of the literature. The literature search identified seven major constructs to guide the construction of this survey instrument. The preliminary survey drafted by the primary investigator underwent a content validation process through the establishment of a review panel of experts. Seven professionals with expertise in healthcare and/or information technology (IT) and multi-media, as well as one older adult community member were invited to serve as panelists. All eight people were invited through email communication in February 2016 and each accepted their invitation to assist with content validation of the survey instrument. However, upon electronic distribution of instructions and research articles to review, one panelist withdrew his participation (D.B.). Table 3 lists each panelist's credentials.

Table 3. Telerehabilitation Survey Instrument Panel of Experts

Panelist	Degree/Credentials	Current Position
DB	BA	Assistant Director Media Resources, Midwestern University, Glendale, Arizona
KB	PT, M.Ed., DPT, GCS, CEEAA	Supervisor Mayo Clinic and PT Geriatrics Residency; Scottsdale, Arizona Adjunct Faculty Northern Arizona University; Phoenix, Arizona
SC	CTS	Audio Visual Coordinator Media Resources Department, Midwestern University, Glendale Arizona
MF	MS	Systems Developer Information Technology Department, Midwestern University; Glendale, Arizona
GH	PT, DPT, GCS, CEEAA	Assistant Professor University of Miami; Miami. Florida; Chair Practice Committee APTA Academy of Geriatrics
HM	BS	Community Representative, retired; Phoenix, Arizona
KS	PT, DPT, CCCE	Physical Therapist and Center Coordinator for Clinical Education

		Banner Thunderbird Hospital; Glendale, Arizona Adjunct Faculty Midwestern University, Glendale Arizona
JS	MS, PA-C, DFAAPA	Associate Professor and Director of Clinical Skills and Simulation Midwestern University; Glendale, Arizona

The TR survey instrument underwent two comprehensive reviews by the panel. Review by each panelist was independent of one another and written feedback was submitted directly to the primary investigator through electronic mail. All panelists were blinded to each other's name and contact information to minimize threats to internal validity. Instructions for review #1 in addition to reference materials were emailed to all eight panelists on March 7, 2016. Two journal articles integral to the field of end-user technology acceptance and fundamental to the seven survey constructs were provided. The reference articles were: 1) Cimperman's "Older adults' perceptions of home telehealth services." *Telemed J E Health.* 2013 and 2) Venkatesh's "User acceptance of information technology: toward a unified view." *MIS Q.* 2003. The introductory letter submitted to panelists as an electronic mail attachment included a confidentiality waiver, an overview of and introduction to the research, detailed instructions for review #1 and review #2, as well as the preliminary draft of the TR survey instrument (Appendix F).

Panelists were given seven calendar days to email their feedback to the investigator. Six of seven panelists completed review #1 within the designated timeframe (J.S. did not completed review #1). Cumulative feedback was then integrated into a second draft of the TR survey instrument. This iteration was emailed to the panel of experts on March 29, 2016. Cumulative rater comments from review #1 and review #2 is located in Appendix H. As with review #1, panel members were given seven calendar days to complete and submit their reviews. All seven panelists submitted feedback within the seven-day timeframe and, therefore, were included in calculation of content validity ratios for each survey item. Review #2 was highlighted by individual panelists rating each survey item as 1) "essential," 2) "useful but not essential" or 3) "not necessary" to the performance of its corresponding construct. This classification system was consistent with a publication by Lawshe entitled, "a quantitative approach to content validity."[179] To quantify the extent to which members of a content evaluation panel perceive overlap between a "test" and a "performance domain," Lawshe developed a formula for calculating a content validity ratio (CVR). Lawshe's formula is represented in Figure 5.

$$CVR = \frac{n_e - N/2}{N/2}$$

*n_e represents the number of panelists labeling an item "essential"
*N represents the total number of panelists

Figure 5. Content Validity Formula (Lawshe, 1975)

When fewer than half of a review panel indicate that an item was essential, the CVR is a negative value. If half of the panelists indicate that an item was essential and the other half does not, the CVR is zero. When more than half of the panelists but fewer than all indicate that an item is essential, the CVR is between zero and 0.99. Like a correlation coefficient, the closer the CVR was to 1.0, the greater the chance that an item was accepted rather than rejected.[179] Lawshe calculated minimum values of CVR based upon the total number of review panelists. For example, the target minimum CVR value for a panel of 8 should be 0.75 at a 95% confidence interval level although Lawshe indicates that an item CVR with less than the minimal value does *not* mean it must be rejected. Further, use of the CVR process does not preclude use of other determinants for retaining items in the final form of a survey. Figure 6 outlines the calculated CVR for each item that remained in review #2. This figure includes item 6c (*Greater access to a physical therapist was a good reason to start using a computer*) which was unanimously approved by panelists for addition to the final Telerehabilitation (TR) survey.

	1. Performance Expectancy / Perceived Usefulness							2. Effort Expectancy					3. Social Influence			
Expert Panelist	Q1a	Q1b	Q1c	Q1d	Q1e	Q1f	Q1g	Q2a	Q2b	Q2c	Q2d	Q2e	Q3a	Q3b	Q3c	Q3d
01	E	U	E	E	E	U	E	E	N	E	E	E	U	N	N	N
02	E	E	E	E	U	E	U	E	E	E	E	E	U	U	U	E
03	E	E	E	E	E	U	U	E	E	E	E	E	U	E	E	E
04	E	E	E	E	U	U	E	E	E	E	E	E	E	U	E	U
05	U	E	E	E	E	E	E	U	E	E	U	U	U	N	N	N
06	E	E	U	U	E	E	E	E	E	E	E	E	E	E	E	E
07	E	E	U	U	N	E	N	E	E	E	E	U	E	U	E	E
mean	1.86	1.86	1.7	1.7	1.43	1.57	1.43	1.86	1.7	2	1.86	1.7	1.43	1	1.29	1.29
CVR	0.71	0.71	0.43	0.43	0.14	0.14	0.14	0.71	0.71	1	0.71	0.43	-0.14	-0.42	0.14	0.14

	4. Facilitating Condition				5. Perceived Security						6. Computer Anxiety			7. Physician's Opinion				
Expert Panelist	Q4a	Q4b	Q4c	Q4d	Q5a	Q5b	Q5c	Q5d	Q5e	Q5f	Q6a	Q6b	Q6c	Q7a	Q7b	Q7c	Q7d	
01	E	E	E	U	U	E	E	E	E	N	E	E	E	U	E	N	E	
02	E	E	E	E	E	U	E	E	E	U	U	E	E	U	U	E	U	
03	U	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	U	
04	E	E	U	E	E	E	E	E	E	E	U	E	U	E	U	E	E	
05	E	E	E	U	U	U	E	E	E	U	U	E	U	U	U	E	U	
06	E	E	E	E	E	E	E	E	U	E	E	E	E	E	E	E	E	
07	E	E	E	U	E	E	E	E	U	N	E	E	U	U	E	E	E	
mean	1.86	2	1.86	1.57	1.7	1.7	2	2	1.7	1.14	1.57	2	1.57	1.43	1.57	1.7	1.57	1.66
CVR	0.71	1	0.71	0.14	0.43	0.43	1	1	0.43	-0.14	0.14	1	0.14	-0.14	0.14	0.71	0.14	0.42

Figure 6. Telerehabilitation Survey Instrument Content Validation Ratios

The average CVR of related items is also referred to the content validity index (CVI). According to Lawshe, the CVI represents the average percentage of over-lap between the test items and the "performance domain" or construct under analysis. The mean CVR or the CVI for all seven constructs was 0.42. The CVI for each of the seven composite sections was as follows: 1) Performance expectancy / perceived usefulness: 0.38; 2) Effort expectancy: 0.71; 3) Social influence: -0.07; 4) Facilitating conditions: 0.64; 5) Perceived security: 0.52; 6) Computer anxiety: 0.43; 7) Physician's opinion: 0.21. Similar to the CVR, the CVI can also be used when considering the acceptance or rejection of individual items or domains.[179] Had Lawshe's recommended minimum target CVR value of 0.75 (for a panel of 8) be held to its strictest statistical interpretation, three of the seven construct categories and 28 out of the 33 survey items would have been eliminated. For the exploratory purpose on the usefulness of this tool on this population, no survey items were deleted from inclusion in the final draft due to low CVR or CVI values; rather, these items were retained for further analysis of and comparison with internal consistency among pre- and post-test survey scores.

To examine the reliability of the 33-item TR survey instrument, composite scores for each of the seven construct categories were calculated. Internal consistency, or survey homogeneity, reflects the extent to which items measure the same characteristic or construct. This value was measured using Cronbach's Alpha (α). A construct that yields similar scores across all items has a high degree of internal consistency and, therefore, yields a higher alpha level (0 to 1.00).[37] Pre-test scores for all participants (n=84; 39 intervention group, 45 control group) were analyzed for each item among all seven constructs or sub-categories of the TR survey. The survey instrument was found to have excellent internal consistency among *pre-test* scores with construct 1 (performance expectancy/perceived usefulness; $\alpha = 0.955$), construct 2 (effort expectancy; $\alpha = 0.965$), and construct 6 (computer anxiety; $\alpha = 0.906$), good internal consistency with construct 3 (social influence; $\alpha = 0.890$) and construct 5 (perceived security; $\alpha = 0.884$), and acceptable internal consistency with construct 4 (facilitating conditions; $\alpha = 0.742$) and construct 7 (physician's opinion; $\alpha = 0.794$). Post-test scores for all participants were analyzed for each item among all seven constructs. Five participants in the control group were unable to be reached to complete their post-test survey and, therefore, reduced the sample size for the post-test analysis from 84 to 79 (39 intervention group, 40 control group). The survey instrument was found to have excellent internal consistency among *post-test* scores with construct 1 (performance expectancy/perceived usefulness; $\alpha = 0.959$), construct 2 (effort expectancy; $\alpha = 0.969$), construct 3 (social influence; $\alpha = 0.916$), and construct 5 (perceived security; $\alpha = 0.927$), good internal consistency with construct 6 (computer anxiety; $\alpha = 0.816$), and acceptable internal consistency with construct 7 (physician's opinion; $\alpha = 0.783$); however, construct 4 (facilitating conditions; $\alpha = 0.645$) demonstrated less than acceptable internal consistency. Overall, the mean Crohnbach's alpha levels calculated across all constructs reveals good internal consistency with pre-test (α∝ = 0.877) and post-test (α = 0.859) surveys. Table 4 lists and compares pre- and post-test alpha levels for each construct.

Table 4. Internal Consistency of the Telerehabilitation Survey Instrument

Survey Construct	Pre-test Cronbach's α	Post-test Cronbach's α
1. performance expectancy /perceived usefulness	0.955	0.959
2. effort expectancy	0.965	0.969
3. social influence	0.890	0.916
4. facilitating conditions	0.742	0.645
5. perceived security	0.884	0.927
6. computer anxiety	0.906	0.816
7. physician's opinion	0.794	0.783
Mean for all constructs	*0.877*	*0.859*

The probability of drawing incorrect conclusions increases as the number of repeated tests increases.[37] To control for this and eliminate the need for numerous Bonferroni corrections that would be needed to account for a 33-item survey, a total composite score was calculated for each construct. A univariate analysis of variance (ANOVA) was performed comparing the total composite scores between groups for all seven constructs and revealed the following statistical findings. For construct 1, the intervention group scored significantly higher (M = 41.97, SD = 7.314) relative to the control group (M = 31.78, SD = 12.559; $F(1, 76) = 23.431$, $p < .001$, $\eta^2 = 0.236$). For construct 2, the intervention group scored significantly higher (M = 28.28, SD = 7.056) relative to the control group (M = 20.50, SD = 9.304; $F(1, 76) = 21.294$, $p < .001$, $\eta^2 = 0.219$). For construct 3, there was no significant main effect in intervention (M = 15.64, SD = 8.695) relative to control (M = 15.58, SD = 6.644; $F(1, 76) = 1.497$, $p = .225$, $\eta^2 = 0.019$). For construct 4, the intervention group scored significantly higher (M = 21.77, SD = 4.960) relative to the control group (M = 19.37, SD = 4.510; F(1, 76) = 8.182, p = .005, η^2 = 0.097). For construct 5, the intervention group scored significantly higher (M = 34.79, SD = 6.453) relative to the control group (M = 26.10, SD = 9.432; F(1, 76) = 21.637, p < .001, η^2 = 0.222). For construct 6, there was a nonsignificant upwards trend with the intervention group (M = 16.49, SD = 4.303) relative to the control group (M = 14.10, SD = 5.042; F(1, 76) = 2.924, p = 0.091, η^2 = 0.037). For construct 7, there was a nonsignificant upwards trend with the intervention group (M = 21.67, SD = 3.779) relative to the control group (M = 18.13, SD = 6.661; F(1, 76) = 2.924, p = 0.057, η^2 = 0.047). Table 5 lists the results from the ANCOVA statistical calculations including effect sizes using the Partial Eta squared analysis.

Table 5. Telerehabilitation Survey Instrument Analysis of Covariance (ANCOVA), Mean Composite Scores (SD), Level of Significance, and Effect Sizes Comparing Pre- and Post-test Scores Among Groups

Construct	Group	Pre Mean (SD)	Post Mean (SD)	F	p	Partial Eta^2
1	Experimental	35.03 (9.75)	41.97 (7.31)	23.431	<0.001*	0.236
	Control	32.03 (12.27)	31.78 (12.56)			
2	Experimental	20.18 (4.18)	28.28 (7.06)	21.294	<0.001*	0.219
	Control	17.22 (6.10)	20.50 (9.30)			
3	Experimental	16.74 (6.61)	15.64 (8.70)	1.497	0.225	0.019
	Control	14.20 (7.80)	15.58 (6.64)			
4	Experimental	19.38 (6.18)	21.77 (4.96)	8.182	0.005*	0.097
	Control	19.83 (5.60)	19.37 (4.51)			
5	Experimental	30.05 (6.68)	34.79 (6.45)	21.637	<0.001*	0.222
	Control	27.28 (9.07)	26.10 (9.43)			
6	Experimental	15.26 (4.06)	16.49 (4.30)	2.924	0.091	0.037
	Control	13.68 (5.55)	14.10 (5.04)			
7	Experimental	20.18 (4.18)	21.67 (3.78)	2.924	0.057	0.047
	Control	17.58 (5.87)	18.13 (6.66)			

* = p $\leq$0.05

The maximum point values for each composite score varied for each construct based upon the number of items approved by the panel of experts. Construct 1 (performance expectancy/perceived usefulness) had the most items (7) with a maximum of 49 points. Construct 6 (computer anxiety) had the least number of items (3) with a maximum of 21 points. (Appendix I)

The control group (n= 45) was essentially the "survey-only" group completing the Fall History Questionnaire, Stay Independent Brochure Questionnaire, and the TR Survey Instrument at baseline as well as a follow-up post-test TR survey approximately 1 month following their pre-testing. The control group did not play a role with calculating the reliability and validity of a telerehabilitation delivery system. The experimental or intervention group (n = 39) completed the Fall History Questionnaire, Stay Independent Questionnaire, and the Telerehabilitation Survey Instrument at baseline and the TR survey again immediately following their individual fall screening tests and measures (Figure 2). The fall screening tests consisted of the Functional Reach Test (FRT), Time-Up and Go Test (TUG), 4-Meter Walk Test (4MWT), 4-Stage Balance Tests (narrow stance, narrow stride stance, tandem stance, and single-limb stance), and the 30-second Chair Rise Test (30STS) simultaneously scored by two face-to-face and two telerehab raters in real-time, and the Mini-BEST was scored simultaneously by two face-to-face raters. The appointed lead telerehab clinician (rater 1) provided the verbal instructions for all of the fall screening tests with the exception of the face-to-face reference standard, the Mini-BEST. The Mini-BEST was not evaluated with the synchronous audio-visual connection due to safety concerns with remote implementation. Consistent with methodologies and rationale described in Chapter 3, the same telerehab rater provided instructions for all members of the experimental group to eliminate potential threats to internal validity that changes in voice, personality, or gender may induce. The order of the fall screening tests were varied to prevent post-test bias or consistency of effects when completing the TR Survey.

To examine the reliability, validity, and potential impact that exposure to a telerehabilitation delivery system has on older adults, 39 members of the experimental group participated in a series of standardized fall screening tests. Following the standardized rater training on the fall risk screening tools described in Chapter 3, baseline interrater agreement was calculated to establish reliability among raters using five pilot subjects. Because recruitment of licensed physical therapists with at least two years of experience treating geriatric clientele proved difficult to secure and coordinate with available physical plant resources at Midwestern University, 3rd year physical therapy students with a GPA of at least 3.0 on a 4.0 scale served as primary face-to-face and remote raters. Rater consistency was maintained for the majority of environments, roles, and data collection dates. Rater 1 from the face-to-face and telerehab environments as well as both Mini-BEST raters were the same for all participants. However, rater 2 varied for two of the seven data collection dates for reasons outside of the investigator's control. This slight variability necessitated the implementation of a two-factor random effects model to supplement reliability data.

Baseline reliability was established following standardized rater training using five pilot subjects. Each rater was assessed for face-to-face test scoring reliability with an expert physical therapy clinician with over 19 years of experience. Outcomes from this pilot testing are as follows: For the Mini-BEST, Cronbach's alpha was 0.982 with $p<0.001$ among the 3 raters trained for this test. For the 4-Meter Walk Test, Cronbach's alpha was 0.971 – 0.995 with $p<0.001$ – 0.002 among the 5 raters trained for this test. For the Tinetti Gait instrument, Cronbach's alpha was 0.857 – 1.000 with $p<0.001$ – 0.49 among the 5 raters trained for this test. For the Functional Reach Test, Cronbach's alpha was 0.916 – 0.992 with $p<0.001$ – 0.017 among the 5 raters trained for this test. For the STEADI balance, strength, and mobility tests (TUG, four-stage balance, 30STS), Cronbach's alpha ranged from 0.975 - 1.000 with $p<0.001$ – 0.002 among the 5 raters trained for these tests.

Research Question 2

The following information pertains to the data analysis process of research question 2 (*Are fall risk screening conclusions that are derived remotely equivalent to other reference standard face-to-face screening tools?*). This research question and subsequent analyses tested the hypothesis that there lacks equivalence between fall risk conclusions from remote raters implementing the STEADI and face-to-face raters implementing the Mini-BEST.

Prior to analyzing the relationship and level of agreement between the Mini-BEST and telerehab STEADI, agreement between face-to-face and remote raters scoring the STEADI algorithm was established. Intraclass correlation coefficient (ICC) analysis indicated a 99.1% agreement between face-to-face rater 1 (M = 1.97 on a 3-point risk scale, SD = 0.843) and telehealth rater 1 (M= 2.00 on a 3-point risk scale, SD = 0.827; Cronbach's alpha (38) = 0.991, p < 0.001), and a strong inter-item correlation of risk assignment among rater environments (r = 0.981, p < 0.001) when analyzing the STEADI algorithm in its published three-tiered risk scale. Because sensitivity, specificity, and receiver operating characteristic (ROC) curves require a dichotomous variable for their analysis, the three-tiered STEADI algorithm was also calculated as a two-tiered categorization by combining moderate and high classifications into an elevated risk category. The kappa statistic indicated an almost perfect significant (k = 0.943, p <0.001) agreement between the face-to-face rater (M = 1.67, SD = 0.530) and the lead telehealth rater (M= 1.67, SD = 0.478), and a strong inter-item correlation of risk assignment among rater environments (r = 0.940, p < 0.001) when analyzing the STEADI algorithm as a two-tiered risk scale.

Examining the concurrent validity between conclusions from the face-to-face reference standard, the Mini-BEST, and conclusions from the telerehab STEADI revealed moderate, significant relationship between the two screening tests using the Spearman's rho correlation coefficient (r = 0.447, p = 0.004). Because the Mini-BEST is a dichotomous scale and the CDC's STEADI algorithm has three levels of fall risk, moderate and high fall risk levels on the STEADI were again combined into one risk level to create a nominal variable similar to the Mini-BEST. After consolidating the three risk levels into a dichotomous scale, the relationship between the Mini-BEST and STEADI weakened (r = 0.258, p = 0.113). However, the relationship between the Mini-BEST and a STEADI demonstrated equivalence with a weaker insignificant relationship with both TR (r = 0.258, p = 0.113) and face-to-face (r = 0.283, p = 0.081) environments when the STEADI was reduced from its published three-tiered risk model. Using a Spearman rho correlation coefficient to examine the relationship between the STEADI algorithm's published three-tiered fall risk model and the simplified two-tiered model revealed a strong, significant relationship for the telerehab (r = 0.866, p <0.001) and face-to-face (r = 0.882, p = <0.001) raters.

The next step in examining the validity of the telerehab STEADI and its concurrent validity with the face-to-face Mini-BEST was to calculate the sensitivity, specificity, and likelihood ratios. Table 6 summarizes the validity of both the STEADI and Mini-BEST in terms of their ability to accurately assess the presence or absence of a target condition or dichotomous risk outcomes from other screening tools. The telerehab STEADI demonstrated excellent sensitivity at 89%, but low specificity (40%), positive likelihood (1.48) and negative likelihood ratios (0.28). The high sensitivity value (89%) confirms the STEADI's ability to obtain a positive screening outcome when a positive fall risk was *also* concluded by the reference standard, Mini-BEST (i.e. target condition was present). Conversely, fall risk conclusions from the face-to-face Mini-BEST were able to differentiate participant fall risk conclusions from the telerehab

STEADI. Fall risk outcomes used to test the validity of the Mini-BEST compared with outcomes from the STEADI indicated low sensitivity (31%) and a negative likelihood ratio (0.75); however, high specificity (92%) and a moderate positive likelihood ratio (4.0) were calculated. The high specificity value confirms the Mini-BEST's ability to obtain a negative test when a negative (low) fall risk was also concluded by the STEADI (i.e. the condition was absent). Similar to calculating the Receiver Operating Characteristic (ROC) Curves that are described in subsequent sections of Chapter 4, six independent variables from the Fall History Questionnaire (fall history since age 65, 12-month fall history, 12-month emergent care, fracture history, 6-month medication change history, and 6-month prospective falls), prospective follow-up interviews, and risk conclusions from the Stay Independent Brochure were used to further examine the validity of the STEADI algorithm and for comparison with the reference standard, Mini-BEST. Table 7 reveals good sensitivity of the STEADI (75%) and excellent specificity of the Mini-BEST (89.5%) with similar positive or negative risk results concluded on the Stay Independent Brochure. Similarly, the telerehab STEADI has by far better sensitivity with "diagnosing" positive 6-month prospective fall incidences (80%), retrospective fall history since age 65 (76%), 12-month fall history (73%), 12-month emergent care history (86%), fracture history (75%), and 6-month medication change history (73%), whereas the Mini-BEST has much better specificity measures for 6-month prospective fall incidence (85%), fall history since age 65 (90%), 12-month fall history (88%), 12-month emergent care history (78%), fracture history (74%), and 6-month medication change history (71%). Overall, positive and negative likelihood ratios indicated limited usefulness and mostly small effects in each test's ability to rule-in or rule-out factors typically associated with screening tool test results. This is likely influenced by a less than ideal sample size and an elevated history of falls with sampled participants.

Table 6. Comparative Analysis of Sensitivity, Specificity, and Likelihood ratios for the Telerehab STEADI and Mini-BEST

Independent Variable	STEADI (telerehab)	Mini-BEST
STEADI		
Sensitivity	n/a	30.8%
Specificity		92.3%
(+) LR		4.0
(-) LR		0.75
Mini-BEST		
Sensitivity	88.9%	n/a
Specificity	40.0%	
(+) LR	1.48	
(-) LR	0.28	
Stay Independent Brochure		
Sensitivity	75.0%	35.0%
Specificity	42.1%	89.5%
(+) LR	1.30	3.33
(-) LR	0.59	0.73
Fall History		
Sensitivity	75.9%	27.6%
Specificity	60.0%	90.0%
(+) LR	1.90	3.45
(-) LR	0.40	0.73
12-month Fall History		
Sensitivity	72.7%	31.8%
Specificity	41.2%	88.2%
(+) LR	1.24	2.70
(-) LR	0.66	0.77
6-month prospective falls		
Sensitivity	80.0%	50.0%
Specificity	38.5%	84.6%
(+) LR	1.3	3.25
(-) LR	0.52	0.59
12-month Emergent Care		
Sensitivity	85.7%	28.5%
Specificity	37.5%	78.0%

(+) LR	1.37	1.31
(-) LR	0.38	0.91
Fracture History		
Sensitivity	75.0%	12.5%
Specificity	35.5%	74.2%
(+) LR	1.16	0.48
(-) LR	0.70	1.18
6-month Medication Changes		
Sensitivity	72.7%	9.1%
Specificity	35.7%	71.4%
(+) LR	1.13	0.32
(-) LR	0.76	1.27

n = 39

As a supplement to examining the validity of a telerehabilitation delivery system, the fall screening tools with established cut-off points (FRT, 4MWT, TUG, tandem stance, 30STS) were examined for their validity when implemented by a remote rater. As outlined in Chapter 3, there are two cut-off points published for the FRT (7" and 10"). When examining results of the FRT from telerehab and face-to-face raters, the 7" cut-off point had perfect 100% specificity with identifying participants without a fall history since age 65. This was equivalent for both test environments. However, sensitivity values were much lower when using the FRT results to classifying a positive fall history since age 65 (14 – 31% for 7 and 10" cut scores) and 12-month fall history (9 – 32% for 7" and 10" cut scores), and predict 6-month prospective fall incidence (0 – 20% for 7" and 10" cut scores). Despite this, very good specificity scores were also calculated for the FRT's ability to test higher than the 7" and 10" cut-off scores when, in fact, the participant lacked a prior 12-month fall history (71-88%) and 6-month prospective falls (69-89%) for both telerehab and face-to-face environments. As with sensitivity, specificity calculations were most accurate using the FRT's 7" cut-off point.

Validity calculations of the 4MWT revealed similar results to the FRT in that specificity was good to excellent among telerehab conclusions for fall history since age 65 (88%), 12-month fall history (82%), and 6-month prospective fall incidence (81%). The face-to-face environment calculated a somewhat higher specificity level indicating excellent (90%) negative fall rate “diagnostic” ability for both retrospective fall history variables, but average (77%) level specificity for predicting negative 6-month prospective fall incidence. Sensitivity levels for the 4MWT classifying retrospective fallers and predicting prospective falls were unacceptable for both rater environments.

Like the 4MWT and FRT, the TUG was also calculated to have poor sensitivity conclusions with this investigation. However, specificity levels for classifying a negative fall history since age 65 was excellent for both telerehab (90%) and face-to-face (90-100%) environments using both the 12-second and 13-second cut-off points. Specificity was average to good for classifying negative 12-month retrospective fallers and predicting 6-month prospective fall rates for both environments. As previously outlined, the STEADI algorithm references a 12-second cut-off point for the TUG but the literature generally agrees on a 13-second cut-off point for fall risk among community-dwelling older adults. That said, specificity remained acceptable to good (73-85%) for both environments and both cut points when using the TUG to identify those with negative 12-month fall history and 6-month follow-up fall rates. Based upon this data, no recommendations can be made to discern a 12-second versus a 13-second cut-off score.

The cut-off point for fall risk published in the STEADI algorithm for tandem stance was less than 10 seconds and the tandem stance was the only component of the 4-Stage Balance Test to have a referenced fall risk value within the STEADI toolkit. That said, the tandem stance was calculated to have acceptable to good specificity (70%) in identifying participants who have not fallen since age 65 for both left and right test positions among both telerehab and face-to-face environments. Specificity is not useful, however, when examining the tandem stance test's validity with 12-month fall history (53-59%) or with 6-month prospective fall incidence (62-65%).

Lastly, the 30STS Test demonstrates acceptable specificity at 70% with its ability to identify non-fallers since age 65 with telerehab and face-to-face environments. While the probability of correctly identifying those with 12-month retrospective falls (50-51%) and 6-month prospective falls (50-60%) increases as compared to the overall fall history since turning age 65, the sensitivity remains relatively low for both environments and for all three independent variable categories. Table 7 lists complete sensitivity, specificity, and likelihood ratios for each of these four fall risk screening tools. Overall, calculated likelihood ratios for each fall screening tool are limited in their effect and usefulness.

Table 7. Comparative Analysis of Sensitivity, Specificity, and Likelihood Ratios for Dependent Variable Tool Ability to Classify and Predict Self-Reported Fall History

Dependent Variable	**Telerehabilitation**		**Independent Variables**	**Face-to-Face**	
Functional Reach Test	7" cut	10" cut		7" cut	10" cut
Sensitivity	13.8%	24.1%	*Fall History since age 65*	17.2%	31.0%
Specificity	100%	70.0%		100%	70.0%
(+) LR	n/a	0.80		n/a	1.03
(-) LR	0.86	1.08		0.86	0.98
Sensitivity	9.1%	22.7%	*12-month Fall History*	13.6%	31.8%
Specificity	88.2%	70.6%		88.2%	70.6%
(+) LR	0.77	0.77		1.16	1.08
(-) LR	1.03	1.09		0.98	0.97
Sensitivity	0.0%	10.0%		0.0%	20.0%

	Specificity	88.5%	73.1%	*6-month prospective falls*	88.5%	69.2%
	(+) LR	0.0	0.37		0.0	0.65
	(-) LR	1.13	1.23		1.13	1.16
4-meter Walk Test						
	Sensitivity	36.4%		*Fall History since age 65*	31.0%	
	Specificity	88.2%			90.0%	
	(+) LR	3.09			3.10	
	(-) LR	0.72			0.77	
	Sensitivity	36.4%		*12-month Fall History*	31.0%	
	Specificity	82.4%			90.0%	
	(+) LR	2.06			3.10	
	(-) LR	0.77			0.77	
	Sensitivity	40.0%		*6-month prospective falls*	40.0%	
	Specificity	80.8%			76.9%	
	(+) LR	2.08			1.73	
	(-) LR	0.74			0.78	
Timed-Up and Go Test		12sec cut	13sec cut		12sec cut	13sec cut
	Sensitivity	41.3%	23.7%	*Fall History since age 65*	34.5%	31.0%
	Specificity	90.0%	90.0%		90.0%	100%
	(+) LR	4.14	2.37		3.45	n/a
	(-) LR	0.65	0.85		0.73	0.69
	Sensitivity	40.9%	27.3%	*12-month Fall History*	31.8%	27.3%
	Specificity	76.5%	76.5%		76.5%	82.4%
	(+) LR	1.74	1.16		1.35	1.55
	(-) LR	0.77	0.95		0.89	0.88
	Sensitivity	50%	40%	*6-month prospective falls*	50.0%	40.0%
	Specificity	73.1%	80.8%		76.9%	84.6%
	(+) LR	1.86	2.08		2.17	2.60
	(-) LR	0.68	0.74		0.65	0.71

Tandem Stance Test	L	R		L	R
Sensitivity	37.9%	37.9%	*Fall History since age 65*	41.4%	37.9%
Specificity	70.0%	70.0%		70.0%	70.0%
(+) LR	1.26	1.26		1.38	1.26
(-) LR	0.89	0.89		0.84	0.89
Sensitivity	31.8%	31.8%	*12-month Fall History*	36.4%	27.3%
Specificity	58.8%	58.8%		58.8%	52.9%
(+) LR	0.77	0.77		0.88	0.58
(-) LR	1.16	1.16		1.08	1.37
Sensitivity	20.0%	40.0%	*6-month prospective falls*	30.0%	30.0%
Specificity	61.5%	65.4%		61.5%	65.4%
(+) LR	0.52	1.16		0.78	0.87
(-) LR	1.3	0.92		1.14	1.07

30-second Chair Rise			
Sensitivity	55.2%	*Fall History since age 65*	48.3%
Specificity	70.0%		70.0%
(+) LR	1.84		1.61
(-) LR	0.64		0.74
Sensitivity	59.1%	*12-month Fall History*	50.0%
Specificity	64.7%		64.7%
(+) LR	1.67		1.42
(-) LR	0.63		0.77
Sensitivity	60.0%	*6-month prospective falls*	50.0%
Specificity	53.8%		57.7%
(+) LR	1.3		1.18
(-) LR	0.74		0.87

n = 39

Supplemental Data for the STEADI Algorithm

As was discussed in Chapter 3, the STEADI algorithm and fall-risk assessment has little published data to date. Although sensitivity and specificity levels are poor for the STEADI's ability to classify the presence of prior falls, a two-tiered risk algorithm demonstrates good sensitivity with identifying 6-month prospective fallers (80%). Integral to research question 2, these findings are equivalent for both rater environments. Like the STEADI algorithm, the CDC's Stay Independent Brochure Questionnaire has little published data other than it supports the inclusion of multi-factorial risks, and it is also in need of data examining its relationship with other variables. A score of four or more is considered a positive screen and worthy of further fall risk investigation according to CDC recommendations (Appendix B). The intervention group ($n = 39$) had an average score of 4.38 ($SD = 3.31$) with a range of 0 to 13, and the control group ($n = 45$) had an average score of 3.96 ($SD = 3.16$) with a range of 0 to 10 on the Stay Independent Brochure. Twenty or 51.3% of the intervention group and 23 or 51.1% of the control group scored four or more points on this questionnaire. A one-way ANOVA confirmed no significant difference between groups ($p = 0.545$) for results from the Stay Independent Brochure (Table 2). As previously discussed, the relationship between fallers, those with multiple prior falls, a history of fall-related fractures, and even assistive device use was not published by the CDC. Although not integral to testing the null hypotheses in this investigation, Table 9 demonstrates a disproportionate amount of older adult (50%) participants classified as "low risk" based upon results from the TUG, four-stage balance, and 30STS tests but self-reporting multiple falls. Furthermore, a disproportionately low percentage of participants reported fall-related fractures relative to those classified as having an elevated fall risk following TUG, four-stage balance, and 30STS testing. Lastly, increasing risk level was not proportionate with advancing age, and two of

13 respondents classified as having “low” fall risk by the STEADI algorithm fell within 6 months following participation in this investigation.

Table 8. Classification of STEADI Algorithm for Intervention Group (face-to-face)

	Low Risk (n = 14)	Moderate Risk (n = 12)	High Risk (n = 13)
Mean Age	73.3 years	78.3 years	73.6 years
Prior Falls	n = 8 (57%)	n = 8 (67%)	n = 13 (100%)
Multiple Falls	n = 7 (50%)	n = 4 (33%)	n = 11 (85%)
Prior Fall Fractures	n = 2 (14%)	n = 2 (17%)	n = 3 (23%)
Prospective Falls (6mo) (n = 36)	n = 2 (15%)	n = 2 (20%)	n = 6 (46%)
Assistive Device Use	n = 1 (7%)	n = 1 (8%)	n = 6 (46%)

n = 39

Although supplemental to research question 2, clinically relevant ROC analyses were calculated using results from the Stay Independent Brochure and the following dichotomous test variables from the Fall History Questionnaire: fall history since age 65, 12-month fall history, fracture history, 12-month emergent care, 6-month medication change, and 6-month prospective fall incidence. ROC analysis resulted in an area under the curve (AUC) of 0.710 (95% CI = 0.528 – 0.892, p = 0.05) for fall history since age 65 and AUC of 0.746 (95% CI = 0.585 – 0.907, p = 0.009) for 12-month fall history, indicating good balance of sensitivity and specificity for both independent variables. However, unfavorable AUC for fracture history 0.591 (95% CI = 0.346 – 0.836, p = 0.484), for 12-month emergent care AUC of 0.623 (95% CI = 0.398 – 0.848, p = 0.314), 6-month medication changes AUC of 0.523 (95% CI = 0.319 – 0.726, p = 0.827), and 6-month prospective falls AUC of 0.677 (95% CI = 0.491 – 0.863, p = 0.104) were calculated. A Stay Independent Brochure score of four or greater should absolutely be predictive of fall risk and prospective fall incidence. In essence, the outcomes from these ROC analyses are consistent with the CDC's screening algorithm in meeting their minimum standard with validity calculations as it can classify retrospective fall history. However, as per AUC calculations, the Stay Independent Brochure score was unable to classify other important variables such as fracture history or predict future falls, bringing into question the predictive validity of the algorithm.

The relationship between the Stay Independent Brochure score and the final STEADI fall risk categorization also needs to be determined. Although the Stay Independent Brochure is a part of the overall STEADI fall screening decision making algorithm, the quantitative relationship between this questionnaire and the three-tiered STEADI risk algorithm is unknown and currently unreported in the literature. Spearman's rho correlation coefficient calculation revealed a low to moderate but significant relationship between these two variables ($r = 0.432$, $p = 0.006$). However, the relationship between the two tools is greatly reduced when analyzing the STEADI algorithm as a dichotomous (nominal) variable ($r = 0.265$, $p = 0.102$). This reduced correlation trend was also observed when comparing the concurrent validity of the remote STEADI and face-to-face Mini-BEST. Kappa and Spearman correlation calculations comparing the Stay Independent Brochure risk categorization and a two-tiered STEADI risk categorization revealed a low ($K = 0.172$, $r = 0.181$, $p = 0.257$) level of agreement with the telerehab rater and a low ($K = 0.225$, $r = 0.233$, $p = 0.146$) level of agreement with the face-to-face rater. This conflicting data highlights a need for additional investigation into the STEADI toolkit.

In addition to evaluating the concurrent validity of the TR STEADI and the face-to-face Mini-BEST, one of the goals of this investigation was to establish equivalency or consistency of the STEADI among face-to-face and telerehab (remote) raters. This overlaps with research questions 2 and 3 as without consistency and reliability across rater settings, there cannot be validity. As outlined in Chapter 2, fall screening tests included in the STEADI are safer and easier to implement remotely as compared to the Mini-BEST. To further investigate the validity of the STEADI algorithm, ROC analyses were calculated using fall risk conclusions from the STEADI algorithm (TR) and fall history since age 65, 12-month fall history, fracture history, 12-month emergent care, 6-month medication change, and 6-month prospective fall incidence variables. Analysis using the STEADI algorithm as the dependent variable resulted in an AUC of 0.755 (95% CI = 0.600 – 0.910, p = 0.017) for fall history since age 65 indicating a good balance of sensitivity and specificity. However, an AUC of 0.682 (95% CI = 0.514 – 0.850, p = 0.054) was calculated for 12-month fall history, an AUC of 0.455 (95% CI = 0.220 – 0.689, p = 0.726) for fracture history, an AUC of 0.643 (95% CI = 0.426 – 0.860, p = 0.242) was calculated for 12-month emergent care, an AUC of 0.484 (95% CI = 0.292 – 0.675, p = 0.876) was calculated for 6-month medication changes, and an AUC of 0.669 (95% CI = 0.465 – 0.873, p = 0.120) for prospective falls all indicated poor levels of sensitivity and specificity. AUC for both the STEADI algorithm risk score and the STEADI Stay Independent Brochure both demonstrated significant and good sensitivity and specificity with classifying fall history since turning age 65. When the three-tiered STEADI fall risk algorithm was analyzed as a dichotomous two-tiered variable, all AUC analyses became less significant and less sensitive and specific for classifying all five of the independent variables from the Fall History Questionnaire.

Despite the Mini-BEST's superior psychometric properties outlined in Chapter 2, the literature is inconclusive regarding its predictive validity among community-dwelling older adults. ROC analyses combining fall risk cut-off data from face-to-face implementation of the Mini-BEST and the five previously mentioned independent variables used in the AUC analysis for the STEADI were also calculated. An AUC of 0.615 (95% CI = 0.429 – 0.801, p = 0.095) for fall history since age 65, an AUC of 0.614 (95% CI = 0.420 – 0.808, p = 0.275) was calculated for 12month fall history, an AUC of 0.375 (95% CI = 0.195 – 0.555, p = 0.230) for fracture history, an AUC of 0.565 (95% CI = 0.356 – 0.774, p = 0.533) was calculated for 12-month emergent care, an AUC of 0.430 (95% CI = 0.234 – 0.626, p = 0.502) for 6-month medication changes, and an AUC of 0.612 (95% CI = 0.427 – 0.797, p = 0.306) for ?? all revealed poor sensitivity and specificity. These results bring into question the classification and predictive ability of the Mini-BEST with the six selected independent variables tested in the sampled population of community-dwelling older adults.

Despite the insignificant AUC values when examining Mini-BEST fall risk outcomes with independent test variables from the Fall History Questionnaire and follow-up prospective fall rates, examination of ROC curves using the Mini-BEST as the dependent variable and the STEADI algorithm as the test variable revealed more significant results. ROC analysis resulted in an AUC of 0.810 (95% CI = 0.639 – 0.981, p = 0.003) indicating good sensitivity and specificity. When tested with a two-tiered STEADI risk variable, sensitivity and specificity are reduced and insignificant with an AUC of 0.654 (95% CI = 0.480 – 0.828, p = 0.121). When examining the Mini-BEST with risk determined by the Stay Independent Brochure, ROC analysis resulted in an AUC of 0.672 (95% CI = 0.501 – 0.844, p = 0.066), indicating an average predictability with near significance of this validity assessment. This data confirms a relationship between risk outcomes determined by the Mini-BEST and STEADI risk algorithm consistent with sensitivity and specificity data trends outlined in Table 6.

Research Question 3

The following information pertains to the results associated with research question 3 (*Are outcomes of fall screening measures that are performed remotely consistent with those* *performed face-to-face?)*. This research question and subsequent analyses tested the hypothesis that there was no difference in scoring or fall risk conclusions between remote (telerehab) and face-to-face raters simultaneously scoring participants with the Timed Up and Go (TUG) Test, 30-second Chair Rise (30STS), 4-Stage Balance, Performance-Oriented Mobility Assessment Gait (POMA-G) Tool, 4-meter Walk Test (4MWT), and Functional Reach Test (FRT), or the fall risk categorization on the STEADI algorithm.

Reliability calculations using ICC analysis for the *FRT* indicated a 97.8% agreement between face-to-face raters ($p < 0.001$) and a 98.4% agreement between telehealth raters ($p < 0.001$). Integral to this research question, however, was the level of agreement between the test environments, telehealth and traditional face-to-face. ICC analysis indicated a 96% agreement between face-to-face (M = 11.32 inches, SD = 3.46) and telehealth (M= 11.31 inches, SD = 2.99; Cronbach's alpha (38) = 0.962, $p < 0.001$) raters. ICC values demonstrate excellent interrater and inter-environment reliability.

The 7 inches functional reach (FR) cut-off point is described as "limited functional balance" and the 10 inches FR is considered normal reach for older adults.[148,181] Analysis of agreement of two different cut-off points for fall risk were utilized and assessed for reliability among rater environments. Cut-off score classifications are nominal variables that required the use of the kappa statistic as opposed to ICC values. Reliability analysis comparing face-to-face and telehealth rater risk categorization of FRT results revealed a moderate (K = 0.874) level of agreement using a 10" reach cut-off value, but a weak (K = 0.544) level of agreement using 7 inches reach cut-off value ($p < 0.001$). To account for the random effects from subjects and to fully appraise the agreement of all four raters, a two-factor random effects model was used to calculate ICC values. A high degree of reliability was found between all four measures, with an average ICC of 0.987 and a 95% confidence interval ranging from 0.979 to 0.993 ($F(38, 114) = 75$, $p < 0.001$). Table 9 outlines reliability data and inter-item matrix correlation data for the FRT.

Table 9. Functional Reach Test Interclass Correlation Coefficient (ICC) and Kappa Correlation Coefficient Comparing Raters, Environments, and Fall Risk Levels

Location/Rater	Best (SD) (inches)	Correlation Coefficient	P	r
Highest F2F R1	11.32 (3.46)	ICC = 0.978	<0.001	0.957
Highest F2F R2	11.23 (3.37)			
Highest TH R1	11.31 (2.99)	ICC = 0.984	<0.001	0.968
Highest TH R2	11.19 (2.89)			
Highest F2F	11.32 (3.46)	ICC = 0.962	<0.001	0.937
Highest TH	11.31 (2.99)			
Fall Risk F2F 10”	-	K = 0.874	<0.001	-
Fall Risk TH 10”	-			
Fall Risk F2F 7”	-	K = 0.544	<0.001	-
Fall Risk TH 7”	-			
Random Effects Model	-	ICC = 0.987	<0.001	-

n = 39

Reliability calculations using ICC analysis for the *4MWT* indicated a 99.3% agreement between face-to-face raters ($p < 0.001$) and a 95.8% agreement between telehealth raters ($p < 0.001$). Integral to this research question, however, was the level of agreement between the test environments, telehealth and traditional face-to-face. ICC analysis indicated a 95.4% agreement between face-to-face raters (M = 1.20 m/sec, SD = 0.32) and telehealth raters (M= 1.14 sec, SD = 0.25; Cronbach’s alpha (38) = 0.954, $p < 0.001$). ICC values demonstrate excellent interrater and inter-environment reliability.

The 1.0 m/sec cut-off point is considered normal walking speed and reduced fall risk among older adults using a three-tiered risk classification system published by Fritz and Lusardi: low fall risk or “green flag” $\geq$1.0 m/sec, moderate fall risk or “yellow flag” 0.61 – 0.99 m/sec, high fall risk or “red flag” $\leq$ 0.60 m/sec ($p < 0.001$).[151] Yellow and red flag categories (<1.0 m/sec) were combined as elevated risk for statistical analysis of dichotomous fall risk categorizations. Reliability analysis comparing face-to-face and telehealth rater risk categorization of the 4-meter walk test results revealed a strong (K = 0.866) level of agreement ($p < 0.001$). To account for the random effects from subjects and to fully appraise the agreement of all four raters, a two-factor random effects model was used to calculate ICC values. A high degree of reliability was found between all four measures, with an average ICC of 0.987 and a 95% confidence interval ranging from 0.969 to 0.991 ($F(38, 114) = 75$, $p < 0.001$) for the 4MWT. Table 11 outlines reliability data and inter-item matrix correlation data for the 4MWT.

Table 10. 4-meter Walk Test Interclass Correlation Coefficient (ICC) and Kappa Correlational Coefficient (K) Comparing Raters, Environments, and Fall Risk Levels

Location/Rater	Mean Best (SD)	Correlation Coefficient	P	r
Best F2F R1	1.20m/sec (0.32)	ICC = 0.993	<0.001	0.986
Best F2F R2	1.22m/sec (0.31)			
Best TH R1	1.14m/sec (0.25)	ICC = 0.958	<0.001	0.927
Best TH R2	1.16m/sec (0.29)			
Best F2F	1.20m/sec (0.32)	ICC = 0.954	<0.001	0.936
Best TH	1.14m/sec (0.25)			
Fall Risk F2F	-	K= 0.866	<0.001	-
Fall Risk TH	-			
Random Effects Model	-	ICC = 0.987	<0.001	-

n = 39

Reliability calculations using ICC analysis for the *TUG* indicated a 99.9% agreement between face-to-face raters ($p < 0.001$) and a 99.9% agreement between telehealth raters ($p < 0.001$). As with all fall screening tests selected for inclusion in this telerehab investigation, the level of agreement between the test environments are integral to study outcomes. ICC analysis indicated a 99.7% ($p < 0.001$) agreement between face-to-face raters (M = 11.25 sec, SD = 4.47) and telehealth raters (M= 11.58 sec, SD = 4.60; Cronbach's alpha (38) = 0.997, $p < 0.001$). ICC values demonstrate excellent interrater and inter-environment reliability.

The STEADI references a different cut-off point (12 sec) than the literature (13 sec).[20,181] Therefore, reliability of scoring for two cut-off points for the TUG's fall risk were utilized and assessed for reliability between test environments. Kappa analysis comparing face-to-face and telehealth rater risk categorization of TUG results revealed a strong (K = 0.941) level of agreement using a 12-second cut-off value and a strong level of agreement (K = 0.930) using a 13-second cut-off value for fall risk ($p < 0.001$). Kappa values demonstrate an almost perfect observed proportion of agreement using both the 12-second and 13-second cut-off scores confirming excellent inter-environment rater reliability with fall risk categorization using the TUG. To account for the random effects from subjects and to fully appraise the agreement of all four raters, a two-factor random effects model was used to calculate ICC values. A high degree of reliability was found between all four measures, with an average ICC of 0.999 and a 95% confidence interval ranging from 0.996 to 0.999 ($F(38, 114) = 1055$, $p < 0.001$) for the TUG. Table 11outlines ICC, kappa, and inter-item matrix correlation data for the TUG.

Table 11. Timed-Up and Go Interclass Correlation Coefficient (ICC) and Kappa Correlational Coefficient (K) Comparing Raters, Environments, and Fall Risk Levels

Location/Rater	Mean Best (SD) (seconds)	Correlation Coefficient	P	r
Best F2F R1	11.25 (4.47)	ICC = 0.999	<0.001	0.998
Best F2F R2	11.14 (4.54)			
Best TH R1	11.58 (4.60)	ICC = 0.999	<0.001	0.998
Best TH R2	11.63 (4.54)			
Best F2F	11.25 (4.47)	ICC = 0.997	<0.001	0.995
Best TH	11.58 (4.60)			
Fall Risk F2F 12sec	-	K = 0.941	<0.001	-
Fall Risk TH 12sec	-			
Fall Risk F2F 13sec	-	K = 0.930	<0.001	-
Fall Risk TH 13sec	-			
Random Effects Model	-	ICC = 0.999	<0.001	-

n = 39

Reliability ICC analysis for the *POMA-G* indicated a 91.8% agreement between face-to-face raters ($p < 0.001$) and a 92.4% agreement between telehealth raters ($p < 0.001$). ICC analysis calculated a less than ideal 79.2% agreement between face-to-face raters (M = 10.56, SD = 1.53) and telehealth raters (M= 10.85, SD = 1.20; Cronbach's alpha (38) = 0.792, p <

0.001). ICC values demonstrate excellent interrater reliability and acceptable to good inter-environment reliability for the POMA-G. Cut-off points for the gait section of the POMA are not available; therefore, kappa values for proportion of agreement of fall risk categorization between face-to-face and telehealth environments are unable to be calculated. To account for the random effects from subjects and to fully appraise the agreement of all four raters, a two-factor random effects model was used to calculate ICC values. A high degree of reliability was found between all four measures, with an average ICC of 0.913 and a 95% confidence interval ranging from 0.839 to 0.945 ($F(38, 114) = 11.5$, $p = 0.001$) for the POMA-G. Table 12 outlines ICC data and inter-item matrix correlation data for the POMA-G.

Table 12. Tinetti Gait (POMA-G) Interclass Correlation Coefficient (ICC) Analyses Comparing Raters and Environments

Location/Rater	Mean Best (SD) (seconds)	Correlation Coefficient	P	r
Highest F2F R1	10.56 (1.54)	ICC = 0.918	<0.001	0.849
Highest F2F R2	10.36 (1.60)			
Highest TH R1	10.85 (1.20)	ICC = 0.924	<0.001	0.862
Highest TH R2	10.94 (1.11)			
Highest Score F2F	10.56 (1.53)	ICC = 0.792	<0.001	0.675
Highest Score TH	10.85 (1.20)			
Random Effects Model	-	ICC = 0.913	<0.001	-

n = 39

Reliability ICC analysis for the *30STS* indicated a 99.7% consistency of agreement between face-to-face raters ($p < 0.001$) and a 99.7% consistency of agreement between telehealth raters ($p < 0.001$). Concerning inter-environment reliability, ICC analysis indicated a 99.7% ($p < 0.001$) agreement between face-to-face raters ($M = 10.18$, $SD = 4.48$) and telehealth raters ($M= 10.08$, $SD = 4.44$); Cronbach's alpha (38) = 0.997, $p < 0.001$). ICC values demonstrate excellent interrater and inter-environment reliability.

Cut-off points for the 30STS vary by age and gender and were calculated according to the STEADI's fall risk chart.[20] Kappa statistical analysis comparing face-to-face and telehealth rater risk categorization of the 30STS revealed a strong (K= 0.897) level of agreement ($p < 0.001$). To account for the random effects from subjects and to fully appraise the agreement of all four raters, a two-factor random effects model was used to calculate ICC values. A high degree of reliability was found between all four measures, with an average ICC of 0.998 and a 95% confidence interval ranging from 0.997 to 0.999 ($F(38, 114) = 645.8$, $p < 0.001$) for the 30STS. Table 13 outlines ICC, kappa, and inter-item matrix correlation data for the 30STS Test.

Table 13. 30-second Sit-to-Stand Interclass Correlation Coefficient (ICC) and Kappa Correlational Coefficient (K) Analyses Comparing Raters, Environments, and Fall Risk Levels

Location/Rater	Mean Best (SD) (repetitions)	Correlation Coefficient	P	r
Highest F2F R1	10.18 (4.48)	ICC = 0.997	<0.001	0.994
Highest F2F R2	10.28 (4.55)			
Highest TH R1	10.08 (4.44)	ICC = 0.997	<0.001	0.995
Highest TH R2	10.31 (4.66)			
Reps F2F	10.18 (4.48)	ICC = 0.997	<0.001	0.995
Reps TH	10.08 (4.44)			
Fall Risk F2F	-	K = 0.897	<0.001	-
Fall Risk TH	-			
Random Effects Model	-	ICC = 0.998	<0.001	-

n = 39

Reliability calculations using ICC analysis for the *single limb stance* (SLS) indicated a 99.4% agreement on the right lower extremity (RLE) and a 97.8% agreement on the left lower extremity (LLE) between face-to-face raters ($p < 0.001$), and a 99.3% agreement on the RLE and a 96.7% agreement on the LLE between telehealth raters ($p < 0.001$). ICC analysis indicated a 99.2% agreement between face-to-face raters (M = 5.47 sec, SD = 3.89) and telehealth raters (M= 5.41 sec, SD = 3.94; Cronbach's alpha (38) = 0.992, $p < 0.001$) for the RLE, and a 95.6% agreement between face-to-face raters (M = 5.55 sec, SD = 3.99) and telehealth raters (M= 5.12 sec, SD = 3.94; Cronbach's alpha (38) = 0.956, $p < 0.001$) for the LLE. ICC values demonstrate excellent interrater and inter-environment reliability.

Cut-off points for the SLS component of the STEADI's 4-Stage Balance Test are not available; therefore, kappa values for agreement of fall risk categorization between face-to-face and telehealth environments are unable to be calculated. To account for the random effects from subjects and to fully appraise the agreement of all four raters, a two-factor random effects model was used to calculate ICC values. A high degree of reliability was found between all four measures, with an average ICC of 0.980 and a 95% confidence interval ranging from 0.968 to 0.989 ($F(38, 114) = 50$, $p < 0.001$) for the SLS. Table 14 outlines ICC data and inter-item matrix correlation data for the SLS.

Table 14. Single Limb Stance Interclass Correlation Coefficient (ICC) Analyses Comparing Raters and Environments

Location/Rater	Mean Best (SD) (seconds)	Correlation Coefficient	P	r
Best F2F R1 - RLE	5.47 (3.89)	ICC = 0.994	<0.001	0.989
Best F2F R2	5.38 (3.95)			
Best F2F R1 - LLE	5.55 (3.99)	ICC = 0.978	<0.001	0.958
Best F2F R2	5.35 (3.93)			
Best TH R1 - RLE	5.41 (3.94)	ICC = 0.993	<0.001	0.987
Best TH R2	5.53 (3.94)			
Best TH R1 – LLE	5.12 (3.94)	ICC = 0.967	<0.001	0.937
Best TH R2	5.32 (4.05)			
Best F2F - RLE	5.47 (3.89)	ICC = 0.992	<0.001	0.985
Best TH	5.41 (3.94)			
Best F2F - LLE	5.55 (3.99)	ICC = 0.956	<0.001	0.916
Best TH	5.12 (3.94)			
Random Effects Model	-	ICC = 0.980	<0.001	-

n = 39

Reliability calculations using ICC analysis for the *tandem stance* test revealed a 99.7% agreement on the RLE and a 99.8% agreement on the LLE between face-to-face raters ($p < 0.001$), and a 99.6% agreement on the RLE and a 100% agreement on the LLE between telehealth raters ($p < 0.001$). Integral to this research question, however, was the level of agreement between the test environments, telehealth and traditional face-to-face. ICC analysis indicated a 99.5% agreement between face-to-face raters (M = 7.83 sec, SD = 3.37) and telehealth raters (M= 7.79 sec, SD = 3.36; Cronbach's alpha (38) = 0.995, p < 0.001) for the RLE, and a 99% agreement between face-to-face raters (M = 7.79 sec, SD = 3.40) and telehealth raters (M= 7.87 sec, SD = 3.46; Cronbach's alpha (38) = 0.990, p < 0.001) for the LLE. ICC values demonstrate excellent interrater and inter-environment reliability.

Using the STEADI's cut-off score of 10 seconds for elevated fall risk, kappa analysis comparing face-to-face and telehealth rater risk categorization of tandem stance revealed a strong (K = 0.889) level of agreement (p < 0.001) in fall risk categorization for the RLE, and an almost perfect (K = 0.945) level agreement (p < 0.001) in fall risk categorization for the LLE. To account for the random effects from subjects and to fully appraise the agreement of all four raters, a two-factor random effects model was used to calculate ICC values. A high degree of reliability was found between all four measures on both lower extremities. The average ICC was 0.997 with a 95% confidence interval ranging from 0.996 to 0.998 (F(38, 114) = 377, p < 0.001) for the LLE, and an average ICC of 0.998 and a 95% confidence interval ranging from 0.998 to 0.999 (F(38, 114) = 655, p < 0.001) for the RLE. Table 15 outlines ICC, kappa, and inter-item matrix correlation data for tandem stance.

Table 15. Tandem Stance Interclass Correlation Coefficient (ICC) and Kappa Correlation Coefficient (K) Analyses Comparing Raters, Environments, and Fall Risk Levels

Location/Rater	Mean Best (SD) (seconds)	Correlation Coefficient	P	r
F2F R1 - RLE	7.83 (3.37)	ICC = 0.997	<0.001	0.995
F2F R2	7.82 (3.44)			
F2F R1 - LLE	7.79 (3.40)	ICC = 0.998	<0.001	0.996
F2F R2	7.76 (3.48)			
TH R1 - RLE	7.79 (3.36)	ICC = 0.996	<0.001	0.992
TH R2	7.80 (3.45)			
TH R1 - LLE	7.87 (3.46)	ICC = 1.000	<0.001	0.999
TH R2	7.86 (3.48)			

F2F - RLE	7.83 (3.37)	ICC = 0.995	<0.001	0.989
TH	7.79 (3.36)			
F2F - LLE	7.79 (3.40)	ICC = 0.990	<0.001	0.981
TH	7.87 (3.46)			
Fall Risk F2F - RLE	-	K = 0.889	<0.001	-
Fall Risk TH	-			
Fall Risk F2F - LLE	-	K = 0.945	<0.001	-
Fall Risk TH	-			
Random Effects Model	-	ICC = 0.997	<0.001	-

n = 39

Reliability calculations using ICC analysis for the *narrow stride* stance indicated a 100% agreement on the RLE and a 99.2% agreement on the LLE between face-to-face raters ($p < 0.001$), and a 99.9% agreement on the RLE and a 100% agreement on the LLE between telehealth raters ($p < 0.001$). ICC analysis indicated a 99.9% agreement between face-to-face raters (M = 9.53 sec, SD = 1.69) and telehealth raters (M= 9.53 sec, SD = 1.75; Cronbach's alpha (38) = 0.999, $p < 0.001$) for the RLE, and an 85.9% agreement between face-to-face raters (M = 9.77 sec, SD = 1.02) and telehealth raters (M= 9.61 sec, SD = 1.80; Cronbach's alpha (38) = 0.859,) $p < 0.001$) for the LLE. ICC values demonstrate excellent interrater and inter-environment reliability. Cut-off points for the narrow stride stance component of the STEADI's four-stage balance test are not available; therefore, kappa values for agreement of fall risk categorization between face-to-face and telehealth rater environments are unable to be calculated. To account for the random effects from subjects and to fully appraise the agreement of all four raters, a two-factor random effects model was used to calculate ICC values. A high degree of reliability was found between all four measures on both lower extremities. The average ICC was 0.948 with a 95% confidence interval ranging from 0.915 to 0.970 ($F(38, 114) = 19$, $p < 0.001$) for the LLE, and an average ICC of 1.000 and a 95% confidence interval ranging from 1.000 to 1.000 ($F(38, 114) = 3462$, $p < 0.001$) for the RLE narrow stride. Table 16 outlines ICC data and inter-item matrix correlation data for the narrow stride stance.

Table 16. Narrow Stride Stance Interclass Correlation Coefficient (ICC) Analyses Comparing Raters and Environments

Location/Rater	Mean Best (SD) (seconds)	Correlation Coefficient	P	r
F2F R1 - RLE	9.54 (1.69)	ICC = 1.000	<0.001	1.000
F2F R2	9.55 (1.65)			
F2F R1 - LLE	9.77 (1.02)	ICC = 0.992	<0.001	0.985
F2F R2	9.75 (0.99)			
TH R1 - RLE	9.52 (1.74)	ICC = 0.999	<0.001	0.999
TH R2	9.54 (1.68)			
TH R1 - LLE	9.61 (1.80)	ICC = 1.000	<0.001	1.000
TH R2	9.61 (1.80)			
F2F - RLE	9.53 (1.69)	ICC = 0.999	<0.001	0.999
TH	9.53 (1.75)			
F2F - LLE	9.77 (1.02)	ICC = 0.859^	<0.001	0.878
TH	9.61 (1.80)			
Random Effects Model	-	ICC = 0.948	<0.001	-

n = 39 ^subject 18 had large contrast in mean times between F2F /TH (6 vs. 0 sec)

Reliability calculations using ICC analysis for the *narrow stance test* indicated a 100% agreement between face-to-face raters ($p < 0.001$) and a 100% agreement between telehealth raters ($p < 0.001$). Comparing test environments, ICC analysis indicated a 100% agreement between face-to-face raters (M = 9.68 sec, SD = 1.39) and telehealth raters (M= 9.68 sec, SD = 1.40; Cronbach's alpha (38) = 1.000, $p < 0.001$). ICC values demonstrate excellent interrater and inter-environment reliability. The CDC does not include cut-off points for the narrow stance component of the STEADI's 4-Stage Balance Test; therefore, kappa values for agreement of fall risk categorization between face-to-face and telehealth environments are unable to be calculated. To account for the random effects from subjects and to fully appraise the agreement of all four raters, a two-factor random effects model was used to calculate ICC values. A high degree of reliability was found between all four measures, with an average ICC of 1.000 and a 95% confidence interval ranging from 1.000 to 1.000 ($F(38, 114) = 26544$, $p < 0.001$) for the SLS Table 17 outlines ICC data and inter-item matrix correlation data for the narrow stance.

Table 17. Narrow Stance Interclass Correlation Coefficient (ICC) Analyses Comparing Raters and Environments

Location/Rater	Mean Best (SD) (seconds)	Correlation Coefficient	P	r
Highest F2F R1	9.68 (1.39)	ICC = 1.000	<0.001	1.000
Highest F2F R2	9.67 (1.41)			
Highest TH R1	9.68 (1.40)	ICC = 1.000	<0.001	1.000
Highest TH R2	9.67 (1.43)			
Highest F2F	9.68 (1.39)	ICC = 1.000	<0.001	1.000
Highest TH	9.68 (1.40)			
Random Effects Model	-	ICC = 1.000	<0.001	-

n = 39 **USED FIRST TRIAL FOR STATISTICAL PURPOSES AS 2ND TRIALS WERE ALL 10SEC

Receiver Operating Characteristic (ROC) Curve Analyses

To further analyze the reliability and comparative validity of telerehabilitation, ROC analyses were integrated to compare outcomes from telerehabilitation and face-to-face rater environments. This section compares ROC data for each of the nine fall screening tools simultaneously scored by face-to-face and telerehab raters with fall history since age 65, 12-month fall history, 12-month emergent care history, fall-related fracture history, six-month medication change history, 6-month prospective fall history, and outcomes from the Mini-BEST, Stay Independent Brochure Questionnaire, and STEADI algorithm. The area under a ROC curve quantifies the overall ability of the 9 standardized tests to discriminate between participants with a positive result and those with a negative result to the independent variables.

The *Functional Reach Test* (FRT) scores were calculated by selecting best distance scored of the two trials by rater 1 from each environment. The FRT demonstrated the largest variation when comparing the area under the curve (AUC) volume and significance among rater environments as compared to the other eight fall screening tests. The FRT demonstrated poor diagnostic ability to classify participants with an overall fall history, their 12-month fall history, fracture history, 6-month medication change history, and 6-month prospective falls, as well as predict STEADI risk calculation using the three-tiered scoring. Despite this lack of significance using ROC analysis, all five of these independent variables were equally insignificant with low AUC values among both test environments. These environment equivalencies coincide with ICC values in Table 10. However, inequivalence with the FRT predicting outcomes from the Stay Independent Brochure and classifying 12-month emergent care variables was calculated among rater environments. The FRT demonstrated fair but significant sensitivity and specificity for predicting the Stay Independent Brochure with an AUC of 0.717 (95% CI = 0.556 – 0.878, p = 0.020) for face-to-face, but a lower insignificant AUC 0.655 (95% CI = 0.483 – 0.828, p = 0.097) for telerehab. ROC analysis of the FRT classifying the 12-month emergent care reflects a near significant AUC of 0.710 (95% CI = 0.508 – 0.911, p = 0.085) for telerehab, and an insignificant AUC 0.647 (95% CI = 0.399 – 0.895, p = 0.227) for face-to-face. The FRT demonstrated fair but significant sensitivity and specificity for predicting fall-risk outcomes from a two-tiered STEADI, and near significance (TR) with predicting outcomes on the Mini-BEST. ROC analysis of the FRT predicting the two-tiered STEADI calculated an AUC of 0.759 (95% CI = 0.595 – 0.923, p = 0.009) for telerehab, and an AUC 0.765 (95% CI = 0.603 – 0.927, p = 0.008) for face-to-face. ROC analysis of the FRT predicting the Mini-BEST calculated an AUC of 0.701 (95% CI = 0.498 – 0.904, p = 0.053) for telerehab, and an AUC 0.721 (95% CI = 0.522 – 0.919, p = 0.034) for face-to-face. Table 18 outlines ROC analysis data comparing equivalence of validity measures for each environment scoring the FRT.

Table 18. Functional Reach Test: Comparative Analysis of Telerehabilitation and Face-to-Face Screening using Receiver Operating Characteristic Curves

Independent Variable		Telerehabilitation	Face-to-Face
Fall History			
Positive (yes) = 29			
	AUC	0.586	0.581
	p Value	0.421	0.450
12-month Fall History			
Positive (yes) = 22			

	AUC	0.504	0.477
	p Value	0.966	0.810
12-month Emergent Care Positive (yes) = 7			
	AUC	0.710	0.647
	p Value	0.085	0.227
Fracture History Positive (yes) = 6			
	AUC	0.361	0.379
	p Value	0.284	0.350
6-month Medication Changes Positive (yes) = 11			
	AUC	0.630	0.570
	p Value	0.212	0.502
Mini-BEST Positive (yes) = 11			
	AUC	0.701	0.721
	p Value	0.053	0.034*
Stay Independent Brochure Positive (yes) = 20			
	AUC	0.655	0.717
	p Value	0.097	0.020*
STEADI Risk (3-tiered) Positive (yes) = 11			
	AUC	0.631	0.664
	p Value	0.206	0.115
STEADI Risk (2-tiered) Positive (yes) = 26			
	AUC	0.759	0.765
	p Value	0.009*	0.008*
6-month Prospective Falls Positive (yes) = 10 [n=36]			
	AUC	0.467	0.485
	p Value	0.764	0.888

Notes. n = 39 * = p ≤0.05

Chapter 5 will discuss some of the limitations and feasibility of conducting the FRT remotely that may have contributed to the variations in ROC results between environments.

Four-meter Walk Test (4MWT) scores were calculated by selecting the fastest time of the two trials recorded by rater 1 from each environment. Overall, the 4MWT demonstrated equivalence when comparing the AUC volumes and significance levels for each environment.

ROC calculations resulted in low and insignificant AUC for the 4MWT classifying the presence of prior falls, 12-month fall history, 12-month emergent care, fracture history, and 6-month medication changes, as well as predicting 6-month prospective falls. Despite poor sensitivity and specificity with classifying the presence of these variables from the Fall History Questionnaire, all six of these independent variables were equally insignificant with similar AUC values among both test environments. However, ROC analysis of the 4MWT calculated significant fair to good AUC for predicting fall risk conclusions of the Mini-BEST, Stay Independent Brochure, and the STEADI indicating a meaningful balance of sensitivity and specificity rates. ROC analysis of the 4MWT predicting the Mini-Best calculated an AUC of 0.773 (95% CI = 0.579 – 0.966, p = 0.009) for telerehab, and an AUC of 0.774 (95% CI = 0.579 – 0.970, p = 0.008) for face-to-face. ROC analysis of the 4MWT predicting the Stay Independent Brochure calculated an AUC of 0.778 (95% CI = 0.627 – 0.928, p = 0.003) for telerehab, and an AUC 0.778 (95% CI = 0.631 – 0.924, p = 0.003) for face-to-face. ROC analysis of the 4MWT predicting the STEADI (three-tiered risk) calculated an AUC of 0.771 (95% CI = 0.554 – 0.988, p = 0.009) for telerehab, and an AUC 0.766 (95% CI = 0.552 – 0.981, p = 0.010) for face-to-face. ROC analysis was also calculated for a converted dichotomous scale STEADI for statistical purposes. ROC analysis of the 4MWT predicting the two-tiered STEADI calculated an AUC of 0.790 (95% CI = 0.648 – 0.932, p = 0.004) for telerehab, and an AUC 0.822 (95% CI = 0.691 – 0.954, p = 0.001) for face-to-face. Table 19 outlines ROC analysis data comparing equivalence of validity measures for each environment scoring the 4MWT.

Table 19. 4-Meter Walk Test: Comparative Analysis of Telerehabilitation and Face-to-Face Screening using Receiver Operating Characteristic Curve

Independent Variable		**Telerehabilitation**	**Face-to-Face**
Fall History			
Positive (yes) = 29			
	AUC	0.628	0.640

	p Value	0.234	0.193
12-month Fall History			
Positive (yes) = 22			
	AUC	0.586	0.584
	p Value	0.365	0.372
12-month Emergent Care			
Positive (yes) = 7			
	AUC	0.683	0.629
	p Value	0.133	0.289
Fracture History			
Positive (yes) = 6			
	AUC	0.442	0.465
	p Value	0.654	0.785
6-month Medication Changes			
Positive (yes) = 11			
	AUC	0.588	0.584
	p Value	0.399	0.417
Mini-BEST			
Positive (yes) = 11			
	AUC	0.773	0.774
	p Value	0.009*	0.008*
Stay Independent Brochure			
Positive (yes) = 20			
	AUC	0.778	0.778
	p Value	0.003*	0.003*
STEADI Risk (3-tiered)			
Positive (yes) = 11			
	AUC	0.771	0.766
	p Value	0.009*	0.010*
STEADI Risk (2-tiered)			
Positive (yes) = 26			
	AUC	0.790	0.882
	p Value	0.004*	0.001*
6-month Prospective Falls			
Positive (yes) = 10 [n=36]			
	AUC	0.531	0.473
	p Value	0.778	0.805

n = 39 * = p $\leq$0.05

Timed-up and Go Test (TUG) scores were calculated by selecting the fastest time of the two trials recorded by rater 1 from each environment. Overall, the TUG demonstrated equivalence when comparing the AUC volumes and significance levels for each test environment. Similar to the 4MWT, the TUG demonstrated significant fair to good AUC volumes when analyzing the TUG's ability to categorize other standardized screening tools serving as independent variables, However, the TUG demonstrated poor ability to classify outcomes of prior falls, 12-month emergent care, fracture history, and 6-month medication changes, as well as predicting 6-month prospective fall incidence. Unlike the 4MWT, the TUG approached significance with classifying fall history ($p = 0.085 – 0.088$) although AUC volumes were low. Despite poor sensitivity and specificity with classifying these variables from the Fall History Questionnaire and predicting 6-month prospective fall rates, all six of these independent variables were equally insignificant with equivalent AUC values among both telerehab and face-to-face test environments. ROC analysis of the TUG calculated significant AUC volumes for predicting fall risk conclusions of the Mini-BEST, Stay Independent Brochure, and the STEADI indicating fair to good sensitivity and sensitivity levels. ROC analysis of the TUG predicting the Mini-BEST calculated an AUC of 0.795 (95% CI = 0.604 – 0.987, $p = 0.005$) for telerehab, and an AUC 0.784 (95% CI = 0.592 – 0.976, $p = 0.006$) for face-to-face. ROC analysis of the TUG predicting the Stay Independent Brochure calculated an AUC of 0.750 (95% CI = 0.601 – 0.915, $p = 0.006$) for telerehab, and an AUC 0.754 (95% CI = 0.595 – 0.913, $p = 0.007$) for face-to-face. ROC analysis of the TUG predicting the STEADI (three-tiered risk) calculated an AUC of 0.825 (95% CI = 0.653 – 0.996, $p = 0.002$) for telerehab, and an AUC 0.834 (95% CI = 0.670 – 0.998, $p = 0.001$) for face-to-face. ROC analysis of the 4MWT for predicting outcomes of a two-tiered STEADI scale demonstrated the best balance of sensitivity and specificity with an AUC of 0.858 (95% CI = 0.744 – 0.972, $p < 0.001$) for telerehab, and an equivalent AUC 0.864 (95% CI = 0.752 – 0.976, $p < 0.001$) for face-to-face. Table 20 outlines ROC analysis data comparing equivalence of validity measures for each environment scoring the TUG.

Table 20. Timed-Up and Go Test: Comparative Analysis of Telerehabilitation and Face-to-Face Screening using Receiver Operating Characteristic Curve

Independent Variable		Telerehabilitation	Face-to-Face
Fall History			
Positive (yes) = 29			
	AUC	0.683	0.684
	p Value	0.088	0.085
12-month Fall History			
Positive (yes) = 22			
	AUC	0.572	0.572
	p Value	0.444	0.444
12-month Emergent Care			
Positive (yes) = 7			
	AUC	0.661	0.690
	p Value	0.188	0.120
Fracture History			
Positive (yes) = 6			
	AUC	0.500	0.508
	p Value	1.000	0.953
6-month Medication Changes			
Positive (yes) = 11			
	AUC	0.523	0.536
	p Value	0.827	0.731
Mini-BEST			
Positive (yes) = 11			
	AUC	0.795	0.784
	p Value	0.005*	0.006*
Stay Independent Brochure			
Positive (yes) = 20			
	AUC	0.758	0.754
	p Value	0.006*	0.007*
STEADI Risk (3-tiered)			
Positive (yes) = 11			
	AUC	0.825	0.834
	p Value	0.002*	0.001*
STEADI Risk (2-tiered)			
Positive (yes) = 26			
	AUC	0.858	0.864
	p Value	<0.001*	<0.001*
6-month Prospective Falls			
Positive (yes) = 10 [n=36]			
	AUC	0.527	0.546
	p Value	0.805	0.672

n = 39 * = p ≤0.05

The *30-second Chair Rise* (30STS) scores were calculated by referencing the number of repetitions scored by rater 1 from each environment. Like many of the other dependent variables, the 30STS demonstrated significant equivalence when comparing the AUC volume with other standardized screening tools serving as independent variables but not with classifying prior falls, 12-month emergent care, fracture history, or 6-month medication changes. The 30STS was also not able to predict 6-month prospective falls. Despite poor sensitivity and specificity with predicting these variables, all these independent variables were equally insignificant with equivalent AUC values among both telerehab and face-to-face test environments. Consistency among rater environments is the main focus of research question 3.

ROC analysis of the 30STS calculated significant AUC for predicting fall risk conclusions of the Mini-BEST, Stay Independent Brochure, and the STEADI indicating fair to excellent sensitivity and specificity. ROC analysis of the 30STS predicting the Mini-BEST calculated an AUC of 0.768 (95% CI = 0.587 – 0.949, $p = 0.010$) for telerehab, and an AUC 0.755 (95% CI = 0.571 – 0.939, $p = 0.014$) for face-to-face. ROC analysis of the 30STS predicting the Stay Independent Brochure calculated an AUC of 0.734 (95% CI = 0.577 – 0.892, $p = 0.012$) for telerehab, and an AUC 0.713 (95% CI = 0.551 – 0.875, $p = 0.023$) for face-to-face. ROC analysis of the 30STS predicting the STEADI (three-tiered risk) calculated an AUC of 0.791 (95% CI = 0.638 – 0.943, $p = 0.005$) for telerehab, and an AUC 0.773 (95% CI = 0.611 – 0.934, $p = 0.009$) for face-to-face. Like the 4MWT, ROC analysis of the 30STS for predicting outcomes of a two-tiered STEADI scale demonstrated the best balance of sensitivity and specificity with an AUC of 0.910 (95% CI = 0.822 – 0.998, $p < 0.001$) for telerehab, and an AUC 0.888 (95% CI = 0.788 – 0.987, $p < 0.001$) for face-to-face. Table 21 outlines ROC analysis data comparing equivalence of validity measures for each environment scoring the 30STS.

Table 21. 30-second Sit-to-Stand Test: Comparative Analysis of Telerehabilitation and Face-to-Face Screening using Receiver Operating Characteristic Curve

Independent Variable		Telerehabilitation	Face-to-Face
Fall History			
Positive (yes) = 29			
	AUC	0.636	0.631
	p Value	0.204	0.222
12-month Fall History			
Positive (yes) = 22			
	AUC	0.575	0.564
	p Value	0.428	0.497
12-month Emergent Care			
Positive (yes) = 7			
	AUC	0.647	0.629
	p Value	0.227	0.289
Fracture History			
Positive (yes) = 6			
	AUC	0.412	0.396
	p Value	0.496	0.425
6-month Medication Changes			
Positive (yes) = 11			
	AUC	0.573	0.599
	p Value	0.483	0.341
Mini-BEST			
Positive (yes) = 11			
	AUC	0.768	0.755
	p Value	0.010*	0.014*
Stay Independent Brochure			
Positive (yes) = 20			
	AUC	0.734	0.713
	p Value	0.012*	0.023*
STEADI Risk (3-tiered)			
Positive (yes) = 11			
	AUC	0.791	0.773
	p Value	0.005*	0.009*
STEADI Risk (2-tiered)			
Positive (yes) = 26			
	AUC	0.910	0.888
	p Value	<0.001*	<0.001*
6-month Prospective Falls			
Positive (yes) = 10 [n=36]			

	AUC	0.490	0.527
	p Value	0.930	0.805

n = 39 * = p ≤0.05

The *Tinetti Gait* (POMA-G) scores were calculated by referencing the score of rater 1 from each environment. Like the FRT, equivalency among environments was not consistently observed with the data. The POMA-G demonstrated variation between environments when comparing the AUC volume and significance with classifying prior fall history since age 65 and predicting the two-tiered STEADI. Significance and more favorable sensitivity and specificity was calculated in the face-to-face environment indicating possible inaccuracies with gait observations with the remote rater. However, like many of the other eight screening tests, the POMA-G demonstrated insignificance and poor to fair sensitivity and specificity classifying 12-month fall history, 12-month emergent care, fracture history, and 6-month medication change, and was unable to accurately predict 6-month prospective falls. ROC analysis of the POMA-G calculated significant AUC for predicting fall risk conclusions of the Mini-BEST, Stay Independent Brochure, and the three-tiered STEADI with AUC levels consistent with fair to good sensitivity and specificity. Face-to-face rater AUC volume was higher telerehab rater AUC volume for all three independent variables that showed significance and favorable AUC volumes. ROC analysis of the POMA-G predicting the Mini-BEST calculated an AUC of 0.748 (95% CI = 0.593 – 0.903, p = 0.017) for telerehab, and an AUC 0.812 (95% CI = 0.624 – 1.000, p = 0.003) for face-to-face. ROC analysis of the POMA-G predicting the Stay Independent Brochure calculated an AUC of 0.757 (95% CI = 0.602 – 0.911, p = 0.006) for telerehab, and an AUC 0.811 (95% CI = 0.674 – 0.947, p = 0.001) for face-to-face. ROC analysis of the POMA-G predicting the STEADI (three-tiered risk) calculated an AUC of 0.792 (95% CI = 0.647 – 0.937, p = 0.005) for telerehab, and an AUC 0.812 (95% CI = 0.624 – 1.000, p = 0.003) for face-to-face. Table 22 outlines ROC analysis data comparing equivalence of validity measures for each environment scoring the POMA-G.

Table 22. POMA Tinetti Gait Score: Comparative Analysis of Telerehabilitation and Face-to-Face Screening using Receiver Operating Characteristic Curve

Independent Variable		Telerehabilitation	Face-to-Face
Fall History			
Positive (yes) = 29			
	AUC	0.664	0.760
	p Value	0.127	0.015*
12-month Fall History			
Positive (yes) = 22			
	AUC	0.614	0.618
	p Value	0.229	0.213
12-month Emergent Care			
Positive (yes) = 7			
	AUC	0.478	0.672
	p Value	0.855	0.159
Fracture History			
Positive (yes) = 6			
	AUC	0.409	0.409
	p Value	0.484	0.484
6-month Medication Changes			
Positive (yes) = 11			
	AUC	0.531	0.550
	p Value	0.767	0.629
Mini-BEST			
Positive (yes) = 11			
	AUC	0.748	0.812
	p Value	0.017*	0.003*
Stay Independent Brochure			
Positive (yes) = 20			
	AUC	0.757	0.811
	p Value	0.006*	0.001*
STEADI Risk (3-tiered)			
Positive (yes) = 11			
	AUC	0.792	0.812
	p Value	0.005*	0.003*
STEADI Risk (2-tiered)			
Positive (yes) = 26			
	AUC	0.621	0.737
	p Value	0.222	0.017*
6-month Prospective Falls			
Positive (yes) = 10 [n=36]			

	AUC	0.504	0.571
	p Value	0.972	0.514

n = 39 * = p ≤0.05

The *single limb stance* (SLS) scores were calculated by selecting the time for the left and for the right lower extremities recorded by rater 1 for each test environment. The SLS demonstrated fair to good AUC volumes, significance (p ≤ 0.05), equivalence among both test environments when examining outcomes from the Mini-BEST, Stay Independent Brochure, the converted two-tiered STEADI, and the three-tiered STEADI (LLE only) but not with classifying prior falls, 12-month emergent care, fracture history, and 6-month medication changes. Despite poor sensitivity and specificity with classifying independent variables from the Fall History Questionnaire and prospective fall rates, all six of these variables along with the RLE three-tiered STEADI demonstrated equivalent AUC values and insignificance among both TR and face-to-face test environments. As mentioned, ROC analysis of the SLR calculated significant AUC for predicting fall risk conclusions of the Mini-BEST, Stay Independent Brochure, and the three-tiered STEADI indicating fair to good sensitivity and specificity. ROC analysis of the SLS predicting the Mini-BEST calculated an AUC on the RLE of 0.792 (95% CI = 0.630 – 0.955, p = 0.005) and an AUC on the LLE of 0.758 (95% CI = 0.591 – 0.925, p = 0.013) for telerehab, and an AUC on the RLE of 0.813 (95% CI = 0.656 – 0.970, p = 0.003) and an AUC on the LLE of 0.740 (95% CI = 0.572 – 0.908, p = 0.021) for face-to-face. ROC analysis of the SLS predicting the Stay Independent Brochure calculated an AUC on the RLE of 0.771 (95% CI = 0.620 – 0.923, p = 0.004) and an AUC on the LLE of 0.775 (95% CI = 0.620 – 0.930, p = 0.003) for telerehab, and an AUC on the RLE of 0.776 (95% CI = 0.615 – 0.919, p = 0.004) and an AUC on the LLE of 0.772 (95% CI = 0.615 – 0.930, p = 0.004) for face-to-face. ROC analysis of the SLS predicting the two-tiered STEADI calculated an AUC on the RLE of 0.713 (95% CI = 0.540 – 0.886, p = 0.032) AUC on the LLE of 0.811 (95% CI = 0.672 – 0.949, p = 0.002) for telerehab, and an AUC on the RLE of 0.704 (95% CI = 0.529 – 0.880, p = 0.040) and an AUC on the LLE of 0.817 (95% CI = 0.674 – 0.959, p = 0.001) for face-to-face. Table 23 outlines ROC analysis data comparing equivalence of validity measures for each environment scoring the SLS.

Table 23. Single Limb Stance Test: Comparative Analysis of Telerehabilitation and Face-to-Face Screening using Receiver Operating Characteristic Curve

Independent Variable		**Telerehabilitation**		**Face-to-Face**	
Fall History					
Positive (yes) = 29		RLE	LLE	RLE	LLE
	AUC	0.566	0.647	0.588	0.619
	p Value	0.541	0.172	0.412	0.267
12-month Fall History					
Positive (yes) = 22					
	AUC	0.508	0.533	0.501	0.507
	p Value	0.932	0.723	0.989	0.944
12-month Emergent Care					
Positive (yes) = 7					
	AUC	0.443	0.676	0.473	0.560
	p Value	0.634	0.148	0.826	0.621
Fracture History					
Positive (yes) = 6					
	AUC	0.399	0.513	0.361	0.417
	p Value	0.436	0.922	0.284	0.120
6-month Medication Changes					
Positive (yes) = 11					
	AUC	0.565	0.620	0.601	0.667
	p Value	0.533	0.248	0.333	0.108
Mini-BEST					
Positive (yes) = 11					
	AUC	0.792	0.758	0.813	0.740
	p Value	0.005*	0.013*	0.003*	0.021*
Stay Independent Brochure					
Positive (yes) = 20					
	AUC	0.771	0.775	0.767	0.772
	p Value	0.004*	0.003*	0.004*	0.004*
STEADI Risk (3-tiered)					
Positive (yes) = 11					
	AUC	0.662	0.722	0.670	0.705
	p Value	0.119	0.033*	0.101	0.049*
STEADI Risk (2-tiered)					
Positive (yes) = 26					
	AUC	0.713	0.811	0.704	0.817
	p Value	0.032*	0.002*	0.040*	0.001*

6-month Prospective Falls Positive (yes) = 10 [n=36]					
	AUC	0.481	0.629	0.494	0.612
	p Value	0.860	0.237	0.958	0.306

n = 39 * = p ≤0.05

The *tandem stance* scores were calculated by selecting the time for the left and for the right lower extremities recorded by rater 1 for each test environment. The tandem stance test demonstrated similar significant equivalence to other fall screening tests when comparing area AUC volumes. The exception was that the Stay Independent Brochure score outcomes that demonstrated significance only on the LLE for the face-to-face rater. Despite poor sensitivity and specificity with predicting prospective falls, Stay Independent Brochure outcomes, and the three-tiered STEADI outcomes, and with classifying prior falls, 12-month emergent care, fracture history, and 6-month medication changes, AUC values and insignificance levels among both TR and face-to-face test environments are very equivalent. As was the case with the SLS test, the tandem stance test also had higher AUC volumes and demonstrated statistical significance on the LLE as opposed to the RLE.

ROC analysis of the tandem stance calculated significant AUC for predicting fall risk conclusions of the Mini-BEST (LLE only) and the two-tiered STEADI indicating fair sensitivity and specificity levels. ROC calculations of the tandem stance predicting the Mini-BEST revealed an AUC on the LLE of 0.773 (95% CI = 0.595 – 0.951, p = 0.009) for telerehab, and an AUC on the LLE of 0.752 (95% CI = 0.571 – 0.932, p = 0.016) for face-to-face. ROC analysis of tandem stance predicting the two-tiered risk STEADI calculated an AUC equivalent on both the RLE and LLE of 0.769 (95% CI = 0.625 – 0.913, p = 0.007) for telerehab, and an AUC on the RLE of 0.769 (95% CI = 0.625 – 0.913, p = 0.007) and an AUC on the LLE of 0.788 (95% CI = 0.650 – 0.927, p = 0.004) for face-to-face. AUC for the two-tiered STEADI was fair but strongly significant for both rater environments implementing the tandem stance test. Table 24 outlines

ROC analysis data comparing equivalence of validity measures for each environment scoring the tandem stance.

Table 24. Tandem Stance Test: Comparative Analysis of Telerehabilitation and Face-to-Face Screening using Receiver Operating Characteristic Curve

Independent Variable		**Telerehabilitation**		**Face-to-Face**	
Fall History					
Positive (yes) = 29		RLE	LLE	RLE	LLE
	AUC	0.547	0.528	0.538	0.533
	p Value	0.664	0.797	0.723	0.760
12-month Fall History					
Positive (yes) = 22					
	AUC	0.471	0.460	0.425	0.473
	p Value	0.755	0.671	0.428	0.777
12-month Emergent Care					
Positive (yes) = 7					
	AUC	0.542	0.558	0.603	0.545
	p Value	0.728	0.634	0.400	0.128
Fracture History					
Positive (yes) = 6					
	AUC	0.598	0.480	0.611	0.470
	p Value	0.448	0.876	0.392	0.815
6-month Medication Changes					
Positive (yes) = 11					
	AUC	0.555	0.455	0.539	0.485
	p Value	0.596	0.662	0.708	0.888
Mini-BEST					
Positive (yes) = 11					
	AUC	0.597	0.773	0.633	0.752
	p Value	0.349	0.009*	0.201	0.016*
Stay Independent Brochure					
Positive (yes) = 20					
	AUC	0.588	0.663	0.584	0.686
	p Value	0.347	0.081	0.369	0.048*
STEADI Risk (3-tiered)					
Positive (yes) = 11					
	AUC	0.576	0646	0.516	0.675
	p Value	0.463	0.160	0.876	0.092
STEADI Risk (2-tiered)					
Positive (yes) = 26					
	AUC	0.769	0.769	0.769	0.788
	p Value	0.007*	0.007*	0.004*	0.004*
6-month Prospective Falls					
Positive (yes) = 10 [n=36]					

	AUC	0.500	0.408	0.460	0.446
	p Value	1.000	0.397	0.711	0.621

n = 39 * = p ≤0.05

Narrow stride scores were calculated by selecting the time for the left and for the right lower extremities recorded by rater 1 for each test environment. The narrow stride stance test demonstrated equivalence of AUC values and similar insignificance of p values with classifying and predicting all ten independent variables. All AUC values demonstrated poor sensitivity and specificity. Table 25 outlines ROC analysis data comparing equivalence of validity measures for each environment scoring the narrow stride stance test.

Table 25. Narrow Stride Stance Test: Comparative Analysis of Telerehabilitation and Face-to-Face Screening using Receiver Operating Characteristic Curve

Independent Variable		**Telerehabilitation**		**Face-to-Face**	
Fall History					
Positive (yes) = 29		RLE	LLE	RLE	LLE
	AUC	0.488	0.469	0.488	0.466
	p Value	0.910	0.772	0.910	0.748
12-month Fall History					
Positive (yes) = 22					
	AUC	0.519	0.495	0.519	0.492
	p Value	0.843	0.955	0.843	0.932
12-month Emergent Care					
Positive (yes) = 7					
	AUC	0.545	0.558	0.545	0.554
	p Value	0.714	0.634	0.714	0.661
Fracture History					
Positive (yes) = 6					
	AUC	0.455	0.470	0.455	0.470
	p Value	0.726	0.815	0.726	0.815
6-month Medication Changes					
Positive (yes) = 11					
	AUC	0.446	0.464	0.446	0.464
	p Value	0.607	0.731	0.607	0.731
Mini-BEST					
Positive (yes) = 11					
	AUC	0.636	0.591	0.636	0.591
	p Value	0.190	0.382	0.190	0.382
Stay Independent Brochure					
Positive (yes) = 20					

	AUC	0.575	0.550	0.575	0.550
	p Value	0.423	0.593	0.423	0.593
STEADI Risk (3-tiered)					
Positive (yes) = 11					
	AUC	0.576	0.529	0.576	0.526
	p Value	0.463	0.779	0.463	0.803
STEADI Risk (2-tiered)					
Positive (yes) = 26					
	AUC	0.558	0.538	0.558	0.538
	p Value	0.561	0.699	0.561	0.699
6-month Prospective Falls					
Positive (yes) = 10 [n=36]					
	AUC	0.442	0.462	0.442	0.462
	p Value	0.596	0.724	0.596	0.724

n = 39 * = p ≤0.05

Narrow stance scores were calculated by selecting the time recorded from the first trial by rater 1 from each test environment. Scores from the first trial needed to be used in statistical calculations of validity because all participants scored a perfect 10 out of 10 seconds on trial two. Similar to the narrow stride stance test, the narrow stance test demonstrated equivalence in its inability to classify or predict all ten independent variables among both test environments. All AUC values demonstrated poor sensitivity and specificity. Overall, analysis for both environments scoring the narrow stride stance test revealed equivalently low AUC values and insignificant p values. Table 26 outlines ROC analysis data comparing equivalence of validity measures for each environment scoring the narrow stance test.

Table 26. Narrow Stance Test: Comparative Analysis of Telerehabilitation and Face-to-Face Screening using Receiver Operating Characteristic Curve

Independent Variable		**Telerehabilitation**	**Face-to-Face**
Fall History			
Positive (yes) = 29			
	AUC	0.469	0.469
	p Value	0.772	0.772
12-month Fall History			
Positive (yes) = 22			
	AUC	0.495	0.495
	p Value	0.955	0.955

12-month Emergent Care			
Positive (yes) = 7			
	AUC	0.558	0.558
	p Value	0.634	0.634
Fracture History			
Positive (yes) = 6			
	AUC	0.470	0.470
	p Value	0.815	0.815
6-month Medication Changes			
Positive (yes) = 11			
	AUC	0.464	0.464
	p Value	0.731	0.731
Mini-BEST			
Positive (yes) = 11			
	AUC	0.591	0.591
	p Value	0.382	0.382
Stay Independent Brochure			
Positive (yes) = 20			
	AUC	0.550	0.550
	p Value	0.593	0.593
STEADI Risk (3-tiered)			
Positive (yes) = 11			
	AUC	0.529	0.529
	p Value	0.779	0.779
STEADI Risk (2-tiered)			
Positive (yes) = 26			
	AUC	0.538	0.538
	p Value	0.699	0.699
6-month Prospective Falls			
Positive (yes) = 10 [n=36]			
	AUC	0.462	0.462
	p Value	0.724	0.724

n = 39 * = p $\leq$0.05

Findings

Research question 1 (*What effect does exposure to a telerehabilitation delivery system have on underlying attitudes and beliefs of older adults about the perceived usefulness of this healthcare delivery option?*) led to the creation of a survey instrument suitable to quantify change following a telerehabilitation experience, and the instrument served as a valid method to compare post-test data with control group participants. Overall, the survey instrument, as implemented in this study, demonstrated good internal consistency with pre-test ($\alpha = 0.877$) and post-test surveys ($\alpha = 0.859$). Because construct 4 (facilitating conditions) demonstrated less than acceptable post-test internal consistency ($\alpha = 0.645$), relationships among each of the four items in construct 4 were further examined. Pearson's correlation was selected to stay consistent with the parametric statistical analysis, ANCOVA. Poor to weak correlations were concluded between the 3rd item, Q4c, of construct 4 (I believe that technology advancements are important to meeting my healthcare needs) and item Q4a (I believe having access to a physical therapist outweighs the cost of purchasing a computer or table; r = 0.129 pre-test, r = -0.092 post-test) and item Q4b (I believe the benefit of consistently accessing a physical therapist outweighs the cost of internet service in my home; r = 0.207 pre-test, r = 0.009). Correlation between item Q4c and the remaining item, Q4d (I believe that healthcare providers will also provide technical support to me), demonstrated moderate correlation (r = 0.721 pre-test, r = 0.472 post-test). Items Q4a and Q4b had strong pre-test correlation (r = 0.813 pre-test, r = 0.760 post-test), and item Q4d had weak to acceptable correlation with Q4a (r = 0.291 pre-test, r = 0.292 post-test) and Q4b (r = 0.347 pre-test, r = 0.327 post-test) as compared to item Q4c with other items in construct 4. Therefore, it was recommended that Q4c (I believe that technology advancements are important to meeting my healthcare needs) be eliminated or tested or reassigned to a more appropriate construct in future iterations of the TR survey instrument.

If content validity ratios were integrated to the strict minimum values suggested by Lawshe (CVR $\geq$ 0.99 if n = $\leq$ 7), the TR survey would have included only five (Q2c, Q4b, Q5c, Q5d, & Q6b) of the 33 items, and would have integrated components of only four of seven constructs supported in the technology acceptance literature. Table 27 outlines pre-experimental content validity data with post-experimental pre- and post-test internal consistency levels.

Table 27. Comparison of Content Validity Values and Internal Consistency Levels of the Telerehabilitation Survey Instrument

Survey Construct	Item CVRs	CVI	Pre-test α level	Post-test α level
1. performance expectancy /perceived usefulness	0.71	0.38	0.955	0.959
	0.71			
	0.43			
	0.43			
	0.14			
	0.14			
	0.14			
2. effort expectancy	0.71	0.71	0.965	0.969
	0.71			
	1.0			
	0.71			
	0.43			
3. social influence	-0.14	-0.07	0.890	0.916
	-0.42			
	0.14			
	0.14			
4. facilitating conditions	0.71	0.64	0.742	0.645
	1.0			
	0.71			
	0.14			
5. perceived security	0.43	0.52	0.884	0.927
	0.43			
	1.0			
	1.0			
	0.43			
	-0.14			
6. computer anxiety	0.14	0.43	0.906	0.816
	1.0			
	0.14			
7. physician's opinion	-0.14	0.21	0.794	0.783
	0.14			
	0.71			
	0.14			
Mean for all constructs	*0.42*	*.40*	*0.877*	*0.859*

Findings suggested that there were few connections between recommendations from the panel of experts and statistical tests of homogeneity. For example, social influence had the lowest CVR value but also had good to excellent internal consistency of pre- and post-test surveys. In follow-up to the null hypothesis that there was no difference in attitudes and beliefs of older adults exposed to this investigation's real-time telerehabilitation application and older adults in the control group, pre- and post-test composite score comparisons for constructs 1 (performance expectancy /perceived usefulness), 2 (effort expectancy), 4 (facilitating conditions), and 5 (perceived security) statistically refute this hypothesis. Additionally, the composite score comparisons for construct 7 (physician) was approaching significance ($p = 0.057$). The TR survey instrument ANCOVA data, mean composite scores (SD), level of significance, and effect sizes comparing pre- and post-test scores among groups can be found in Table 4. The final version of the TR survey instrument implemented in data collection is found in Appendix I. Overall, statistical appraisal of the survey indicates that there are many strengths of this preliminary TR survey instrument. Chapter 5 further discusses these strengths, study outcomes, recommendations, and limitations.

Research question 2 (*Are fall risk screening conclusions that are derived remotely equivalent to other reference standard face-to-face screening tools?*) led to the establishment of comparative validity measures among remote and face-to-face environments as well as concurrent validity comparing fall risk conclusions derived remotely with a face-to-face reference standard. Correlation and receiver operating characteristic curves (ROC) confirmed that that sensitivity and specificity measurements from telerehab raters were relatively equivalent to sensitivity and specificity measurements from face-to-face raters when comparing area under the curve (AUC) and p-value significance. These analyses conclude that being evaluated by either the face-to-face or telerehab rater group had no difference in classifying predicting a participant's score on any of the independent variable measures.

Comparison of a dichotomous dependent variable (screening tool) and a dichotomous independent variable (fall history, for example) led to the formulation of true positives, false positives, true negatives, and false negative data from the 39 participants of the experimental group. Stratification of this data led to the calculation of sensitivity, specificity, and likelihood ratios for the STEADI toolkit and the selected reference standard, the Mini-BEST, as well as the FRT, 4MWT, TUG, 30STS, and tandem stance. As noted, concurrent validity between the telerehab STEADI and the face-to-face reference standard was established and confirmed by moderate significant correlation (r = 0.447, p = 0.004) with fall risk categorization, and very good sensitivity (89%) of the STEADI confirming a positive fall risk conclusion from the Mini-BEST and excellent specificity (92%) of the Mini-BEST confirming a negative (low) fall risk conclusion on the STEADI. Overall, the STEADI was found to have stronger positive predictive values and the Mini-BEST was found to have stronger negative predictive values for the incidence of prospective falls and the classification of 12-month emergent care, fracture history, and 6-month medication change history.

Good to excellent specificity data was calculated for all five of the nine individual fall screening tests with established cut-off scores that were primarily used with the establishment of feasibility and reliability in research question 3. Specificity ranged from 70% - 100%% for the 30STS, tandem stance, TUG, 4MWT, and FRT’s ability to confirm a negative finding from participant’s self-reported fall history since age 65. Of this group, the TUG and 4MWT had the most consistent and highest levels of specificity (88-100%). Specificity became more variable with classifying self-reported negative 12-month retrospective and predicting 6-month prospective fall rates. Specificity ranged from 53-90% with levels on the 30STS and tandem stance both below 70%. The 4MWT had the most consistent and highest levels of specificity with confirming no falls in the previous 12-months. Lastly, the 30STS and tandem stance underperformed with predicting negative 6-month prospective falls (54-65%), and variability was identified with specificity values of the TUG, 4MWT, and FRT (73-89%). Overall, the FRT's seven inches cut-off score had much better specificity levels than the 10 inches cut-off mark for all fall prediction and classification data. To a lesser contrast than the FRT's two-level cut score comparisons, the TUG's 13-second cut-off mark had slightly better negative predictive and classification ability than the 12-second mark cited in the STEADI toolkit. Supplemental correlation data can be found in Appendix J.

Research question 3 (*Are outcomes of fall screening measures that are performed remotely consistent with those performed face-to-face?*) led to the confirmation that telerehab scoring and fall-risk categorization was consistent with face-to-face scoring and fall-risk categorization among screening tools integrated into this investigation. Kappa statistics demonstrated moderate to excellent strength of agreement (0.544 – 0.945), intraclass correlation coefficients demonstrated excellent to perfect agreement (0.918 – 1.000), and matrix correlation calculations confirmed good to perfect relationships (0.675 – 1.000) with scoring and fall risk categorization, where applicable, among both test environments with significance ($p < 0.05$) for the Timed Up and Go (TUG) Test, 30-Second Chair Rise (30STS), 4-Stage Balance (narrow stance, narrow stride stance, tandem stance, and single limb stance), Performance-Oriented Mobility Assessment Gait (POMA-G) Tool, 4-meter Walk Test (4MWT), and Functional Reach Test (FRT). Additionally, the raters from telerehab and face-to-face environments demonstrated significant interrater reliability agreement with the published three-tiered risk scale (99% agreement, $r = 0.981$, $p <0.001$), and with the modified two-tiered risk scale ($K = 0.943$, $r = 0.945$, $p <0.001$).

Two other areas of analysis not directly addressed by the three research questions relate to the relationship between the Stay Independent Brochure scores and the overall STEADI algorithm, and whether the statistically modified two-tiered STEADI (low, high) was interchangeable or as good as the three-tiered STEADI (low, moderate, high). Spearman rho correlation analysis revealed a fair correlation ($r = 0.325$, $p = 0.044$) between the Stay Independent Brochure and the three-tiered STEADI risk conclusions, and a poor and insignificant correlation ($r = 0.181$, $p = 0.269$) between the Stay Independent Brochure and a two-tiered STEADI risk model. ICC revealed an insignificant 31% agreement between the Stay Independent Brochure and the STEADI risk classifications. All factors considered, the preliminary step in the STEADI tool kit (Stay Independent Brochure) and the final classification algorithm of the STEADI do not produce consistent results. Despite ROC analyses revealing mostly significant and acceptable AUC for the Stay Independent Brochure and STEADI risk classification independent of one another, the two classifications lack reliability of agreement and lack strong evidence to support their relationship.

When comparing a prospective two-tiered with the current three-tiered STEADI risk models, both have significant and positive relationships with many of the nine individual screening tools as per matrix correlations and AUCs. Further, there was a significant excellent correlation between the two risk models ($r = 0.945$, $p < 0.001$). However, another purpose of the three-tiered model developed by the CDC was to provide more specific recommendations catering to three different groups with theoretical unique follow-up needs as opposed to a two-tiered, dichotomous model that many other screening tests employ (i.e. risk or no risk). Therefore, future investigations can reference this research and continue to use a two-tiered risk model when needed to support statistical calculations. However, the three-tiered model has better clinical applicability and, as described in Chapters 2 and 3, the published three-tiered STEADI algorithm including the Stay Independent Brochure is consistent with recommendations from the American and British Geriatrics Societies.[35,79]

Summary of Results

The telerehabilitation survey was constructed, appraised for face and content validity by a 7-member panel of experts, proven to have good overall internal consistency with pre- and post-test scoring, and was sensitive to change demonstrating significant change in experimental post-testing scores among four of seven survey constructs (n = 84).

The STEADI algorithm was appraised for consistency and relationships among variables that comprise the algorithm's flowchart and ultimate risk categorization. Fall risk categorization of the STEADI was found to have excellent 99% agreement between telehealth and face-to-face rater environments (n = 39). The TR and face-to-face rater scoring the STEADI algorithm had excellent correlation using Spearman's rho (r = 0.981, p <0.001). Overall, the STEADI was found to have good sensitivity with predicting or classifying the positive presence of 6-month prospective falls (80%), falls since age 65 (76%), falls in the prior 12-months (73%), fall-related fracture history (75%), 12-month emergent care use history (86%), 6-month medication change history (80%), score >4 on the Stay Independent Brochure Questionnaire (75%), and fall risk concluded by the Mini-BEST (89%). The telerehab three-tiered STEADI was concluded to have moderate concurrently validity with the face-to-face Mini-BEST (r = 0.447, p = 0.004). These findings are supported by the following Spearman's rho correlation findings: moderate significant correlation (r = 0.447, p = 0.004) using the three-tiered TR STEADI. However, the relationship between the Mini-BEST and a STEADI demonstrated a weaker insignificant relationship with both TR (r = 0.258, p = 0.113) and face-to-face (r = 0.283, p = 0.081) environments when the STEADI was reduced from a three-tiered to a consolidated two-tiered risk model. Nonetheless, both tools proved to be reliable and valid instruments for healthcare professionals to consider implementing.

It is notable that sensitivity and specificity values from the STEADI and Mini-BEST demonstrated an inverse relationship with predicting and classifying outcomes from independent variables. More specifically, the TR STEADI demonstrated stronger sensitivity values whereas the Mini-BEST demonstrated stronger specificity values.

Reliability analysis using ICC and kappa concluded good to perfect significant agreement of scoring and fall risk conclusions between telehealth and face-to-face raters when implementing the FRT, TUG, 30STS, 4MWT, POMA-G, narrow stance, narrow stride stance, tandem stance, and single limb stance. In addition, ROC analysis revealed relative equivalency of AUC curves for each of these nine individual screening tests and their ability or inability to classify prior fall, fracture, emergent care, and medication change histories, as well as predict future falls and relative equivalency among predicting risk conclusions from the Mini-BEST, Stay Independent Brochure, and a two- and three-tiered STEADI risk categorization. The exceptions to equivalence of AUC values among telerehab and face-to-face environments was with the POMA-G and FRT bringing into question the feasibility and accuracy of conducting these two screening tests with basic audio-visual conferencing equipment. Chapter 5 will further elaborate on the implications and limitations of these results, and their impact on this proposal’s problem statements and research question hypotheses.

CHAPTER FIVE: DISCUSSION

Discussion

The Clinical Guidance Statement from the APTA's Academy of Geriatric Physical Therapy states that physical therapists should play a role in questioning older adults about the presence, frequency, and circumstances surrounding falls and in the screening for balance impairments and gait abnormalities.[35] This was a vital step towards improving the independence of community-dwelling elders and costs associated with falls in those age 65 and older. As Chapter 2 highlighted, there are a battery of fall risk screening and outcome measures available for healthcare providers to employ. Because few screening tools are appropriate in all settings and appropriate for all patients,[35,78] this investigation tested a variety of fall screening tools felt to be safe and potentially feasible to implement by a remote physical therapist. In many cases, clinicians integrate more than one fall risk screening tool to more accurately screen and therefore, guide their clients with necessary wellness or follow-up evaluation actions. Contemporary recommendations, however, suggest that multi-factorial fall risk assessments be conducted annually to further appraise an individual's full scope of fall risks. The CDC's Stopping Elderly Accidents, Deaths & Injuries (STEADI) Toolkit for healthcare providers was an example of one such screening instrument.[20]

The Stay Independent Brochure questionnaire analyzes a multitude of factors as a pre-cursor to the STEADI's balance, lower extremity strength, and mobility assessment. Together, along with the patient's fall and fall-related injury history, this multi-factorial fall risk screening algorithm creates a three-tiered risk categorization to guide provider recommendations and client follow-up.[20] Like all nine fall-risk screening tools selected for inclusion in this investigation, the STEADI has the potential to impact our nation's healthcare crisis related to fall-related disability and their economic consequences. The challenge, however, is finding more innovative, readily available, cost-effective, and sustainable models for the provision of fall prevention health services to older adults. Telerehabilitation has the potential to assist with this challenge.

Results of this investigation not only confirmed that many older adults are receptive to computer-assisted access to a physical therapist, but post-test survey scores indicate that one experience with a telerehab delivery system significantly enhanced participant attitudes and behavioral intention to adopt telerehab services from a physical therapist. To that end, implementation of all nine screening tools proved to have good to perfect agreement between remote and face-to-face raters. Furthermore, implementation of all nine screening tools including the integration of the STEADI algorithm proved to be feasible and safe within the controlled methods employed by this investigation. The one caveat to the feasibility was feedback from raters indicated that the Functional Reach Test (FRT) required repeated instructions from the lead telerehab rater prior to most participants beginning to comprehend the test protocol. In addition to end-user acceptability, test reliability, and feasibility, use of a telerehabilitation delivery system proved to be have clinically meaningful valid outcomes as per congruency with specificity calculations and area under the curve agreement with face-to-face risk outcomes. Lastly, use of the STEADI algorithm for categorization of fall risk among community-dwelling older adults was concurrently valid with the robust gold-standard, Mini-BEST.

Results from this investigation established a foundation to guide clinicians and researchers engaging in telerehabilitation or telehealth so that just like with face-to-face traditional practice decisions, they can combine their clinical judgement with pending publications from this investigation to select the most appropriate fall risk screening tool for their off-site clients. Although there are limitations and delimitations to this investigation and results should be integrated with caution, this investigation was able to quantify acceptability, reliability, and validity for the integration into future research, clinical practice, and as a foundation for healthcare policy advocacy.

This investigation was rooted in 3 major problem statements: 1) While telehealth delivery systems have demonstrated the potential to assist with the screening for and the prevention of elderly falls, its validity and reliability in doing so had not yet been established. 2) While telehealth may be an option for some individuals, little was known about the attitudes and beliefs of older adults with regard to receiving telecommunications-aided physical therapy services and whether or not those attitudes and beliefs would be influenced by a telerehab experience. 3) Falls in the elderly are a serious public health problem resulting in U.S. spending billions of dollars treating the sequelae of injurious falls. More sustainable models for the provisions of health services to prevent the physical disability and economic impact of elderly falls is needed. The stated *purpose* of this investigation was to explore the acceptability, feasibility, reliability, and validity of telehealth-delivered fall risk and mobility screening in an older adult population. This investigation was the first of its kind to use synchronous telehealth applications to comprehensively screen elderly fall risks and measure the perceived usefulness of a telerehabilitation delivery system among community-dwelling older adults.

There have been concerns in research that most tools simply focus on the examination or screen of balance, overall mobility, lower extremity strength, gait, and/or that some tools overlap multiple constructs. This lack of clarity impedes implementation of evidence-informed clinical practice and the creation of clinical practice guidelines. This overlap of screening and outcomes tools for multiple constructs across multiple patient populations is exemplified by classically utilized and referenced tools such as the Berg Balance Test, TUG, and Tinetti POMA.[65]

Nonetheless, the contemporary literature and the most current Clinical Practice Guidelines from the American and British Geriatrics Societies recommend a multi-factorial fall risk assessment.[35] The STEADI toolkit was developed in response to these guidelines. One of the goals of this investigation was to assess its reliability when implemented remotely.

The STEADI was designed to be a simple but evidenced-based method for healthcare providers to more readily incorporate fall risk screening and fall prevention interventions into their everyday clinical practice. It also provides an important link between clinical care and community-based fall prevention programs such as the Otago and A Matter of Balance. While the STEADI was developed in response to AGS/BGS recommendations and CDC fall prevention initiatives, the toolkit lacks statistical data for the quality assurances needed to maximize its clinical impact on population health. Despite the Stay Independent Brochure questionnaire and the overall STEADI algorithm lacking consistency of agreement, they serve different functions and both screening tools individually classified overall fall history since age 65 and 12-month fall history of this study's sampled population. It is also notable that the STEADI was also able to predict the 6-month prospective fall incidence with 80% sensitivity. Furthermore, and most importantly, this investigation has proven the STEADI to be a safe, feasible, reliable, and valid method of administering a multi-factorial fall screening tool through a telerehab delivery system. The STEADI has excellent sensitivity (89%) for confirming a positive fall risk outcome on the face-to-face reference standard, the Mini-BEST, and the STEADI can also be used in combination with other fall risk screening tools that this investigation found to be equivalently safe, reliable, and valid to face-to-face implementation. Based upon the outcomes of this investigation, best utility of the instruments tested would be the FRT (88-100% with 7" cut score), 4MWT (81-88%), and TUG (73-90%). These three screening tools have good to excellent specificity using a telerehab delivery system and could be complimentary supplements or alternatives to the STEADI depending on the clinical needs of the population and resources available to the examiner.

Much of the literature supports the notion that a reported elderly fall incident drives the screening assessment process.[20,35,168] In contrast, an older adult can indicate that they have fallen in the past year on the Stay Independent Brochure, but if their total score across the 12 questions on this brochure was less than 4, the older adult will be classified as low risk and they are not screened for gait, strength, and balance (TUG, 30STS, Four-Stage Balance Tests) impairments. This appears to be a weakness of this CDC resource. Because all study participants received fall screening testing regardless of their Stay Independent Brochure score or fall history, this investigation was able to identify discrepancies with the flow of the STEADI's current algorithm. For example, eight of this study's 14 participants classified as low risk reported prior falls, seven reported multiple falls, two reported prior fall-related fractures, and at least two fell within 6-months after testing (Table 8). This also highlights the possible need to integrate alternative screening tools other than what the CDC has adopted for the STEADI. According to the STEADI's intervention algorithm, a low risk classification results only in patient education, calcium and vitamin D prescription or intake verification, and referral to a community-based exercise program. Despite 57% of this study's low risk participants reporting prior falls, the current CDC algorithm does not support a referral to physical therapy for a more detailed examination or skilled intervention. This is in direct contradiction to the literature that states those who fall are two to three times more likely to fall again,[36,189] and that an individual's risk of falling increases with each decade of life.[190] Lastly, the STEADI algorithm integrates the TUG, 30STS, and the 4-Stage Balance Test. However, only the TUG was listed as recommended and the other two tests are listed as optional despite each test measuring a different construct (mobility, standing balance, LE strength). Furthermore, the 30STS and the only portion of the four-stage balance test with a cut-off score (tandem stance) both demonstrated less than optimal sensitivity (tandem 20-41%; 30STS 48-60%) and specificity (tandem 59-70%; 30STS 54-70%) with classifying prior and predicting future falls (Table 7). Regardless, this investigation integrated all three tests and considered a participant as having at least a moderate risk in accordance with the algorithm if any one of the three screening tests revealed a positive finding. As mentioned above, this investigation found that a disproportionate number of fallers lacked significant findings on the TUG, 30STS, and/or the 4-Stage Balance Tests concluded by both telerehab and face-to-face rater environments. It is possible, however, that this finding is specific to the sampled population and not a generalizable finding to all older adults.

To properly address research questions 2 and 3, all members of the experimental group participated in all three functional screening tests included in the STEADI. As noted in Chapter 4, ICC analysis indicated a 99% agreement and excellent inter-item correlation ($r = 0.981$) between both rater environments when scoring the three-tiered STEADI. That being said, results from the telerehab raters are as reliable and valid as if the screen was performed face-to-face. Thus, these aforementioned unintended results from this telerehab investigation suggest that screening tools included in the STEADI require further analysis by the CDC so that better congruency exists between positive or negative test results and prior fall history. Suggested options for supplemental data analysis include further investigating the predictive validity of and possibly altering the current cut-off points for the three screening tools, integrating replacement or supplemental optional screening tools that are more sensitive to retrospective and prospective falls/fall risks, and providing healthcare providers the ability to match screening tests with patient presentation, and/or altering the weight of prior falls on the 12-item Stay Independent Brochure to ensure all persons with self-reported falls have the opportunity to receive further assessment. An example of a possible need to alter a fall-risk cut-off value is with the TUG. The CDC lists a 12-second cut-off time in the STEADI toolkit, but the literature mostly cites a 13-second cut-off score. Results from this investigation indicate that the 13-second cut-off score has greater specificity with classifying a negative incidence of 12-month prior falls and with predicting negative 6-month future falls (Table 7).

The purpose and hypotheses of this research necessitated all participants receive fall risk screening, thus, creating an opportunity to observe the mismatch between fall and fracture history and their low fall risk classification (Table 5). This is an important factor that may have gone unreported based upon the current flow diagram on the STEADI algorithm. In the end, the intent of the STEADI is for medical providers of various disciplines to more readily include a standardized screening process into their examinations so that interventions can be more proactive than reactive in addressing falls.[20,170] To accomplish these over-arching population health goals of older adults, the STEADI toolkit and any other multi-factorial screening tools must be rigorously tested and modified, as appropriate, to maximize their sensitivity and specificity with falls and fall-related adverse events.

There is a growing body of research applying foundational theories rooted in the technology acceptance model (TAM). As an extension of Davis' TAM work, Venkatesh spearheaded contemporary advancements for predicting end-user adoption of technology by incorporating components of the theory of reasoned action (TRA), TAM, motivational models, theory of planned behavior, the combined theory of planned behavior/TAM, model of personal computer use, diffusion of innovations theory, and social cognitive theory.[118,191] In anticipation of the expansion of health-related technologies, the population growth and wellness needs of older adults, and evolving in-home tele-monitoring applications, many researchers began to explore end-user adoption of these technologies and included older adults as potential end-users.[54,76,191] It is notable that no articles that investigated the attitudes and beliefs of older adults using standardized acceptance models such as the TAM focused on synchronous connections of providers with end-users for health screening purposes. This investigation will be a unique contribution to the literature base because it was the first of its kind to examine the perceived usefulness of a telerehabilitation delivery system for examining fall risk in older adults. Since then, the literature base has continued to evolve by further examining the attitudes and preferences of older adults. One such example was an Australian publication that outlined the sporadic consumer uptake of telehealth services. Russell et al specifically cited the aging Australian population, rising healthcare costs, and the expectations of older adults to remain in their homes as opposed to moving to residential care facilities as reasons to survey older adults for predictors of home telehealth adoption. In this investigation, Russell et al examined the influence of six factors: demographics, health status and usage, mobility and ease of access to healthcare, technology usage and anxiety with technology, telehealth attitudes, and personality traits.[191] Unlike this dissertation study, Russell et al collected only baseline data through an online survey and placed a tremendous focus on demographic factors such as access to providers and hospitals, geographic residence (rural vs. urban), and presence of chronic conditions to test predictive models. Their findings refuted the hypothesis that telehealth was for residents of rural communities. In fact, their regression models concluded that neither geographical location nor distance from a hospital were significant predictors of intention to adopt telehealth services. Further, the presence of chronic diseases, which implies dependence on medical care, was also unrelated to intention to adopt. Although convenience of accessing healthcare providers was moderately correlated with adoption intentions ($r = 0.49$), convenience nor personality factors including risk aversion were significant predictors of use in their regression model. Conclusions from Russell et al did find that trust in telehealth ($\beta = 0.35$), TAM ($\beta = 0.27$), healthcare habits ($\beta = -0.20$), dissatisfaction with traditional healthcare ($\beta = 0.19$), and online behaviors ($\beta = 0.09$) were significant predictors of intention to adopt.[191] While Russell et al did integrate some key questions from the technology acceptance and psychology literature, they did not operationally define what they meant by many of these constructs. Furthermore, they did not publish their survey questions, so it was difficult to compare its generalizability to older adults in the United States or make direct comparisons with the survey instrument constructed and quantified in this investigation. Russell et al indicated that the TAM was a significant finding; however, Davis' Technology Acceptance Model highlights perceived usefulness and perceived ease of use, neither of which were mentioned in Russell's publication. Further, the TAM has had several contemporary updates and expansions based mainly upon the collaborative work from Venkatesh.[118] There are potentially valuable common themes between outcomes of this Australian study and this dissertation, but as published, Russell et al make it difficult to further determine implications of their results.

While this investigation was the first known to use synchronous telehealth for the purpose of fall screening among community-dwelling older adults, this investigation was not the first to examine patient satisfaction in response to a telerehab experience. Recent publications from Chumbler et al proposed using post-telerehabilitation telephone surveys for veterans diagnosed with stroke who received tele-monitoring and tele-interventions as a means to quantify patient satisfaction. However, their 2010 article was only a concept paper, and their 2015 publication lacked details of patient satisfaction other than an enhanced satisfaction ($p = 0.029$) with their Veterans Affairs Medical Center hospital care following a six month tele-monitoring program.[192,193] A 2004 publication by Russell et al was one of the first investigations to use a visual analogue scale to survey participants receiving telerehab following a total knee replacement. Satisfaction categories were perceived benefit, contentment with method, recommend to friends, have this treatment again, visual clarity, and audio clarity.[194] Results from this fall screening study revealed that the intervention group scored significantly higher relative to the control group on the TR survey post-test for perceived usefulness, effort expectancy, facilitating conditions, and perceived security. Near significance ($p = 0.057$) was calculated for a fifth construct, physician opinion (Table 5). Of the seven constructs included in the TR survey, the investigator hypothesized that perceived usefulness, facilitating conditions, social influence, computer anxiety, and physician opinion composite scores would show significant change upon post-test scoring of the experimental group, whereas effort expectancy and perceived security were hypothesized to not reflect significant change with post-test surveys. The methods and scope of interaction between the participant and lead TR rater were thought to have a less direct impact on constructs two and five as compared to the other five constructs hypothesized to be influenced by a telerehab session.

While the constructs, the intent of determining end-user adoption, or the effect of a telerehab experience hypothesized in this investigation do not match with the Russell's study, there are common themes of perceived benefit and perceived usefulness that both scored favorably following a real-time telerehab experience. The limitation with Russell's study was that there lacked methodological rigor that was associated with a pre-test comparison and/or a control group. The TR survey instrument constructed in support of research question 1 is the first validated survey tool designed for telerehab clinicians. Although further testing is needed to establish cut-off scores to accurately predict end-user adoption and to refine items for maximal internal consistency, the TR survey instrument will be a unique contribution to the literature. Further discussion about the survey tool can be found in the implications section.

Truter et al along with Russell took yet a different approach with a recent publication examining the validity of remote assessment of low back pain. This study's satisfaction categories were confidence with physical self-examination, recommend to a friend who was unable to travel, as good as face-to-face, visual clarity, audio clarity, and overall satisfaction.[195] While the method of using a visual analogue scale (VAS) and post-test only feedback remain similar to his 2004 study, only clarity of the audio-visual connection remains the same in this 2014 publication. This low back pain investigation can be comparable with the TR survey by analyzing Russell's variable "as good as face-to-face" with the TR survey item 1b (Using a computer to access a physical therapist is/was as good as seeing them face-to-face) and Russell's variable "visual / audio clarity" with the TR item 2d (My interaction with the telerehabilitation equipment is/was clear and understandable). Russell's mean VAS demonstrated 30 of 100mm for "as good as face-to-face," and approximately 70 of 100mm for both visual and audio quality. In contrast, the TR survey measured responses on a 0-7 scale. After removing the five pre-test scores that lacked a post-test response, the mean of all responses were calculated for items 1b and 2d. The experimental group's 1b changed from a mean of 3.87 at baseline to a 5.23 at post-test compared to the control group's baseline mean of 3.33 and a post-test mean of 3.2. Although different scales and methodology are associated with Russell's "as good as face-to-face" results, the TR survey demonstrated a 75% of total score as compared to Russell's 30% of total score. The experimental group's 2d changed from a mean of 4.74 at baseline to a 5.72 at post-test compared to the control group's baseline mean of 4.4 and a post-test mean of 3.88. Although different scales and methodology are associated with Russell's "visual and audio quality" results, this dissertation's TR survey demonstrated a comparable 82% of total score as compared to Russell's 70% of total score from feedback received from participants of his telerehab low back pain assessment study.

Overall, this study was able to demonstrate excellent levels of agreement with raw instrumentation scoring and fall risk using cut-off points as applicable for 10 fall screening instruments included in this investigation: FRT, TUG, 4MWT, 30STS, POMA-G, single limb stance, tandem stance, narrow stride stance, narrow stance, and the CDC's STEADI. While telehealth and telerehabilitation delivery systems have demonstrated the potential to assist with the screening for and the prevention of elderly falls, the feasibility of conducting all of these tests was underdeveloped in the literature. Another recent Australian study by Russell et al also examined the feasibility and reliability of implementing the FRT, TUG, a step test, turning 360 degrees, and the BERG balance test with people diagnosed with Parkinson's disease.[196] While Russell calculated strong levels of agreement via kappa and ICC calculations, instructions for each test were provided by face-to-face raters and not all tests were scored through a synchronous (real-time) telerehab session. For example, the FRT and Berg Balance Test in Russell's study were both scored by a remote therapist but through store-and-forward methods. More specifically, environment agreement was aided by the remote clinician watching a videotaped screening session. This is in contrast this this investigation's synchronous methodology where the telerehab clinician provides all client instructions in real-time. Additionally, Russell et al integrated proprietary software to calibrate FRT results and this was, again, conducted through store-and-forward methods.[196] It is notable, however, that this dissertation had a much lower kappa value (0.544) with 7" cut-off than the 10" cut-off (0.874) with determining inter-environment fall risk agreement indicating that software aided synchronous telerehab may be needed to improve the accuracy of the FRT (Table 9).

The methodology of this investigation demonstrates enhanced external validity compared to the methods employed by Russell et al. Explanations for all tests and measures were provided by the lead remote rater and all raters, whether face-to-face or telerehab, were required to score participants in real-time without the aid of watching a videotape, therefore, creating a more realistic clinical environment for both participants and raters. By creating a more clinically relevant environment, the accuracy of this investigation's telerehab survey post-test results is strengthened. The disadvantage of real-time telerehab without the aid of software that measures and calibrates test outcomes such as with the FRT was that more time was required to implement the FRT and results may not be as accurate. Additional time due to repeated instructions was also experienced with implementing the POMA-G by remote raters. This may be a future barrier due to time constraints of clinicians conducting TR fall risk screening. An additional feasibility concern is that both the FRT and POMA-G calculated larger standard deviations as compared with other screening tools. Although two trials were conducted for most individual screening tests, standard deviations for this investigation are higher for the TUG and FRT as compared to results published by Russell et al. For example, standard deviations calculated for the forward FRT were 2.89 – 3.46 inches, whereas standard deviations for the same test electronically calibrated by Russell were 0.87cm (0.34 inches). It is possible that the repeated measures design and a patient population with greater variability in performance and function contributed to this investigation's higher standard deviation, but it is difficult to ascertain as Russell et al did not publish ranges of screening test outcomes. In addition, the age range used by Russell et al was

45-76 whereas this investigation's experimental group had a mean age of 75 years old. It was notable that this investigation's sample size was over 300% larger and potentially had greater variability among its test population than Russell et al. The variability with the FRT and POMA-G bring to question the feasibility of these two screening tools when implemented through a synchronous telerehab delivery system. The TR POMA-G only had a standard deviation of 1.11 – 1.54, but this is considered higher than ideal considering the tool is a fixed 12-point ordinal scale. Further, the POMA-G had the lowest range of inter-item correlation calculations (r = 0.675 – 0.862) compared to the nine other fall screening tools further bringing to question its accuracy and feasibility. It was also notable that the POMA-G was the only individual screening test to demonstrate inconsistency with significance levels of AUC among environments when classifying prior fall history (Table 22).

Comparison with the Literature – Reliability

This investigation was able to demonstrate excellent inter-environment and interrater reliability among all raters for all 10 telerehab screening test scores and fall risk outcomes. Similar to results from the pilot study of Russell et al involving individuals with Parkinson's disease, reliability measurements are consistent with previous studies investigating face-to-face reliability. For example, Bennie et al reported excellent *Functional Reach Test* (FRT) interrater reliability (ICC = 0.99) among asymptomatic individuals, Duncan et al reported excellent interrater reliability (ICC = 0.98) among community-dwelling elderly, Thomas et al reported excellent interrater reliability (ICC = 0.97) among frail elderly,[148,149] and Weiner et al reported good interrater reliability (ICC = 0.89) among older adults.[147,196] As noted in Table 9, this investigation calculated excellent interrater reliability among face-to-face (ICC = 0.978) and telerehab (ICC = 0.984) raters, and excellent inter-environment reliability agreement (ICC = 0.980).

Wolf et al reported excellent self-selected *gait speed* interrater reliability (ICC = 0.980) among healthy adults.[197] As noted in Table 10, this investigation also calculated excellent interrater reliability among face-to-face (ICC = 0.993) and telerehab (ICC = 0.958) raters, and excellent inter-environment reliability agreement (ICC = 0.954) for the 4MWT.

Podsiadlo and Richardson reported excellent *Timed Up and Go Test* (TUG) interrater reliability (ICC = 0.99) among community-dwelling older adults and Nordin et al reported excellent interrater reliability (ICC = 0.91) among older adult residents of residential care facilities.[124] As noted in Table 11, this investigation calculated excellent interrater reliability among face-to-face (ICC = 0.999) and telerehab (ICC = 0.999) raters, and excellent inter-environment reliability agreement (ICC = 0.997) for the TUG.

Thomas et al reported excellent *Tinetti POMA* (balance and gait sections) interrater reliability (ICC = 0.99) among frail elders.[149] As noted in Table 12, this investigation calculated excellent POMA-G interrater reliability among face-to-face (ICC = 0.918) and telerehab (ICC = 0.924) raters, and average to good inter-environment reliability agreement (ICC = 0.792).

Jones et al reported excellent *30-second chair rise* (30STS) interrater reliability (r = 0.95) among community-dwelling elderly.[162] As noted in Table 13, this investigation calculated excellent interrater reliability among face-to-face (ICC = 0.997; r = 0.994) and telerehab (ICC = 0.997; r = 0.995) raters, and excellent inter-environment reliability agreement (ICC = 0.997; r = 0.995).

According to the Rehabilitation Measures Database, interrater reliability for the single-limb stance was not established.[198] As noted in Table 14, this investigation calculated excellent *single-limb stance* (SLS) interrater reliability among face-to-face (ICC = 0.978 – 0.994) and telerehab (ICC = 0.967 – 0.993) raters, and excellent inter-environment reliability agreement (ICC = 0.956 – 0.992).

Franchigoni et al reported excellent *tandem stance* (i.e. sharpened Romberg) interrater reliability (ICC = 0.99) among healthy women ages 55 – 71.[199] As noted in Table 15, this investigation calculated excellent to perfect interrater reliability among face-to-face (ICC = 0.997 – 0.998) and telerehab (ICC = 0.996 – 1.000) raters, and excellent inter-environment reliability agreement (ICC = 0.990 – 0.995) for the tandem stance.

According to the Rehabilitation Measures Database, interrater reliability for the *narrow stride stance* was not established.[200] As noted in Table 16, this investigation calculated excellent interrater reliability among face-to-face (ICC = 0.992 – 1.000) and telerehab (ICC = 0.999 – 1.000) raters, and excellent inter-environment reliability agreement (ICC = 0.999 – 1.000). Finally, the Rehabilitation Measures Database reports that interrater reliability for the narrow stride stance (Romberg eyes open) was also not established among community-dwelling older adults.[200]

As noted in Table 17, this investigation calculated perfect *narrow stance* interrater reliability among face-to-face (ICC = 1.000) and telerehab (ICC = 1.000) raters, and perfect inter-environment reliability agreement (ICC = 1.000). Like the narrow stride test, interrater reliability data is not available for comparison. A limitation to the ICC values for the 4-Stage Balance Test was that the STEADI limits the screen to 10 seconds in duration, thus increasing the chance of rater agreement with higher functioning research participants.

Comparison with the Literature – Validity

This investigation was also able to calculate predictive and correlation validity indicators for most screening tests integrated into this study. Similar to results from interrater agreement data, validity measurements are mostly compared with face-to-face studies because of the limited development in the telerehabilitation literature. To establish validity of a telerehabilitation delivery system for screening fall risk among community-dwelling older adults, this investigation used ROC characteristics, sensitivity, specificity, and correlation statistics. Methods of establishing and reporting validity metrics in the face-to-face literature base, however, is variable, and therefore, difficult to directly compare with results from all 10 screening tools included in this study. For example, Thomas et al reported *Functional Reach Test* (FRT) sensitivity at 7” (18.5cm) cut-off (75%) and specificity (67%) in distinguishing fallers from non-fallers among frail elderly. Kerr et al calculated ROC characteristics that reported an area under the curve (AUC) of 0.52 in patients with Parkinson’s disease. However, the systematic reviews conducted when assembling FRT data in the Rehabilitation Measures Database did not include any AUC values to predict falls for community-dwelling older adults.[148] As noted in Table 7, this investigation calculated 100% specificity with both face-to-face and telerehab raters but a low sensitivity among face-to-face (17.2%) and among telerehab (13.8%) raters at the same 7” cut-off point. Sensitivity rates for the FRT predicting 6-month prospective fall incidence also remained low. This investigation calculated an equivalent AUC for telerehab (0.586) and face-to-face (0.581) raters despite both values yielding insignificant confidence intervals and poor balance of sensitivity and specificity when classifying fall rates since age 65 (Table 18).

Neither the Rehabilitation Measures Database nor publications on gait speed from Fritz and Lusardi, including their White Paper, cites sensitivity, specificity, or ROC characteristics for *gait speed* and its classification or predictive ability with prior or future falls.[151,172] This investigation, however, was able to calculate validity measures with classifying prior falls among community-dwelling older adults. As noted in Table 7, this investigation calculated excellent specificity for both face-to-face (90%) and telerehab (88%) measurements, but very low sensitivity with distinguishing fallers in both face-to-face (31%) and telerehab (36%) environments. Sensitivity rates did not improve with predicting 6-month prospective fall incidence. This investigation calculated equivalent 4MWT AUC levels for telerehab (0.586) and face-to-face (0.581) raters despite both values yielding insignificant confidence intervals and low AUC levels when classifying the presence of falls since age 65 (Table 19).

Neither the Rehab Measures databased nor the STEADI has sensitivity, specificity, or ROC characteristics for the *30-second chair rise* (30STS) and its ability to distinguish fallers from non-fallers.[20,162] However, this investigation was able to calculate validity values for the 30STS among community-dwelling older adults. As also noted in Table 8, this investigation calculated acceptable 30STS specificity with face-to-face (70%) and telerehab raters (70%) but low sensitivity with distinguishing fallers among face-to-face (48%) and telerehab (55%) raters. AUC levels were insignificant for both rater environments for retrospective and prospective fall incidence (Table 21), and not reported within the systematic review process of Rehabilitation Measures Database.[162]

The *Time Up and Go Test* (TUG) has been validated among a variety of health conditions. Bhatt et al calculated average sensitivity (56%) and specificity (60%) with predicting fall risk. Using a different cut-off time of 11.1 seconds, Whitney et al calculated the TUG to be 80% sensitive and 56% specific in predicting falls among the elderly with vestibulopathic conditions. Balash et al calculated similar results as Bhatt with the TUG being 69% sensitive and

62% specific, and an AUC of 0.65 with predicting fall risk.[124] As outlined in Table 7, this investigation calculated excellent specificity with face-to-face (100%) and telerehab raters (90%) using Shumway-Cook's 13-second cut-off, but low sensitivity with face-to-face (31%) and telerehab (24%) rater abilities to distinguish fall histories of the sampled community-dwelling older adults. In addition, this investigation calculated an equivalent near-significant ($p = 0.085$ – 0.088) AUC among face-to-face (0.684) and telerehab (0.683) raters for the TUG's ability to classify prior falls, and an equivalent but insignificant AUC among face-to-face (0.546) and telerehab (0.527) raters for the TUG's ability to predict 6-month prospective fall incidence (Table 20).

Sensitivity, specificity, or ROC analysis validity metrics are not available for the *tandem stance* in the Rehabilitation Measures systematic review Database. As previously discussed, narrow stride, narrow stance, and the POMA-G do not have established cut-off points, and therefore, are not included in validity measurements or literature comparisons.[201] However, Jacobs' validity metrics for the single limb stance in participants with Parkinson's disease are available for comparison. Jacobs reports a 75% sensitivity and 74% specificity with discerning fall history. Tables 7 and 24 reflect insignificant AUC values for face-to-face (0.466 – 0.488) and telerehab (0.469 – 0.488) raters for overall fall history, and an insignificant equivalent AUC values for face-to-face and telerehab (0.442 – 0.462) raters for prospective fall incidence. Similar to other screening tools that demonstrated more favorable specificity than sensitivity values, the tandem stance (STEADI's 10-second cut-off point[20]) had acceptable specificity with face-to-face (70%) and telerehab (70%) raters, but low sensitivity with distinguishing fallers among face-to-face (38-41%) and telerehab (38%) rater environments (Table 7). It is notable that some investigations analyze components of the 4-Stage Balance Test for longer than the STEADI's

10-second algorithm, and this may have been useful with the population sampled in this investigation. For example, Smithson et al differentiated non-fallers from fallers in their ability to stand in tandem stance for 30 seconds in clients with Parkinson's Disease.[202]

Leddy et al reported excellent sensitivity of 96% and low specificity of 47% of the *Mini-BEST* using an erroneous cut-off value of 32 instead of 28. Specificity was enhanced to 78% and specificity reduced to 88% with a corrected cut-off score of 63% (20/32).[128,129] Despite the majority of research focusing on individuals with neurologic disorders, this robust 14-item clinical balance assessment tool integrates many validated components of other individual or multi-item fall screening tools. A recent publication from Chan and Pang on community-dwelling older adults confirmed excellent interrater reliability (ICC = 0.96 – 0.99) and acceptable to good correlations with the Berg Balance Scale, Activities-specific Balance Confidence Scale, and Functional Gait Assessment among patients with total knee arthroplasty.[203] As previously discussed, healthcare providers continue to lack a gold-standard screening tool that applies to all patient populations and all conditions. However, the Mini-BEST's excellent reliability and correlation with the Berg Balance Scale (r = 0.83 to 0.94), TUG (r = -0.82 to -0.89) and the original BESTest (r = 0.955), its broad scope of items that pertain to balance, and the evolving literature base recommending its use made it an appropriate selection to establish concurrent validity of the telerehab STEADI algorithm.[128,204] Mini-BEST outcomes from this investigation will help to fill an important void in the literature as this investigation, unlike the works previously cited, exclusively recruited community-dwelling older adults and did not discriminate based upon the presence of a health condition such as Parkinson's Disease or non-hemiparetic stroke. As Table 6 outlines, the Mini-BEST had excellent specificity (92%) with predicting low fall risk results on the STEADI, with predicting low risk on the Stay Independent

Brochure (90%), with determining older adults without a fall history (90%), and predicting 6-month fall incidence (85%), and acceptable specificity with classifying fall-related 12-month emergent care utilization (78%), fall-related fracture history (75%), and medication changes in the preceding 6-months (71%). The Mini-BEST was also calculated to have excellent interrater reliability at 98.7% agreement among two face-to-face raters ($ICC = 0.987$, $p < 0.001$).

Implications

The major barriers to the development of telehealth practice patterns for physical therapy identified early in this research proposal are technology, reimbursement, patient safety, and attitudes and beliefs of potential end-users. Although multiple studies have identified inconsistent voice and audio quality making communication between the client and provider more challenging,[11,67] this investigation was able to gain acceptance from all clinician rater participants as "acceptable for clinical practice." This is described in greater detail in the section that examines threats to internal validity.

The second pre-existing barrier to the development of telerehabilitation delivery systems was service reimbursement.[43] Under Medicare Part B, the Medicare physician fee schedule currently lacks a reimbursable Current Procedural Terminology (CPT) code for the remote monitoring and provision of physical therapy services. In addition, physical therapists are not listed as eligible providers for the delivery of telehealth services to Medicare beneficiaries.[69] Provider eligibility is limited to physicians, nurse practitioners, physician assistants, nurse midwives, clinical psychologists, clinical social workers, and clinical nurse specialists. Furthermore, the originating site or the site of the Medicare beneficiary must be at a physician or practitioner office, critical access or regular hospital, rural health clinic, a federally qualified health center, skilled nursing facility, community mental health center, or a hospital-based renal dialysis center.[58] These reimbursement guidelines are for face-to-face or synchronous provider/patient interactions. Although Medicare does not provide reimbursement for store-and-forward or asynchronous telehealth services to any providers,[69] telemonitoring health indicators such as blood sugar, weight, and blood pressure metrics are common to home health agencies, for example. However, these providers are paid under a different prospective payment system, and therefore, exempt from fee schedule or regulatory restrictions. Although the APTA is not currently lobbying for payment of remote physical therapy services, outcomes of this investigation are an additional step in the series of many that will enable telerehab professionals to lobby that some remote applications are the equivalent of traditional face-to-face physical therapy and are deserving of reimbursement consideration.

By identifying fallers before they fall or experience an injury from a fall, telerehabilitation delivery systems have the potential to benefit many stakeholders. It is incumbent upon physical therapists and the international telehealth community to continue to develop the literature base testing the equivalence or non-inferiority of telehealth with face-to-face treatments, create demand among consumers, partner with the private technology sector, and begin to quantify cost-to-benefit ratios.

The next major barrier to the provision of telerehab services was patient safety. Patient safety factors are guarding, type of connection, and jurisdictional law. Face-to-face assessments and interventions provide physical therapists the ability to use themselves and/or support personnel to employ specific guarding and positioning techniques to reduce injury risks to their patients. Although the physical therapist can request the assistance of a friend or relative during a telerehab session, these volunteers likely lack the training and experience of the physical therapist and their staff. As encouraged in Chapter 2, the clinician has an ethical responsibility to determine which tests and measures are safe to remotely implement. Further, these decisions may vary from client to client. While this investigation focused on the feasibility, acceptability, reliability, and validity of a telerehabilitation delivery system appraising older adult fall risks, all 9 functional mobility assessment (FMA) screening tests were implemented under the direction of a remote rater without incident (n = 39). The analysis of the breadth of potential screening tools in Chapter 2 provides some support that use of a safety assistant was sufficient for the implementation of these screening tests under most ordinary circumstances and client presentations. Similar to face-to-face, the use of a safety assistant does not guarantee that a client will not fall during fall screening examinations.

Another component of patient safety relates to the use of real-time vs. store-and-forward technologies. A common store-and-forward application is the collection and assessment of biometric data. As previously outlined, Russell et al utilized store-and-forward videotaping methods to appraise select movement patterns in research procedures. However, this dissertation investigation conducted research with a synchronous internet connection to mimic a more clinically applicable screening process that may have less liability from any adverse events that occur during or after a telerehab session. Delays between data collection, uploading data, and analysis of data with store-and-forward encounters can compromise patient safety, thereby also increasing the liability of the provider(s). It is not suggested that synchronous patient encounters will be free of incident, but rather a provider is able to respond to a patient safety matter in real-time with synchronous connections.

Another component of patient safety barriers relates to licensure. Jurisdictional law, and in situations when healthcare professionals are asked to provide consultation to a patient who resides in a different state, licensure portability are topics integral to the successful expansion of telehealth services.[43] In physical therapy practice, there are no uniform standards for licensure of telehealth practice written into state laws. Currently, face-to-face and distance consultations are treated the same in all but two states.[10] Without expanded portability provisions, a licensed physical therapist is unable to evaluate or treat a client across state borders regardless of proximity or circumstance. Because the role of a state practice act is to protect its population, a lack of licensure portability with uniform standards could potentially harm the recipient of remote healthcare. Ongoing research that ultimately establishes evidence-based telerehab practice may lead to greater acceptability towards remote providers across state lines. Greater cooperation and standardization of Practice Acts among states has aided in reducing access barriers for potential care recipients who reside in rural towns near state borders. The Federation of State Boards of Physical Therapy is gaining cooperation from multiple states in establishing a licensure compact. As of July 2017, fourteen states have enacted physical therapy licensure compact legislation.[205] If this trend continues, telerehab clinicians such as physical therapists can legally provide service in perhaps a timelier manner to an older adult who experienced a recent fall or was experiencing an acute onset of unsteadiness. Although this investigation focused more on the screening and preventive aspects of elderly falls, the example of an older adult who can consult with a physical therapist prior to an injurious fall is potentially beneficial to the person, the payer, and society as a whole in terms of population health and costs savings to entitlement or socialized medicine programs such as Medicare or Medicaid. As outlined in Chapter 1, access barriers contribute to inferior health outcomes among those who reside in rural regions of the U.S. As this investigation concluded (Table 8), fall risk classification is not directly related to fall history.[41] Therefore, remote fall screening tests may be integral in reducing the disability and economic consequences of falls.

The last barrier, and one that was central to this investigation, is the perception and acceptance of older adults towards technologically-delivered healthcare. In contrast to a 2003 study that reported 22.4% of adults over age 60 (n = 350) had used a computer in the previous year,[72] all participants of this investigation had access to either their personal computer/tablet or knew a friend, relative, or a community center such as a library from which they could access the internet. Further, regardless of participant feelings and experiences with technology upon baseline survey, this investigation demonstrated that a single telerehab experience significantly impacted the attitudes and beliefs of older adults towards technology-assisted healthcare in the majority of constructs as per increases in post-test scores with the experimental group versus the control group (Table 5). Now that this TR survey has quantified responses to 33 items on the survey and has demonstrated positive scoring outcomes following a TR experience, it can be concluded that older adults are potentially receptive to telerehabilitation, and biases that older adults are not receptive to technology are false. Follow-up studies including participants from a broader geographic and demographic region, and implementation of fall screening tests in the community as opposed to a university setting will improve external validity, and therefore, have a greater impact on healthcare policy and payment advocacy. It is notable that despite study participants stating that they had access to a computer through various methods noted above, many expressed that they were not "computer savvy" or comfortable using technologies such as computers or smart phones. That said, the creation and validation of a TR survey instrument that focused on Davis' *perceived usefulness* rather than *perceived ease of use* was an important first step. However, future studies will need to analyze the impact of end-users being responsible for the set-up and connection with remote clinicians. After this prospective data analyzing perceived ease of use is gathered, it should be cross-referenced with data such as this investigation that focused on perceived usefulness. Only then will researchers, clinicians, and policy makers have a true and more accurate perspective on the behavioral intension of older adults to participate in technology-delivered healthcare services.

Outcomes from research question one is a positive step forward in a series of many to identify receptive end-users and individual barriers, as well as to measure the impact of innovative care models that connect patients with remote clinicians. The TR survey tool can serve as a basis for modification by other telerehab professions by simply removing reference to "falls" or "physical therapy," and adapting language to fit their needs. It is recommended, however, that modifications to any item, construct, or scale go through a similar content validation process and be piloted for internal consistency with the target population. Pending further investigation that may result in further refinement to the number of items and constructs needed to predict end-user adoption of a telerehabilitation delivery system, the current survey iteration was able to quantify scores and measure a change with prospective repeated measures testing, as applicable. The meaning of the composite scores, other than being a percentage of total for each construct or the whole survey, is yet to be determined as the purpose of this investigation was to examine attitudes and beliefs of older adults towards telecommunications-aided physical therapy services and whether or not those attitudes and beliefs would be influenced by a telerehab experience.

This investigation was successful in addressing conclusions from Peek et al who stated that quantitative post-implementation data was "scarce" in the literature.[119] Until future investigations for construct validity and cut-off points are completed, this survey may still provide short-term benefits to TR clinicians in determining areas where a prospective end-use may need additional support. For example, a person who rates items in construct 3 (social influence) high may benefit from being introduced to others who have experience with telerehab or telehealth. Someone who rates the first two items in construct 4 (facilitating conditions) low may flag the clinician that financial resources may be a limiting factor to their adoption or consistent adherence with a telerehab plan of care. A clinician who notices a low baseline scores for construct 2 (effort expectancy) may need to be cognizant that a client's self-efficacy will be enhanced through clear instructions and technical support. A potential end-user who provides inconsistent baseline ratings in construct 7 (physician opinion) may cue the assessing clinician to first attempt to gain support from the client's physician including educating the physician on the telerehab delivery system. By enhancing physician support and understanding, the clinician may also enhance the client's receptiveness and potential adherence to a telerehab care plan.

Each of the 33 items and seven constructs comprising the TR survey instrument can provide meaningful information to clinicians about the likelihood of client buy-in and areas to focus on when working with clients who are not familiar with telehealth or lack experience with computers. All items have been vetted to be relevant to technology adoption and their respective construct category by a seven-member panel of experts. Telerehab clinicians, physicians, and potential clients should anticipate investing up-front time and resources to setting up and piloting a telerehab visit or two with a trepidus client knowing that this investigation was able to refute the null hypothesis that exposure to a telerehabilitation delivery system would not impact attitudes or beliefs of older adults about telerehabilitation.

Chapter 1 highlighted the roles that physical therapists can serve with restoration of health and function. Information presented also suggested that physical therapists are often underutilized for prevention and wellness services, particularly with Medicare beneficiaries. To that end, interprofessional collaborative practice is one of the cornerstones of healthcare reform initiatives and is ultimately needed in practice settings where pay-for-performance and episode-based rather than fee-for-service payment reform has been implemented. While physical therapists continue to advocate for expansion of Medicare's provider eligibility list, originating site requirements, as well as actualization of APTA direct access and primary care provider initiatives, telerehab professions should also seek collaborative clinical and research partners. Collaboration and a team-based approach focusing on population health and prevention of adverse outcomes would parallel current Medicare share-savings models such as Accountable Care Organizations and Comprehensive Joint Replacement Reform. Demand for, acceptance of, and therefore, payment for a telehealth service consultation from consumers or insurance companies would depend on providers demonstrating "value." Value implies a more equitable balance between cost and quality that, like the aforementioned transition from fee-for-service models, is integral to healthcare reform initiatives.

Recommendations

There are several recommendations for future research that builds upon this investigation. Recommendations for the survey instrument include electronic implementation, confirmation of construct validation, and inclusion of it with testing outside of a controlled university setting. To test outside of a controlled setting, researchers must be cognizant of connectivity barriers and must first test the bandwidth capabilities of their internet connections. Research conducted in participant's homes, for example, pose additional challenges due to variability and uniqueness of each end-user's internet vendor, connection (broadband, fiber optic, wired, wireless), and equipment.

Researchers must also begin to integrate prospective cohort designs to examine long-term effectiveness and cost comparisons with traditional face-to-face care models. There is also a need to focus research and publication initiatives. Reporting of reliability and validity needs to be more standardized in the literature, and a renewed focus on community-dwelling older adults as opposed to condition-specific fall risk is needed. Collaboration among researchers and the establishment of national and international research goals are needed.

Future research employing this study's telerehab survey should consider electronic survey implementation showing only one construct at a time, block the inability to look back at other sections, and randomize the order of constructs and possibly the items to maximize consistency and minimize bias. This recommendation may eliminate some "blanket" negative or positive participant biases that can skew data. Although Russell et al acknowledged that their investigation exploring predictors of home telehealth use by elderly Australians may have induced bias from participants "who have an online presence," alternative data collection methods as described above may not be a limitation as researchers would provide access to a computerized survey by supplying the equipment and integrating clinical testing rather than solely relying on volunteers who have home internet access or an affinity towards technology as was the case with Russell's findings.[191]

The next steps with further validating the TR survey involves using factor analysis and divergent validity processes to confirm construct validity. Additional steps to develop this survey tool involve establishing cut points and analyzing multi-factorial regression formulas that ultimately predict end-user adoption. Deriving meaning from construct composite scores and the survey as a whole is helpful for comparative purposes, particularly with pre- and post-testing, but end-user adoption and plan of care adherence is vital to the appropriate allocation of technical and human resources. This investigation rejected the null hypothesis that experience with a telerehab application would not impact baseline attitudes and beliefs quantified by the TR survey. However, the impact of participants who experience fall screening testing in their home or at a community center, for example, is also recommended for direct comparison with this study's preliminary findings. This will also aide with the integration of Davis' second TAM construct, perceived ease of use. In addition to a change in geographic setting, pre- and post-fall screening survey implementation needs to be tested with a friend, family member, or community representative serving as the safety assistant. The potential effects of group participation such as at a senior citizen or worship center versus alone in one's home also needs to be determined.

Efficacy is the ability to produce a desired or intended result. Because this investigation was able to test hypothesized results through using a telerehabilitation delivery system, the feasibility goal of this investigation was accomplished. This preliminary telerehabilitation investigation was able to prove the feasibility with the setting and internet connection all being controlled to examine the effects on dependent variables and minimize Type II errors rates. In addition to testing outside of a university setting, this research and research from other investigators such as Dr. Russell in Australia, need to begin examining community-based effectiveness, cost-effectiveness, and prospective cohort research designs to maximize external validity and legislative impact. Physical therapists and other providers should also investigate the satisfaction and long-term impact of fall prevention education using real-time telehealth applications. Most importantly, telerehabilitation needs to transcend the conceptual and move towards the actual.

Results from this investigation conclude that prior fall rates of participants may not be representative of larger populations. Based upon self-reported fall histories, 29 of 39 (74%) members of the experimental group reported at least one prior fall since turning age 65. This contrasts with CDC data outlined in Chapter 1 that projects one in three adults age 65 and older fall annually. That being said, sensitivity, specificity, and receiver operator characteristic analyses from this investigation should be interpreted with caution as the sampled population did have a high rate of fall incidence. It is notable that only eight of thirty-six (22%) experimental group participants who responded to prospective inquiries reported falling within 6-months following this investigation. One to two-year prospective fall rates will yield more accurate predictive validity conclusions. Lastly, prospective cohort studies are recommended to measure cost/benefit ratio compared with participants of a control group (i.e. traditional healthcare) in an effort for actualize potential solutions to problem statement 3: *Each year, the U.S. spends billions of dollars treating the sequelae of injurious falls. Overall, the U.S. lacks a sustainable model for the provision of cost-effective healthcare services to older adults.*

An unintended outcome of this investigation and subsequent literature searches revealed a need to standardize reporting in the literature. This recommendation is particularly relevant to systematic review endeavors from researchers or online repositories such as Rehabilitation Measures Database. Three recommendations are made based upon review of research relevant to elderly falls. The first pertains to predictive validity reporting; the second pertains to recommending a renewed focus on community-dwelling older adults; the third recommendation pertains to standardizing data reporting with the evolvement of the telerehab literature. Not all screening tests have sensitivity, specificity, or indicators as to the balance between sensitivity and specificity such as ROC analyses and AUC data. These recommendations are consistent with a systematic review by Scott et al outlined in Chapter 2.[78] Correlation data and construct validation was very common probably due to simpler, less complicated and time-consuming data analyses. Peer reviewers for journals and online database repositories need to be cognizant of the overuse and over-statement of findings associated with correlation. For example, scales such as poor, moderate, good, and excellent need to be standardized with great attention to clinically meaningful conclusions across the physical therapy literature. More specifically, a 0.4 correlation highlighted as a significant “moderate correlation” finding can otherwise be interpreted that 16% of the change in one variable was accounted for by a change in another variable using a coefficient of determination method (r^2). Lastly, a 50% sensitivity or specificity is the equivalent of flipping a coin and should be reported as such. Thresholds for acceptable sensitivity and specificity should be 70% or higher based upon guidelines from Perell et al and Oliver et al.[78] Regarding elderly falls, the geriatric physical therapy community needs to place a renewed emphasis on the community-dwelling older adult. Many contemporary publications focus on specific health conditions such as Parkinson’s disease, multiple sclerosis, or spinal cord injuries, for example. The literature base addressing falls of community-dwelling elders is aging. With wellness, aging in place initiatives, and evolving technologies, the literature base must continue to evolve, retest, repeat, and/or enhance the methodology used in previous studies because the current population of older adults may not be the same as what the aging literature base reflects. For example, the sampled population of this investigation exemplified a group of community-dwelling older adults with higher than average fall rates but also had negative fall risk outcomes with standardized testing as compared to what the literature depicts. Results from the STEADI algorithm exemplifies this perspective (Table 8). Lastly, as the telerehabilitation literature base continues to develop, researchers and telehealth journals should be aware of opportunities for standardization and transparency with data reporting. This will make collaboration, systematic reviews, or meta-analyses more productive and beneficial to the telehealth community at large.

Limitations and Threats

To address to the three research questions (Table 1), an investigation with experimental, quantitative, and cross-sectional frameworks employing both pretest-posttest control group and quasi-experimental static group comparison designs using non-probability sampling methods was conducted. The overall design of this investigation including the inclusion and exclusion criteria are suspect to certain threats to internal and external validity, limitations, and delimitations. According to Portney and Watkins, potential threats to design validity include statistical conclusion validity, construct validity of causes and effects, internal validity, and external validity.[37]

Statistical conclusion validity essentially looks at how reasonable is a research conclusion. Chapter 4 highlights the selection and use of statistical procedures for analyzing data including excellent reliability outcomes as a basis for validity conclusions. Kappa and ICC tests are frequently cited reliability statistics, and correlation, ROC curves, and sensitivity/specificity tests are frequently cited validity statistics in the physical therapy elderly falls literature. In addition, statistical test selection is matched with the level of measurement. For example, kappa for nominal variables, and ICC for ordinal and continuous variables. However, two threats to conclusion validity exist with this investigation: 1) Post-hoc power levels, 2) likelihood ratios, and 3) small effect sizes. Post-hoc power levels (0.683) in this investigation indicate a possible imbalance of risks between potential type I and type II error rates in this study. Positive and negative likelihood ratios listed in Tables 6 and 7 mostly indicate limited usefulness of ruling in or ruling out the presence of past or future fall rates. According to Cohen, partial eta effect sizes in the range of 0.01-0.05 are small.[206] The range of effect sizes for the four constructs that demonstrated significant differences ($p < 0.05$) on post-test scores ranged from 0.097 – 0.0236.

A larger sample size is recommended with future investigations to strengthen the overall power and true effect of statistical conclusions.

Threats relevant to *construct validity* refers to the theoretical conceptualization of the intervention and response variables and whether these have been developed sufficiently to allow reasonable interpretation and generalization of the relationship between variables.[37] The telerehabilitation (TR) survey was developed based upon seven established and researched constructs expressed in the technology acceptance literature. Internal consistency of the content validated instrument used to test hypothesis 1 was calculated to support (not confirm) construct validity of the TR survey instrument (Table 4). However, additional follow-up testing on this newly developed tool is needed in future investigations to maximize the survey's consistency, accuracy, and impact. All of the fall screening tools used to test hypotheses 2 and 3 are well-constructed with defined parameters using established standards and measures. The exception is the STEADI although its component sections and outcome recommendations are supported in the literature.

Construct validity may also have been impeded by the likelihood of bias introduced into this investigation by subjects or raters. Bias was possible because of an inability to control for all prior experiences with technology, fall histories, existing support systems, socio-economic status, or physical therapy in general. Despite this, the investigator clearly defined relevant constructs for all panel of experts' members reviewing the TR survey instrument and for all raters integrating the fall screening tools. However, participants received more implicit operational definitions in an effort to capture feedback specific to the individual participant's broad perspectives and experiences rather than placing limitations that may bound the scope of data analysis. For example, the Fall History Questionnaire did not operationally define a "fall," and the TR survey provided a general operational definition of telerehabilitation (rehabilitation services delivered through the use of real-time audio and video telehealth technologies). If participants asked for further clarification, raters were only permitted to further define telerehabilitation as “accessing a physical therapist through a computer” or “like Skype.” Although there was the potential for rater bias and variability between subjects with the provision of this additional assistance, clarification requests from participants were infrequent, and raters received these instructions to maximize consistency. If participants were still confused after the above re-explanations of telerehabilitation/telehealth, raters advised participants to “do the best you can” when completing their survey(s). This investigation made every effort to balance potential bias explicitly or implicitly projected by raters while concurrently attempting to measure what this investigation was intended to measure.

Procedural controls were in place to minimize the influence of *order effects* or any bias that the order of screening tests may influence a participant’s post-test completion of the TR survey or their performance with fall screening tests. Despite the apparent lack of threats to validity from order effects, *multiple treatment interactions* are potential threats to construct validity. There is a possibility of carryover or combined effects that could have affected post-test survey outcomes because nine telerehabilitation tests and one exclusively face-to-face test (Mini-BEST) were implemented for all members of the intervention group (n = 39). For example, the perception of a poor performance or an “I did better than I thought” performance may have altered participants’ perception of the perceived usefulness of physical therapy and/or the telerehabilitation delivery system.

Length of follow-up between pre- and post-test surveys with the control group was another potential threat to *construct validity* as well as *internal validity*. This investigation was unable to control for participants formally researching or potentially speaking with other people about telerehabilitation or use of technology before the pre-test or the approximately one-month average time-frame between pre- and post-testing of the control group. Participants in the control group may have consciously or subconsciously altered their conceptual thought about telerehabilitation or technology-delivered healthcare in the month prior to completing their post-test survey. Unfortunately, this threat to construct and internal validity was outside of the investigator's control. However, participants of both the control and experimental groups were blinded to their pre-test survey results when completing post-test TR surveys.

Another potential threat to construct validity is *experimental bias*. It is possible that raters and/or participants introduce expectation biases into the study. It is possible that responses to the TR survey, the Stay Independent Brochure, or the Fall History Questionnaire were not reflective of the true perspectives or histories of participants. That being said, a Hawthorne effect cannot be completely ruled-out. Because raters were volunteers, the primary investigator was actively soliciting volunteer participants, and many participants may have wanted to volunteer because this investigation was affiliated with a medical university, for example, it is possible that research participants did not present natural behaviors. It is possible that participants responded more favorably to surveys based upon enthusiasm projected by raters or observed interactions between other participants and raters. Favorable biases including passive gestures, smiles, and appearance could have influenced study outcomes. Additionally, regardless of participant performance, the lead telerehab rater would consistently say, "good job" or "great job" to participants following their participation in individual tests. Lastly, likeability of raters or the primary investigator for the positive or the negative could also have projected bias into participant feedback.

Threats to External Validity

External validity refers to the extent to which the results of an investigation can be generalized beyond the internal specifications of the participant sample and experimental situation, whereas internal validity is concerned with the relationship between independent and dependent variables within specific contexts of data collection.[37] Although the sample size was relatively small and focused to a convenience demographic available in the northwestern and northern suburbs of Phoenix, Arizona, this study was initially thought to have favorable external validity. Descriptive statistics indicate a lot of similarities between the sampled population and the general community-dwelling older adult population represented in the literature. However, the high incidence of fall rates since turning 65 and in the prior 12-months indicate that the sampled population may not be representative of a broader population of older adults. For example, it is well-know that at least one in three adults fall when reaching age 65 and the incidence and risk of falls increase with increasing age and prior history of falls.[36] The mean age was 74.6 for the experimental group and 76 for the control group. However, approximately 74% of the intervention group and approximately 66% of the control group reported falling at least one time since reaching age 65. The incidence of prior falls in the sampled population was much higher in the sampled population than what CDC statistics project (33%). Despite the elevated fall histories, statistically insignificant differences were calculated with gender among experimental (51% female) and control (62% female) groups, the use of assistive walking devices between experimental (21%) and control (18%) groups, 12-month emergent care use between experimental (18%) and control (13%) groups, prior fall-related fractures between experimental (15%) and control (16%) groups, and 6-month medication change occurrences between experimental (28%) and control (36%) groups (Table 2). Despite this population-matched data for each group, this investigation employed non-probability sampling methods which limits the ability to generalize baseline and outcome survey data to reflect the attitudes and beliefs of all older adults in the United States. It is also possible that the sampled population had reporting limitations due to the contrast in self-reported overall fall history with the CDC's national rates of fall incidence. Reporting error and/or the unique characteristics of this sampled population possibly contributed to the lack of sensitivity of fall screening tools classifying retrospective or predicting prospective falls. In essence, the large percentage of participants with prior falls inhibited fall screening tests from discriminating fallers from non-fallers. This investigation did not control for safety awareness or recreational activities such as hiking or IADLs such as high impact activities like cleaning floors or landscaping that may have predisposed this convenience sample to higher fall rate incidence as compared to the CDC incidence projections.

Although participants were not asked to provide detailed demographic data on race, culture, or creed, for example, the majority of participants in the control and intervention groups were Caucasian with English as their preferred language. While diversity of participants are only as diverse as the pool of volunteers who responded to recruitment flyers, presentation, and word of mouth advertising, the Phoenix metropolitan area is considered a "melting pot" rich with many cultural influences including but not limited to Mexican Hispanic and French Canadian cultures, as well as permanent and seasonal residents who did not consider Arizona home until older adulthood. It is notable that one female in the experimental group (n = 39) self-identified herself as a practicing Muslim during pre-investigation question and answer conversations. These examples indicate that TR survey results from this investigation may be somewhat reflective of attitudes and beliefs about TR in other regions of North America. Limits to external validity and generalizability are further discussed in the discussion of delimitations below.

Threats to Internal Validity

Several sources state that threats to *internal validity* are likely present in every experiment to some degree. Potential threats to internal validity are as follows: history, maturation, attrition, testing, instrumentation, and regression to the mean. *History* refers to any confounding effects of specific events, other than the experimental treatment, that may have occurred after the introduction of the test variable between a pre-test and a post-test.[37] History is a potential strong threat to the post-test survey results of the control group. On average, there was a 1-month length of time period between pre-testing and follow-up post-testing of the survey instrument. During this time, members of the control group could have searched the internet about related topics or spoke to other members of the intervention group such as friends or spouses, thus having outside influences affect their post-test feedback. Control and experiment group members all gained baseline knowledge of this investigation's purpose and general framework through initial face-to-face or phone conversations with the primary investigator. Therefore, history effects from conversation and independent inquiries about falls, technology, physical therapy, and/or television or newspaper current events could also have influenced pre-test survey outcomes. It is impossible to determine whether the impact of history had a negative or positive bias on survey outcomes based upon the current dataset. Because there was an immediate completion of the post-test survey with the experimental (telerehab) protocol, history threats were much less likely to have affected study outcomes from this group.

The second potential threat to internal validity is *maturation*. Maturation includes processes that occur simply as a function of the passage of time and are independent of external events. Maturation may cause participants to respond differently on second and subsequent measurements because they have grown more experienced, older, stronger or weaker, healthier or sicker, tired, or bored, for example.[37] Similar to history effects, post-test responses from the control group could have been affected by maturation whereas the experimental group was better insulated from the effects of maturation because of the immediate, same-day post-testing methodology that followed the fall screening testing. Maturation could also have been a barrier with experimental group participants as they progressed through several fall screening tests as there was overlap among test constructs. For example, gait efficiency and quality all relate to successful TUG, 4MWT, and POMA-G outcomes, and participation in one could have assisted a participant to mature and prepare for subsequent tests and measures. To the contrary, a repeated measures design (i.e. two trials of each test) could have induced fatigue, thus creating an adverse maturation effect on validity calculations.

Attrition or experimental mortality is the third potential threat to internal validity. This threat was actualized in the control group with only 40 of 45 post-test survey results secured. There was an imbalance between experimental (n = 39) and control groups (n = 45) because of attrition that occurred between participant recruitment and data collection (i.e. potential participants cancelled or did not show up for their research appointments). Although the five-participant attrition during post-testing of the control group did not create a significant impact on data analysis when comparing the two groups, this attrition may have impacted outcomes of the TR survey particularly if the lost participants represented more extreme viewpoints about or experiences with technology. Of the thirty-nine members of the experimental group, only thirty-six returned 6-month post-investigation phone calls inquiring about prospective fall incidence. This 3-participant attrition may have had a statistical impact in calculating sensitivity and specificity of the screening tools predicting prospective falls. It is notable that the investigator stopped trying to contact the participant after three separate date attempts to reach them by phone.

The next potential threat to internal validity is *testing*. Testing effects refer to the potential effect that pretesting and/or repeated measures testing has on a dependent variable. Testing effects can result in improved performance or increased skill that occurs as a result of familiarity with or practicing a measurement or construct.[37] At its purest most foundational threat level, testing effects occur with the mere act of collecting data. Because 10 separate fall screening tests were performed in one single day of data collection, it is impossible to rule out carryover effects on screening tool outcomes. While this would not impact reliability data examining inter-environment agreement, it may have impacted receiver operating characteristic curves, sensitivity, specificity, and likelihood ratio results. Similar to maturation effects, it is a possibility that testing effects may have induced a positive practice effect or induced a negative performance effect related to fatigue from participating in nine different telerehab screening tools, some of which required multiple trials as well as the face-to-face Mini-BEST, a tenth test, on the same day (Figure 2). To a lesser degree, it is possible that testing effects could have influenced control and experimental group survey post-tests. It is possible that participant confidence was impacted by perceived performance during fall screening testing, and therefore, carried over to post-test survey responses. In addition to the battery of balance and mobility tests methodologically required of the experimental group, it is possible that participants practiced their “balance” prior to their research appointment knowing that this investigation involved “fall risks” of older adults. Outcomes of receiver operator characteristic curves revealed a lack of predictive ability of the TUG, 30STS, and FRT, for example, despite a positive history of self-reported falls since age 65. These statistical findings support concerns that some participants may have practiced balance activities prior to our testing and/or benefited from practice or testing effects from a repeated measures design, and therefore, influenced this study's validity conclusions.[124,148]

Another potential threat also related to *testing* pertains to the completion of the TR survey instrument. A cursory review of pre- and post-test survey scoring did reveal participants answering more favorably towards "strongly agree (7)" or "strongly disagree (0)" among most pre-test surveys. As described in the recommendation section, there may have been some pre-test response testing bias associated with more consistently extreme high or low scores using the 0-7 Likert scales. For reasons unknown, participants who scored more towards either end of the Likert scale on the first few constructs tended to have higher or lower composite scores consistently through the remaining survey construct sections. According to this testing effects theory, the net effect of administering post-tests to examine research question 1 (*What effect does exposure to a telerehabilitation delivery system have on underlying attitudes and beliefs of older adults about the perceived usefulness of this healthcare delivery option?*) could be either an enhanced variation from pre-test scores or a lack of effect due to chance essentially creating the potential for statistical error.[37] It is possible that factors described in the history threat to internal validity could have also contributed to a testing effect on post-test survey scores among participants with majority negative (0) or positive (7) pre-test item scoring tendencies.

Another threat also related to testing is the method by which raters scored participant fall screening tests. Testing is multi-faceted involving the provision of instructions, the interaction between the clinician rater and the participant, and the actual measurement of time or distance, for example. The four-rater model adopted for the simultaneous appraisal of participants under the direction of one lead telerehab rater prohibited all raters from completing the whole process of test and measure. That said, calculation of the reliability of raters and environments was not a true test of reliability but rather assessed the ability of three of the four raters to record measurements. In other words, only one rater conducted a fall screening test while the other raters passively measured performance.

The fifth potential threat to internal validity is the effect of *instrumentation*. Instrumentation is related to the reliability of measurement. The accuracy and reliability of rater agreement between face-to-face and telerehab environments was dependent on the bandwidth strength, and therefore, quality of audio and visual data uploaded and downloaded to and from the lead telehealth rater and the participant. Despite the methodologic control of having information technology network and media staff (IT) available for support and trouble-shooting, there lacks an ability to calibrate strength or speed of upload / download speed between participant sessions or fall screening tests. Thus, there were occasions when pixilated video images impeded or may have reduced the accuracy of rater observations. Unfortunately, Midwestern University IT support was often unable to immediately fix video or audio transmission challenges but rather connectivity seemed to improve over time. IT staff indicated that network “traffic” was variable and, therefore, we should anticipate that upload and download speeds would also be variable. This is despite a more secure, less public internet “bridge” being in place as an added control measure. Raters did notice that pixilated audio-visual data was more likely to be a barrier around 9am and through the lunch-time hours Monday through Friday. Regardless, testing would proceed as scheduled and, despite this observation, physical plant and human resource availability necessitated that data collection mostly be scheduled during these predictably higher internet “traffic” timeframes. This intermittent instrumentation threat did, however, create a realistic, more clinical environment consistent with community-based telerehabilitation barriers outlined in Chapter 1. Anticipating intermittent bandwidth challenges, each telerehab rater was asked to individually rate each participant's session on a three-tiered scale:

1. *Acceptable for clinical practice with minimal to no connectivity issues*
2. *Acceptable for clinical practice but frequent connectivity issues*
3. *Not acceptable for clinical practice due to connectivity issues*

This feedback scale can be referenced on the last page of the rater script (Appendix E). Intraclass correlation coefficient (ICC) analysis was used to examine interrater reliability and agreement of each rater's experience with the audio-video connection quality. ICC revealed an 87.3% agreement between all four rater roles (M = 1.08 to 1.13, SD = 0.27 to 0.34; Cronbach's alpha (38) = 0.873 $p < 0.001$). None of the raters scored any of the 39 participant sessions a "3" indicating that each participant's screening session was "acceptable for clinical practice" despite intermittent connectivity issues. The lead TR rater, rater 1, scored five sessions a "2" with the remaining 34 (87%) sessions a "1." This is an important consideration because this was the lead clinician providing all instructions for the TUG, 4MWT, POMA-G, 30STS, FRT, and the 4-Stage Balance Tests. The lead face-to-face rater, rater 1, scored four sessions a "2" with the remaining 35 (90%) sessions a "1". Comparison of these two raters is important because they were staffed consistently with the same rater for all 39 participants in the experimental group. Furthermore, data from rater 1 for each environment was used in calculations of inter-environment reliability and validity calculations. TR rater 2 scored 36 (92%) of 39 sessions a "1" and face-to-face rater 2 scored 35 (90%) of all sessions a "1." This cumulative feedback from the two telehealth and the two face-to-face rater roles that synchronously tested the feasibility of a telerehabilitation system as a fall screening modality is important to quantifying the effect, if any, that instrumentation may have had on reliability and validity conclusions of this investigation.

Lastly, instrumentation could have impacted the accuracy of inter-environment reliability and validity calculations due to an approximate one second "tape delay" between the participant and telerehab clinician. Furthermore, this one second delay could have negatively impacted participant satisfaction reflected in the post-test telerehab survey. This delay was discovered upon review of recorded sessions as the conclusion of the investigation. For example, an approximate one second delay was observed between when the lead clinician said "go" and when the participant commenced each fall screening test. The investigator was unable to consult IT professionals about this potential threat to internal validity because it was not discovered during the investigation and it was not anticipated as a potential barrier.

Regression to the mean does not appear to have impacted the internal validity of this investigation.

Lastly, the risk of *multiple group threats* to internal validity was minimal due to controlled data collection site, consistency of site layout, raters, registration staff, and conversations between the primary investigator and prospective volunteers such as when speaking to groups at senior citizen centers, for example. Furthermore, descriptive statistics and ANOVA calculations confirm that, except for prior fall history, both groups had insignificant differences among independent variables such as gender, fracture history, and assistive device use, for example. All participants registered, completed surveys, and participated in fall screening tests at Midwestern University's Wellness and Recreation Center that houses the Physical Therapy Program's research laboratory and a separate room of sufficient square feet and equipment to prevent raters who were participating in the telerehab trials from communicating with raters conducting the Mini-BEST testing. Separate data collection and registration spaces also prevented participant and rater observations of participant performance. Any group presentations or individual conversations for purposes of recruitment were provided by one person, the primary investigator. All registration paperwork including informed consent and pre-test survey completion were consistently handled by the same person. This investigation's design included a control group and was, therefore, able to account for selection threats to internal validity though random assignment to control and intervention groups. Furthermore, the statistical analysis of covariance was able to account for any potential group differences.[37]

Limitations and Delimitations

In follow-up to discussion about this study's potential threats to internal and external validity, this investigation has several limitations and delimitations. Limitations are mostly beyond the investigator's control whereas delimitations are factors that were within the investigator's control. *Limitations* of this study include the population sampled, location of the investigation, and the method and connectivity by which data is being transmitted over the internet. Although the target population for this study are community-dwelling older adults that reside in urban and rural settings who may not receive formal fall screening examinations until after an injurious fall occurs, several factors prohibit the investigator from directly sampling this broad population directly in their communities. First, rural settings are two to three hours from the Phoenix metropolitan area. Sampling older adults who reside in rural settings would be cost and time prohibitive to both the participants and the investigator. No transportation resources or funding was available for participant travel time or expenses. As described earlier in Chapter 3, sampling by purposive methods was a more practical way to overcome these cost, time, and geographic barriers.

The most significant barrier to directly sampling this study's target population within their primary residences or community centers was internet connectivity. The internet is a fundamental assumption to the provision of any telehealth service and is required for real-time or store-and-forward methods of data transmission. This particular investigation was more susceptible to the limitations of the internet because remote raters were conducting fall screening assessments in real-time rather than the video-taping and follow-up review method that many telerehab publications employ. Even if the internet is available in a senior citizen center, for example, the quality, security, and strength of the audio-video connections are somewhat outside the control of the primary investigator and his information technology support team, and financial resources were not available to better control these factors. Furthermore, the internet connection used for this investigation was connected to a secure "bridge" provided by a third-party business associate of the University to maximize connectivity and privacy. The end result of inconsistent or poor internet connectivity would be challenges with upload and download speeds that would create distorted images ("pixilation) incompatible with meaningful information exchange. Shaw et al highlighted these specific bandwidth limitations in a community-based pilot study rooted in Glendale, Arizona.[11] Chapters 1 and 2 explain that publicly available internet connectivity has been reported to be insufficient to produce a reliable connection that transmits real-time voice and video data involving movement.[11,67] Despite enhanced availability of 4G signals, cellular networks have inconsistent bandwidth coverage and internet "traffic" demands making wireless cellular connections unreliable.[11] Additionally, the United States' telecommunications infrastructure does not yet have fiber-optic lines available to the majority of urban or rural settings, making wired internet connections also unreliable. Therefore, the investigator opted to conduct this investigation in a controlled environment where a 3rd party company was available to maximize security and available bandwidth. The benefits of this bridge was enhancement of upload and download speeds as to promote better reliability of real-time video data transmission. As mentioned above, this bridge is a dedicated internet line which enhances the security of PHI transmission and shields this study's internet connection from some of the competing bandwidth usage demands from local internet "traffic." Although the investigator implemented safeguards to maximize the reliability and clarity of the audio-visual connection, internet connectivity in general was a limitation rather than a delimitation because many factors associated with connectivity were outside of the investigator's control.

Other study limitations that could have impacted the outcomes of this study include participant and physical therapist rater: 1) attrition due to illness, availability, or transportation barriers, 2) prior experiences and history with physical therapy including non-standardized methods of administering fall screening tools, and healthcare outcomes from friends or relatives who may have experienced falls, physical therapy, etc., 3) pre-existing biases about the integration of telecommunications technologies into healthcare delivery including observed adoption of electronic health records and possibly the influence of "computer" use by their personal physicians, 4) prior unreported experiences with telemedicine from any healthcare discipline, and 5) any negative effects of nature such as regional storms or wind that may impact the consistent connectivity phone or internet required to administer this study. The investigator attempted to schedule an alternate physical therapist rater and recruited 10% more older adults than the projected need based upon a priori power analyses in the event of unexpected illness or transportation issues, for example. There were several participants who were scheduled data collection appointments, but unknown reasons precluded volunteers from attending investigation dates, from completing post-test surveys, or from returning phone calls about surveys or prospective incidence of falls.

The investigator attempted to screen for individuals whose extreme or biased experiences, as either a patient or provider of physical therapy, may have introduced confounding variables into the outcomes of this investigation. The investigator, however, was cautious as to not introduce selection bias delimitations into purposive sampling methods. The execution of the IRB-approved informed consent and the inclusion and exclusion criteria also assisted with sampling of participants who best met the stated purposes of this investigation.

Lastly, the lack of fully developed fall risk cut-off scores among community-dwelling older adults on the Mini-BEST may have impacted validity calculation and outcomes from research question 2. As previously described, age-related normative scores established for each decade of the lifespan were used as a basis for determining fall risk and with comparisons with fall risk conclusions from the STEADI algorithm rather than true cut-off values.

In addition to the limitations outlined above, this investigation had several delimitations. *Delimitations* are factors that are within the investigator's control. Although the establishment of numerous delimitations can impact the generalizability of this study, their purposes are to narrow the focus of the study as to ensure concise testing of stated hypotheses. This study's delimitations include 1) inclusion and exclusion criteria, 2) sampling methodologies, 3) use of a safety assistant during administration of the fall screening test, and 4) the dependent variables (screening tool outcomes) selected to evaluate the inter-environment agreement among independent variables (remote vs. face-to-face), 5) methods by which the telerehabilitation survey was validated for content including experiences from expert panelists, 6) the location where the investigation was conducted, and 7) the use of student raters.

Inclusion and exclusion criteria were established to sample older adults who are at an elevated risk of falls by being age 65 or older. Selected exclusion criteria narrowed the eligible sample population by discriminating against individuals with neurologic, cognitive/intellectual, or advance pulmonary disorders. While these delimitations served to minimize the risk of confounding variables and promote the safety of the participants, older adults who have neurologic or cognitive/intellectual impairment, and/or are oxygen dependent, for example, also reside in homes, apartments, and congregate living arrangements such as group homes. Therefore, older adults with these conditions can still be classified as community-dwelling older adults. Because individuals with certain health conditions or recent hospitalizations were not included in this study, results from the TR survey and validity conclusions including correlations and predictive abilities of screening tests with independent variables such as fall and fracture histories may have been different had the sampled population included participants with a broader scope of health conditions and recent illnesses.

Although randomization of assignment to control or experimental groups occurred, recruitment was one of convenience based upon volunteers who contacted the investigator. While a purposive convenience sampling is also defendable based upon the CDC's aging statistics and this demographic's inherent fall risks, it is also potentially limiting in that participants were mostly local to the Phoenix metropolitan area. Attitudes and preferences towards technology and healthcare preferences are often influenced by prior experiences and observations from within one's local community. As highlighted previously, an end-user's attitude towards technology is likely to be more positive if the individual or group feels it is a priority and they identify a need.[108,207,208] Volunteers may have felt a greater affinity towards technology to access a physical therapist because this study attracted participants with higher fall rates than CDC statistical reports. It is also well-established in the literature that computer use in older adults is influenced by educational level, and therefore, socioeconomic status.[116] Since these factors were not controlled for, they may have impacted the TR survey results. Some participants disclosed having residency in other parts of the United States and Canada, and this could potentially aid the generalizability of results from this investigation. To the contrary, the sampled population is not likely generalizable to older adults who reside in rural and/or medically underserved regions of the U.S. As was addressed in the section that discusses threats to internal validity, sampling from local senior centers and religious congregations, for example, allowed the potential for participants to talk about their experiences and technology preferences since some participants did know each other. There was no way to completely control for inter-participant discussions prior to or after their pre-test involvement with this study.

The use of a "safety assistant" with all telerehab screening tests had strengths and limitations with regards to the external validity of this study. Strengths are represented in how the outcomes of this study may initially impact clinical practice. The investigator envisions scenarios where an able-bodied informal caregiver facilitates a telehealth connection with a remote physical therapist while dually serving as the client's "safety assistant." As previously described, a family member, friend, or community representative (senior center activities coordinator or religious clergy person, for example) could serve the role of a "safety assistant." Admittedly, the safety assistant utilized throughout this investigation was likely better trained than the examples above. This safety assistant was a physical therapy student trained in proper guarding techniques and was familiar with all the screening tests conducted. Furthermore, the safety assistant was a six-foot-tall male whose presence may have indirectly influenced participant performance during fall risk testing and satisfaction levels expressed on post-test surveys. However, it is notable that the same safety assistant served all 39 experimental group participant sessions. Therefore, it can be said that the same influence of the safety assistant, whether positive or negative, was conveyed to all members of the experimental group. It is also notable that the presence of a trained safety assistance was integral to internal review board (IRB) approval and the overall risk management for this grass-roots investigation. As was the case with this study and in clinical practice, safety of participants is paramount above all other factors. Healthcare providers need to exercise sound professional judgement with determining the competence and ability of a remote client's safety assistant when integrating telerehabilitation into their practice. Of note, Russell et al have also utilized safety assistants who possess formal medical training.[196]

The process of content validation of a survey instrument is dependent upon the quality of feedback by an expert panel. Although reference articles foundational to technology acceptance models from were provided, the investigator did not measure the depth or quality of their understanding of the relevant literature base and theoretical framework rooted in the seven survey constructs. Further, feedback on items related to the seven major constructs could have been biased based upon the past experiences or preferences not disclosed to the primary investigator. In fact, feedback from one panelist specifically mentioned prior experiences with family. For example, this panel member stated, "I am trying to look at this as my father would," during their first review. Lawshe's content validation formulas were limited in usefulness, in part, because the panel of experts was assembled based upon employment experience in the fields of healthcare and information technology/media productions but *not* based upon academic subject matter expertise with the theories of technology acceptance and end-user technology adoption. Had Lawshe's recommended minimum target CVR value of 0.75 be held to its strictest statistical interpretation, three of the seven construct categories and 28 out of the 33 survey items would have been eliminated (Figure 6). The lack of practicality of Lawshe's content validation formulas was an unanticipated limitation on survey development. Therefore, the vast majority of all TR survey items were edited and kept in the final survey version rather than deleting items based upon the content validity index methodologies.

The location of this investigation is another delimitation to this investigation's external validity. As previously discussed, internet reliability and, therefore, location is also a limitation. The investigator's decision to conduct this investigation in a consistent, controlled setting was based upon personal experiences and reports from Shaw et al who cited inconsistent transmission of voice and video quality in urban areas of Phoenix, Arizona.[11,67] Because movement-based observations are essential to many of the nine selected fall screening tools included in this investigation, the decision to control for the type and location of the internet connection was made in an effort to avoid type II errors (false negatives). Furthermore, variability in environments may have ultimately influenced participant experiences and, ultimately, the outcomes of the TR surveys. Future studies need to be tested in urban and rural communities to enhance the external validity of this investigation's results.

Another potential delimitation is the use of inexperienced clinicians as raters. Although all telehealth and face-to-face raters received extensive training from an experienced clinician, there is the possibility that their inexperience with test implementation such as timing during single-limb or tandem stance tests, or with distinguishing gait quality characteristics scoring the POMA-G, for example, could have impacted outcomes to validity calculations. The FRT, TUG, 4MWT, 30STS, and tandem stance all have dichotomous cut-off classifications. Therefore, testing errors in scoring by a point or timing by less than a second could have impacted validity conclusions. Although the investigator endeavored to have at least one experienced clinician on each two-member rater team, coordinating human and environmental resources for volunteer raters over several months of data collection became a limitation. However, there is precedent in the telerehabilitation literature established by Russell for the use of Doctor of Physical Therapy (DPT) students as research raters. In addition to student DPT raters, Russell et al have also utilized student occupational therapists with data collection.[196] Nonetheless, each DPT student rater had prior patient care experience as each had already completed one full-time clinical rotation in the second year of their curriculum. To accomplish its purpose of providing annual fall screening to older adults and to promote more consistent communication about fall history and risks, the STEADI algorithm was designed to be implemented by a variety of healthcare professionals. That said, third year DPT students have more advanced and specialized training in the administration of fall risk screening tools than most staff at physician offices and occupational therapists, for example.

In summary, many of this study's limitations and delimitations interface because of the need for a reliable and secure method of transmitting real-time audio and video data. Despite the potential shortcomings outlined above, this research is a vital step towards the attainment of higher-reaching initiatives aimed at producing a more sustainable healthcare model here in the U.S. Accessibility to and cost-effectiveness of screening and preventative activities such as fall initiatives modeled by this grass-roots investigation could assist with enhancing the sustainability of the Medicare benefit, for example. While accessibility, cost-effectiveness, quality, and consumer/provider satisfaction require focused subsequent investigations, the accessibility to more frequent and structured, reliable, and valid fall screening interventions may reduce fall incidence and fracture-related costs among older adults. Furthermore, conclusions from this study may provide the impetus to additional research in the field of telerehabilitation aimed at improving health disparities that exist among geographically displaced and/or medically underserved populations.

Investigation Summary

The purpose of this study was to explore the acceptability, feasibility, reliability, and validity of telehealth-delivered fall risk and mobility screening in an older adult population. The impetus for this investigation is two-fold: 1) preventing elderly falls, and 2) examining the use of synchronous telehealth in an older adult population. To the first point, falls among the elderly have become a national and international public health crisis. The Centers for Disease Control and Prevention indicates that falls are the "leading cause of injury death and the most common cause of nonfatal injuries and hospital admission for trauma among people ages 65 and older."[1] To that end, falls also have significant economic consequences to the individual and payer sources. Each year, the U.S. spends billions of dollars treating the sequelae of injurious falls, and costs will continue to escalate as the elderly population reaches approximately 80 million by the year 2050.[18] Despite legislative initiatives, the U.S. continues to lack a sustainable model for the provision of cost-effective healthcare services to older adults. To address the disability and financial consequences of elderly falls, telerehabilitation was hypothesized to be a suitable supplement to existing fall screening and prevention efforts. Telerehabilitation is theoretically more cost-effective than face-to-face traditional healthcare because of the lack of indirect overhead expenses needed to deliver the care, and it has the potential to improve access for people who reside in medically underserved areas. Several sources, however, conclude that support for telerehab by a physical therapist remains underdeveloped in the literature.

Due in part to a multitude of legislative and technology barriers, the concept of telerehabilitation has not been fully integrated into physical therapy practice. In addition to addressing these barriers and better understanding the acceptability of telerehabilitation by older adults, additional research is needed to address the sparsity of randomized equivalency trials available for clinicians. In essence, the question of whether or not remote fall screening is inferior to traditional face-to-face care was in need of additional investigation. Working towards that end, the following problem statements and hypotheses served as a foundation to this investigation.

Problem Statements

1. While telehealth delivery systems have demonstrated the potential to assist with the screening for and the prevention of elderly falls, its validity and reliability in doing so has not yet been established.
2. While telehealth may be an option for some individuals, little was known about the attitudes and beliefs of older adults with regard to receiving telecommunications-aided healthcare services and whether or not those attitudes and beliefs were influenced by a telerehab experience. Older adults, as end users, may not be receptive to the use of real-time telehealth delivery systems.
3. Each year, the U.S. spends billions of dollars treating the sequelae of injurious falls, and the U.S. lacks a sustainable model for the provision of cost-effective healthcare services to older adults. Telehealth services may provide solutions to this, but research-based supportive evidence is lacking.

Hypotheses (Null)

1. There is no difference in attitudes and beliefs of older adults exposed to this investigation's real-time telerehabilitation application and older adults in the control group.
2. Conclusions from the remote STEADI fall risk screening tool will not be equivalent to conclusions from the face-to-face Mini-BEST fall screening tool.
3. Remote scoring and fall risk categorization of the Timed Up and Go (TUG) Test, 30-second Chair Rise, 4 Four-Stage Balance, Performance-Oriented Mobility Assessment Gait (POMA-G) Tool, 4- meter Walk Test, Functional Reach Test, and STEADI algorithm will not be equivalent to face-to-face raters.

This investigation implemented experimental, quantitative, and cross-sectional frameworks employing both pretest-posttest control group and quasi-experimental static group comparison designs using non-probability sampling methods. This investigation was the first of its kind to use synchronous telehealth applications to appraise elderly fall risks and measure the perceived usefulness of a telerehabilitation delivery system among community-dwelling older adults. This study assembled a panel of experts to content validate a survey tool developed to quantify an older adult's behavioral intention to use and their attitudes towards a telerehabilitation delivery system. The experimental component of this investigation compared two groups with the intervention group completing the survey before and after a telerehabilitation experience that focused on fall risk screening. The experimental portion of this study addressed hypothesis 1. The control group was not exposed to a telerehab delivery system and did not participated in fall risk screening. This investigation carefully selected existing screening tools that were hypothesized to be safe and feasible for remote implementation.

Instructions for all nine screening tools were provided by a remote rater through a laptop computer and webcam. To date, no other published telerehabilitation studies had the remote rater provide the instructions and serve as the lead clinician while simultaneously scoring each test in real-time.

The quasi-experimental component of this investigation addressed hypotheses 2 and 3. The standing Functional Reach Test (FRT), Timed Up and Go Test (TUG), 30-second Chair Rise (30STS) Test, 4-Stage Balance Tests (single limb, tandem, narrow stride, and narrow stance), Performance-Oriented Mobility Assessment Tinetti Gait (POMA-G) Test, 4-meter Walk Test (4 MWT) for the calculation of self-selected gait speed, and Stopping Elderly Accidents, Deaths & Injuries (STEADI) algorithm were all investigated for agreement among remote and face-to-face raters, and for comparison with the reference standard of face-to-face fall risk screening tool, the Mini-BEST.

Results indicate that a telerehabilitation delivery system is a reliable, equivalently valid method of screening and determining fall risk and fall incidence in community dwelling older adults. This study produced a content validated, internally consistent survey instrument designed to determine attitudes and beliefs about telerehabilitation. An experimental design was able to demonstrate a positive significant change in four out of seven survey constructs among the intervention group after exposure to telerehabilitation as compared to post-test controls. Overall, no significant difference was calculated between face-to-face or telerehab raters, and both environments produced equivalency with scoring, fall risk classification, and ability to discern fallers from non-fallers. Good to excellent interrater and interenvironment reliability was calculated for all screening tools. Results from the telerehab STEADI fall risk conclusions were calculated to be concurrently valid with the face-to-face reference standard screening tool, the

Mini-BEST. Lastly, results from receiver operating characteristic curves, sensitivity, specificity, and likelihood ratio calculations were equivalent among remote and face-to-face raters with this sampled population.

Conclusions from statistical analysis refuted all three null hypotheses in favor of accepting the following *alternative hypotheses*:

1. Participation in a real-time telerehab application will influence an older adult's attitudes and beliefs about the perceived usefulness of this healthcare delivery option when compared to a control group.
2. Fall risk conclusions from remote raters implementing the STEADI will be equivalent to fall risk conclusions from face-to-face raters implementing the Mini-BEST.
3. Remote scoring and fall risk categorization of the FRT, TUG, 30STS, Four-Stage Balance, POMA-G, 4MWT, and STEADI algorithm will be equivalent to face-to-face raters.

Understanding factors that drive end-user adoption of internet-hosted healthcare is critically important to develop services and allocate resources to meet to wellness and cost-related needs of older adults and relevant stakeholders. Clinical decisions related to a telerehabilitation delivery system must be based upon research that is reliable, valid, and acceptable to the care recipients. It is imperative that the same deliberate decision-making process and evidenced-based guidance that occurs with face-to-face decisions also occur with the decision to employ a telerehabilitation delivery system. Whether face-to-face or through telehealth, healthcare providers need methods to consistently and accurately discriminate fallers from non-fallers. This investigation hit all of these needs and endeavored to expand the array of remote healthcare delivery options for clinicians and clients.

Appendix A: Technology Acceptance Model's Pre- and Post-Test Questions

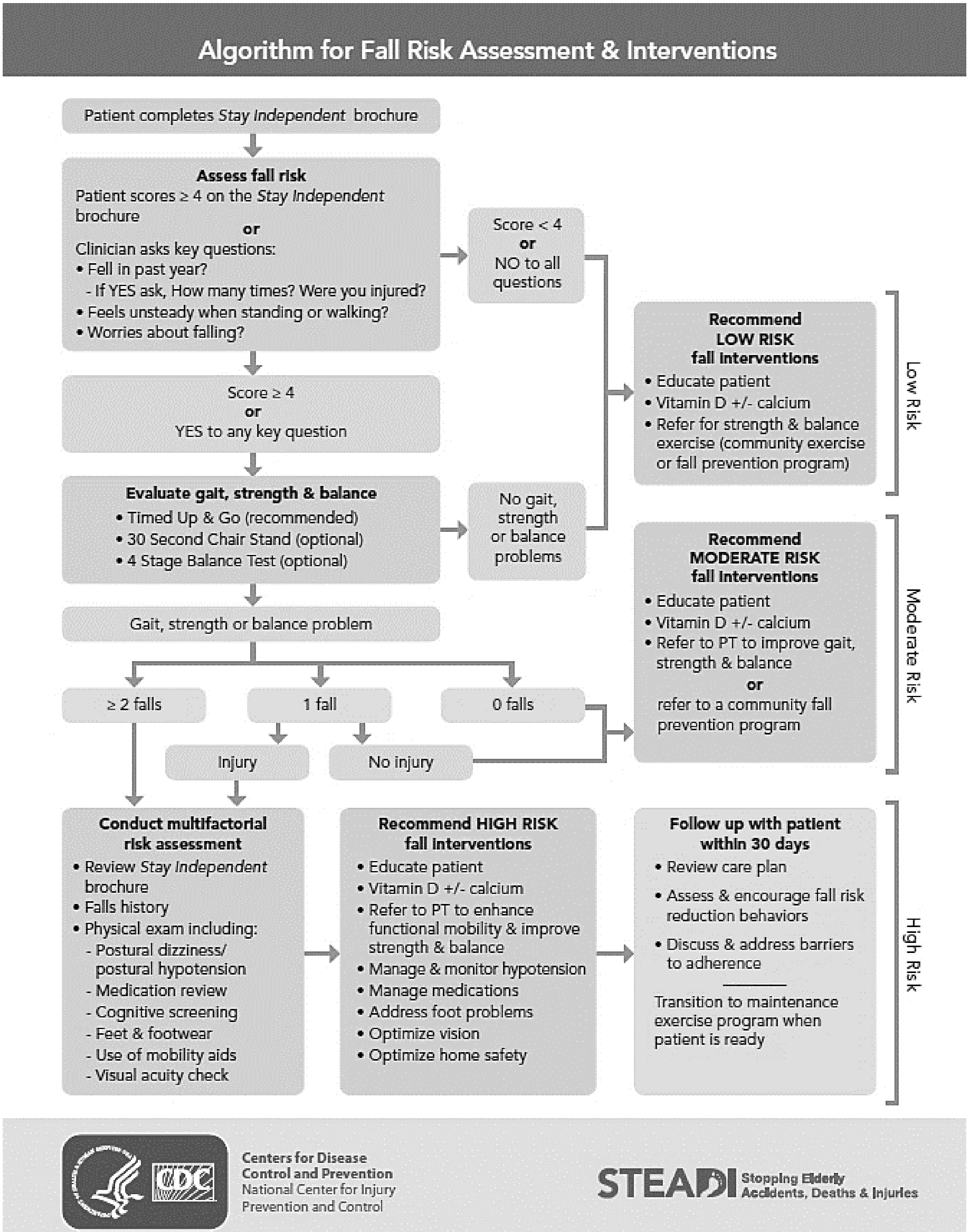
Table 4.2 Perceived Usefulness Item Pools (Davis)

Item #	Item Wording
1	My job would be difficult to perform without electronic mail.
2	Using electronic mail gives me greater control over my work.
3	Using electronic mail improves my job performance.
4	The electronic mail system addresses my job-related needs.
5	Using electronic mail saves me time.
6	Electronic mail enables me to accomplish tasks more quickly.
7	Electronic mail supports critical aspects of my job.
8	Using electronic mail allows me to accomplish more work than would otherwise be possible.
9	Using electronic mail reduces the time I spend on unproductive activities.
10	Using electronic mail enhances my effectiveness on the job.
11	Using electronic mail improves the quality of the work I do.
12	Using electronic mail increases my productivity.
13	Using electronic mail makes it easier to do my job.
14	Overall, I find the electronic mail system useful in my job.

Table 4.3 Perceived Ease of Use Item Pools

Item #	Item Wording
1	I often become confused when I use the electronic mail system.
2	I make errors frequently when using electronic mail.
3	Interacting with the electronic mail system is often frustrating.
4	I need to consult the user manual often when using electronic mail.
5	Interacting with the electronic mail system requires a lot of my mental effort.
6	I find it easy to recover from errors encountered while using electronic mail.
7	The electronic mail system is rigid and inflexible to interact with.
8	I find it easy to get the electronic mail system to do what I want it to do.
9	The electronic mail system often behaves in unexpected ways.
10	I find it cumbersome to use the electronic mail system.
11	My interaction with the electronic mail system is easy for me to understand.
12	It is easy for me to remember how to perform tasks using the electronic mail system.
13	The electronic mail system provides helpful guidance in performing tasks.
14	Overall, I find the electronic mail system easy to use.

Appendix B: Algorithm for Fall Risk Assessment & Interventions



Appendix C: IRB Approval Letters

MIDWESTERN UNIVERSITY
Glendale Campus
19555 N. 59th Avenue
Glendale, AZ 85308
623-572-3728
azorsp@midwestern.edu

Institutional Review Board
Approval of New IRB Application

6/15/16

TO: Robert Nithman, PT, DPT
Associate Professor, CHS-PT

FROM: Chad Carroll, Ph.D.
Chair, Institutional Review Board

RE: The Use of Telehealth for Fall Risk Screening

The IRB has reviewed your proposal for an investigation in human subjects on the above titled Project. The IRB at Midwestern University (Glendale, Arizona) finds that your study fulfills the criteria for Expedited (45 CFR 46.110) review. You are approved to proceed with your project.

Any amendments or modifications to this study must first be reviewed by the Institutional Review Board. Please note that you are approved to study a maximum of 60 human subjects. Any increase in sample size must first be reviewed by the IRB. Please notify the IRB in writing if there are any incidents that occur during your research project or when you have successfully completed your study.

IRB Approval:	6/15/16
IRB Expiration:	6/15/17
Annual/final report due:	5/15/17

Chad Carroll, Ph.D.
Institutional Review Board Chair

IRB Authorization Agreement
Nova Southeastern University relying on a MWU IRB

This IRB authorization agreement is suitable for documenting a formal agreement between Nova Southeastern University and an institutional review board (IRB) on which Nova Southeastern University relies for review of the research activities specified below: This agreement is permitted by human research regulations at 45 CFR 46.114 and 21 CFR 56.114.

1. Institution or organization providing IRB review (Institution A)

Name of Institution or Organization A: Midwestern University
FWA# FWA00006635 FWA expiration date: 9/13/17

2. Institution relying on designated IRB (Institution B)

Name of Institution or Organization B: Nova Southeastern University
IRB Registration: IRB #000002823 IRB registration expiration date: 7/20/19
Federalwide Assurance #000004057 FWA expiration date: 9/29/19

3. Scope of authorization agreement

The officials signing below agree that Nova Southeastern University may rely on the designated IRB at Midwestern University (MWU) both for review under 45 CFR part 46 (and 21 CFR parts 50 and 56, if applicable) and for continuing oversight of the involvement of human subjects in the research described below:

	Institution/Organization A Midwestern University	**Institution B Nova Southeastern University**
Title of Research	The Use of Telehealth for Fall Risk Screening	The Use of Telehealth for Fall Risk Screening
Principal Investigator (name, phone, fax, e-mail	Bob Nithman 623-572-3927 (p) 623-572-3929 (f) nithm@midwestern.edu	Bob Nithman 623-572-3927 (p) 623-572-3929 (f) nithm@midwestern.edu
Primary contact (name, phone, fax, e-mail)	Sepideh S. Hockley, MBA 623-572-3796 (p) 623-572-3730 (f) ssefid@midwestern.edu	William Smith, J.D. 954-262-5311 (p) 954-262-3970 (f) wsmith2@nova.edu

The review and continuing oversight performed by the designated IRB will satisfy the human subjects protection requirements of the HHS regulations (and FDA regulations, if applicable) for the protection of human subjects, as well as the requirements of Midwestern University's FWA. The reviewing IRB must be designated on Nova Southeastern University's FWA. The IRB at Midwestern University will follow written procedures for reporting its findings and actions to appropriate officials at Nova Southeastern University. Relevant minutes of IRB meetings and related records will be made available to Nova Southeastern University upon request. Nova Southeastern University remains responsible for ensuring compliance with the IRB's determination and with the terms of Nova Southeastern University's FWA. This document must be kept on file at both institutions and provided to OHRP upon request.

4. Signatures

Institution A: Midwestern University

Signature
James M. Woods, Ph.D.
Director, Research & Sponsored Programs
Midwestern University
555 31st Street
630-515-6173
jwoods@midwestern.edu

Institution B: Nova Southeastern University

Signature
Donald Rudawsky, Ph.D.
Vice President of Institutional Effectiveness
Nova Southeastern University

MIDWESTERN UNIVERSITY
Glendale Campus
19555 N. 59th Avenue
Glendale, AZ 85308
623-572-3728
azorsp@midwestern.edu

Institutional Review Board
Approval of Amended IRB Protocol

8/19/16

TO: Bob Nithman
Associate Professor

FROM: Wendy Harrison, Ph.D.
Chair, Institutional Review Board

RE: AZ 907 Amendment

The IRB has reviewed your request for an amendment to the above titled Project. The requested amendment has been approved and you may now proceed with your research.

Any further amendments or modifications to this study must first be reviewed by the Institutional Review Board. Please notify the IRB in writing if there are any incidents that occur during your research project or when you have successfully completed your study.

☑ Amendment to original protocol

☐ Amendment to most recently amended protocol

Amendment Request:

Increase sample size to 100 people

Wendy Harrison OD PhD

Wendy Harrison, O.D, Ph.D.
Institutional Review Board Chair

Appendix D: Fall History Questionnaire

Please answer the following questions to the best of your abilities. If you are unsure of some answers, please ask for help from a trusted caregiver, family member, or healthcare provider.

YOUR NAME: ________________________________ **DOB**: _____________________

PRIMARY RESIDENCE: ☐ House ☐ Apartment ☐ Assisted Living ☐ Group Home

PRIMARY CARE DOCTOR: _________________________Phone Number: _________________

How many times have you fallen since turning age 65? ☐ 0 ☐ 3-5 ☐ 1 ☐ 5+ ☐ 1-3	**How frequent do you fall?** ☐ Daily ☐ Yearly ☐ Weekly ☐ I have never fallen ☐ Monthly
How many times have you fallen in the <u>past 12 months</u>? ☐ 0 ☐ 3-5 ☐ 1 ☐ 5+ ☐ 1-3	How many of these falls resulted in you seeking **<u>emergent medical care</u>**? ☐ 0 ☐ 3-5 ☐ 1 ☐ 5+ ☐ 1-3
Has a fall ever resulted in a broken bone or required surgery? ☐ Yes ☐ No	**Where have you fallen?** *(check all that apply)* ☐ Where I live / at home ☐ During the Day ☐ During the Night ☐ In the Community
Please check any walking aides that you use on a regular basis: *(check all that apply)* ☐ Straight Cane ☐ Four legged/Quad Cane ☐ Walker with NO Wheels ☐ Walker with 2 Front Wheels ☐ Walker with 4 Wheels ☐ Crutches ☐ Other: _________________________	**How long have you used a walking aid?** ☐ < 1 year ☐ 5+ years ☐ 1-3 years ☐ not applicable ☐ 3-5 years **Have you had any medication changes in the past 6 months?** ☐ Yes ☐ No
If you use a walking aide, was this prescribed by a healthcare professional? ☐ Yes ☐ No	**Number of times you have been admitted to the hospital in the <u>past 12 months</u>:** ☐ 0 ☐ 3-5 ☐ 1 ☐ 5+ ☐ 1-3

<table>
<tr>
<td>If yes, who prescribed this device for you?
☐ Physical Therapist
☐ Physician
☐ Other: _________________________</td>
<td>Have you <u>ever</u> had a visiting nurse or therapist(s) treat you in your primary residence for any health-related conditions?
☐ Yes
☐ No</td>
</tr>
</table>

Appendix E: Standardized Rater Forms

1 | Telerehabilitation SCRIPT and Scoring Sheet

PARTICIPANT NAME: ________________________________ **RATER:** ☐ 1 ☐ 2

INTRODUCTION TO THE TELEREHABILITATION SESSIONS
(given by lead TH rater):

- *Hello Mr./Ms. ______________________. What name do you prefer when I communicate with you? Okay, ________________________.*
- *Over the next 15-20 minutes, I am going to guide you through a series of standardized fall risk tests.*
- *You can talk to me and ask questions just like you would with any healthcare provider that you would see face-to-face.*
- *You are welcome to approach the computer anytime to better assist with hearing and seeing the instructions.*
- *As a reminder, if you do not feel comfortable attempting one of the tests, please do let me know.*

PARTICIPANT NAME: ________________________________ **RATER:** ☐ 1 ☐ 2

THE TIMED UP AND GO (TUG) TEST

- **Instructions from the TELEREHAB Rater:**
  - *Hello ________________. The purpose of this (first) test is to assess your overall mobility.*
  - *We will repeat this test two times.*
  - *When I say "Go," I want you to:*
    - *Stand up from the chair*
    - *Walk to the line on the floor at your normal pace*
    - *Turn and then walk back to the chair at your normal pace*
    - *Sit down again*
    - *You are able to use your cane or walker if you normally use one.*

- **Instructions for Raters**:
  - On the word, "Go" begin timing
  - Stop timing after the patient has sat back down and record below

Assistive Device Used: ☐ Yes ☐ No ☐ Cane ☐ Quad Cane ☐ 2 WWalker ☐ 4 WWalker ☐ Other___________	
Trial	Time (seconds)
1	
2	
	Mean Time:

- Observed gait or postural deficits:

PARTICIPANT NAME: ___________________________________ **RATER:** ☐ 1 ☐ 2

- ***Circle all that apply***: Slow tentative pace / Loss of Balance / Short Strides / Little or no arm swing / Steadying self on walls, furniture, another person / Shuffling / Not using Assistive Device properly

PARTICIPANT NAME: ________________________________ **RATER:** ☐ 1 ☐ 2

THE 4-STAGE BALANCE TEST

- **Instructions from the TELEREHAB Rater:**
  - *Hello ________________. The purpose of this test is to assess your standing balance.*
  - *We will repeat each of these tests two times.*
  - *I am going to show you pictures of four different foot positions.*
  - *Try your best to stand in each position for 10 seconds. You can hold your arms out or move your body to keep your balance but once you move your feet or make contact with the chair, we will record your time.*
  - *Please hold onto the chair and place your feet in this position: (picture). We will begin timing when you let go of the chair.*
    - *Position 1 PICTURE is narrow base of support (BOS)*
    - *Position 2 PICTURE is narrow stride (heel/arch)*
    - *Position 3 PICTURE is tandem stance (heel/toe)*
    - *Position 4 PICTURE is single limb stance (one leg)*

- **Instructions for Raters:**
  - Record time from when the participant lets go of chair until he/she loses their balance as evidenced by moving their foot position, making contact with the chair with any body part, or when the telerehab rater says "stop" (10 seconds).
  - Each test will be performed 2x switching legs (L/R) the second attempt for phases 2, 3, and 4.

PARTICIPANT NAME: ___________________________________ **RATER:** ☐ 1 ☐ 2

4 Stage Balance Test	Dominant limb: ☐ Right	☐ Left
Position	Trial	Time (seconds)
1: narrow BOS	1	
1: narrow BOS	2	
2: narrow stride	1	
2: narrow stride	2	
3: tandem stance	1	
3: tandem stance	2	
4: single limb stance (R)	1a	
	1b	
4: single limb stance (L)	2a	
	2b	

PARTICIPANT NAME: ___________________________________ **RATER:** ☐ 1 ☐ 2

THE 30-SECOND CHAIR STAND TEST (30 SECOND SIT TO STAND)

- **Instructions from the TELEREHAB Rater:**
  - *Hello ________________. The purpose of this test is to assess your lower body strength.*
  - *This test is performed only one time.*
  - *Please sit in the middle of the chair with your feet flat on the floor. Now, cross your arms across your chest placing your hands on the opposite shoulder (like you are giving yourself a hug).*
  - *When I say "go," rise to a full standing position and then sit back down again.*
  - *Repeat this for 30 seconds*

- **Instructions for Raters:**
  - On "go," begin timing
  - Count the number of times the person comes to a full standing position in 30 seconds
    - If the patient is over halfway to a standing position when 30 seconds have elapsed, count it as a stand.
  - If the person must use his/her arms to stand, stop the test and record "0" for the number and score.

30 Second Chair Rise Test	
Trial	Number of Repetitions
1	

PARTICIPANT NAME: ___________________________________ **RATER:** ☐ 1 ☐ 2

THE 4-METER WALK TEST

- **Instructions from the TELEREHAB Rater:**
  - *Hello ________________. The purpose of this test is to assess your normal walking speed.*
  - *We will repeat this test two times.*
  - *In front of you, you will see 4 lines of tape. Please stand on the line that is farthest from the computer.*
  - *When I say "go," please walk at your normal walking pace to the last / 4th line.*

- **Instructions for Raters**:
  - Begin timing at the second line of tape
  - Stop timing after the patient has reached the third line of tape

Assistive Device Used: ☐ Yes ☐ No ☐ Cane ☐ Quad Cane ☐ 2 WWalker ☐ 4 WWalker ☐ Other__________	
Trial	Time (seconds)
1	
2	
	Mean Time:
	Mean m/sec:

PARTICIPANT NAME: ________________________________ **RATER:** ☐ 1 ☐ 2

FUNCTIONAL REACH TEST

- **Instructions from the TELEREHAB Rater:**
  - *Hello ________________. The purpose of this test is to assess your standing balance when reaching forward.*
  - *We will repeat this test two times.*
  - *Please stand next to, but not touching, the wall.*
  - *Position your arm straight out in front of you with a closed fist lined up with the blue tape.*
  - *Reach as far as you can forward without taking a step.*

- **Instructions for Raters:**
  - Using the yardstick, record the max distance that the person's 3rd metacarpal and record below
  - Also record whether you feel the person has an elevated fall risk based upon each individual reach distance and record below
    - Cut off scores for FRT: 10" normal reach
      : *<7" limited functional balance*

Functional Reach Test		
Trial	Distance (inches)	Elevated Risk ≤7" (Y/N)
1 (R/L)		
2 (R/L)		
	Mean Distance:	

PARTICIPANT NAME: ________________________________ **RATER: ☐ 1 ☐ 2**

TINETTI GAIT ASSESSMENT

- **Instructions from the TELEREHAB Rater:**
  - *Hello ________________. The purpose of this test is to observe how you walk.*
  - *In front of you, you will see 4 lines of tape. Please stand on the line that is CLOSEST to the computer.*
  - *When I say "go," please walk to the far end of the room (to the table) at your usual pace and back at a faster but safe walking pace.*
  - *You are able to use your cane or walker if you normally use one.*
  - *Please walk down and back two times.*

- **Instructions for Raters**:
  - Observe the person's gait and score below.

PARTICIPANT NAME: ______________________________ **RATER:** ☐ 1 ☐ 2

Task		Description of Gait	Possible	Score
10	Initiation of gait (immediately or after told to "go")	Any hesitancy or multiple attempts to start	0	
		No hesitancy	1	
11	Step length and height	a. Right swing foot does not pass left stance foot with step	0	
		b. Right foot passes left stance foot	1	
		c. Right foot does not clear floor completely with step	0	
		d. Right foot completely clears floor	1	
		e. Left swing foot does not pass right stance foot with step	0	
		f. Left foot passes right stance foot	1	
		g. Left foot does not clear floor completely with step	0	
		h. Left foot completely clears floor	1	
12	Step Symmetry	Right and left step length not equal (estimate)	0	
		Right and left step appear equal	1	
13	Step Continuity	Stopping or discontinuity between steps	0	
		Steps appear continuous	1	
14	Path (estimated in relation to floor tiles, 12-inch diameter; observe excursion of 1 foot over about 10 feet of the course).	Marked deviation	0	
		Mild/moderate deviation or uses walking aid	1	
		Straight without walking aid	2	
15	Trunk	Marked sway or uses walking aid	0	
		No sway but flexion of knees or back, or spreads arms out while walking	1	
		No sway, no flexion, no use of arms, and no use of walking aid	2	
16	Walking Stance	Heels apart	0	
		Heels almost touching while walking	1	

0 = highest level of impairment
2 = independent

Total Gait Score (out of 12) =

1 Telerehabilitation SCRIPT and Scoring Sheet
1

PARTICIPANT NAME: ______________________________________ **RATER:** ☐ 1 ☐ 2

Face-to-face <u>and</u> Telehealth Raters:

PLEASE RATE THE QUALITY OF THE AUDIOVISUAL CONNECTION DURING THIS SESSION:

☐ **1 – Acceptable for Clinical Practice with minimal to no connectivity issues**

☐ **2 – Acceptable for Clinical Practice but frequent connectivity issues**

☐ **3 – Not acceptable for Clinical Practice due to connectivity issues**

PARTICIPANT NAME: ________________________________ **RATER:** ☐ 1 ☐ 2

Mini-BESTest: Balance Evaluation Systems Test

ANTICIPATORY ***SUB SCORE:*** **/6**

1. SIT TO STAND
Instruction: *"Cross your arms across your chest. Try not to use your hands unless you must. Do not let your legs lean against the back of the chair when you stand. Please stand up now."*
(2) Normal: Comes to stand without use of hands and stabilizes independently.
(1) Moderate: Comes to stand WITH use of hands on first attempt.
(0) Severe: Unable to stand up from chair without assistance, OR needs several attempts with use of hands.

2. RISE TO TOES
Instruction: *"Place your feet shoulder width apart. Place your hands on your hips. Try to rise as high as you can onto your toes. I will count out loud to 3 seconds. Try to hold this pose for at least 3 seconds. Look straight ahead. Rise now."*
(2) Normal: Stable for 3 s with maximum height.
(1) Moderate: Heels up, but not full range (smaller than when holding hands), OR noticeable instability for 3 s.
(0) Severe: $\leq$ 3 s.

3. STAND ON ONE LEG
Instruction: "Look straight ahead. Keep your hands on your hips. Lift your leg off of the ground behind you without touching or resting your raised leg upon your other standing leg. Stay standing on one leg as long as you can. Look straight ahead. Lift now."

Left: *Time in Seconds Trial 1:_____ Trial 2:_____*
(2) Normal: 20 s.
(1) Moderate: < 20 s.
(0) Severe: Unable.

Right: *Time in Seconds Trial 1:_____ Trial 2:_____*
(2) Normal: 20 s.
(1) Moderate: < 20 s.
(0) Severe: Unable

To score each side separately use the trial with the longest time.
To calculate the sub-score and total score use the side [left or right] with the lowest numerical score [i.e. the worse side].

REACTIVE POSTURAL CONTROL ***SUB SCORE:*** **/6**

4. COMPENSATORY STEPPING CORRECTION- FORWARD
Instruction: "Stand with your feet shoulder width apart, arms at your sides. Lean forward against my hands beyond your forward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall."
(2) Normal: Recovers independently with a single, large step (second realignment step is allowed).
(1) Moderate: More than one step used to recover equilibrium.
(0) Severe: No step, OR would fall if not caught, OR falls spontaneously.

5. COMPENSATORY STEPPING CORRECTION- BACKWARD
Instruction: "Stand with your feet shoulder width apart, arms at your sides. Lean backward against my hands beyond your backward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall."
(2) Normal: Recovers independently with a single, large step.
(1) Moderate: More than one step used to recover equilibrium.
(0) Severe: No step, OR would fall if not caught, OR falls spontaneously.

6. COMPENSATORY STEPPING CORRECTION- LATERAL
Instruction: "Stand with your feet together, arms down at your sides. Lean into my hand beyond your sideways limit. When I let go, do whatever is necessary, including taking a step, to avoid a fall."

Left
(2) Normal: Recovers independently with 1 step (crossover or lateral OK).
(1) Moderate: Several steps to recover equilibrium.
(0) Severe: Falls, or cannot step.

Right
(2) Normal: Recovers independently with 1 step (crossover or lateral OK).
(1) Moderate: Several steps to recover equilibrium.
(0) Severe: Falls, or cannot step.

Use the side with the lowest score to calculate sub-score and total score.

SENSORY ORIENTATION ***SUB SCORE:*** **/6**

7. STANCE (FEET TOGETHER); EYES OPEN, FIRM SURFACE
Instruction: "Place your hands on your hips. Place your feet together until almost touching. Look straight ahead. Be as stable and still as possible, until I say stop."
Time in seconds:________
(2) Normal: 30 s.
(1) Moderate: < 30 s.
(0) Severe: Unable.

8. STANCE (FEET TOGETHER); EYES CLOSED, FOAM SURFACE

Instruction: "Step onto the foam. Place your hands on your hips. Place your feet together until almost touching. Be as stable and still as possible, until I say stop. I will start timing when you close your eyes."

Time in seconds:________

(2) Normal: 30 s.
(1) Moderate: < 30 s.
(0) Severe: Unable.

9. INCLINE- EYES CLOSED

Instruction: "Step onto the incline ramp. Please stand on the incline ramp with your toes toward the top. Place your feet shoulder width apart and have your arms down at your sides. I will start timing when you close your eyes."

Time in seconds:________

(2) Normal: Stands independently 30 s and aligns with gravity.
(1) Moderate: Stands independently <30 s OR aligns with surface.
(0) Severe: Unable.

DYNAMIC GAIT ***SUB SCORE:*** /10

10. CHANGE IN GAIT SPEED

Instruction: "Begin walking at your normal speed, when I tell you 'fast', walk as fast as you can. When I say 'slow', walk very slowly."

(2) Normal: Significantly changes walking speed without imbalance.
(1) Moderate: Unable to change walking speed or signs of imbalance.
(0) Severe: Unable to achieve significant change in walking speed AND signs of imbalance.

11. WALK WITH HEAD TURNS – HORIZONTAL

Instruction: "Begin walking at your normal speed, when I say "right", turn your head and look to the right. When I say "left" turn your head and look to the left. Try to keep yourself walking in a straight line."

(2) Normal: performs head turns with no change in gait speed and good balance.
(1) Moderate: performs head turns with reduction in gait speed.
(0) Severe: performs head turns with imbalance.

12. WALK WITH PIVOT TURNS

Instruction: "Begin walking at your normal speed. When I tell you to 'turn and stop', turn as quickly as you can, face the opposite direction, and stop. After the turn, your feet should be close together."

(2) Normal: Turns with feet close FAST ($\leq$ 3 steps) with good balance.
(1) Moderate: Turns with feet close SLOW ($\geq$4 steps) with good balance.
(0) Severe: Cannot turn with feet close at any speed without imbalance.

13. STEP OVER OBSTACLES

Instruction: "Begin walking at your normal speed. When you get to the box, step over it, not around it and keep walking."

(2) Normal: Able to step over box with minimal change of gait speed and with good balance.
(1) Moderate: Steps over box but touches box OR displays cautious behavior by slowing gait.
(0) Severe: Unable to step over box OR steps around box.

14. TIMED UP & GO WITH DUAL TASK ***[3 METER WALK]***

Instruction TUG: "When I say 'Go', stand up from chair, walk at your normal speed across the tape on the floor, turn around, and come back to sit in the chair."

Instruction TUG with Dual Task: "Count backwards by threes starting at ___. When I say 'Go', stand up from chair, walk at your normal speed across the tape on the floor, turn around, and come back to sit in the chair. Continue counting backwards the entire time."

TUG: ________seconds; Dual Task TUG: ________seconds

(2) Normal: No noticeable change in sitting, standing or walking while backward counting when compared to TUG without Dual Task.
(1) Moderate: Dual Task affects either counting OR walking (>10%) when compared to the TUG without Dual Task.
(0) Severe: Stops counting while walking OR stops walking while counting.

When scoring item 14, if subject's gait speed slows more than 10% between the TUG without and with a Dual Task the score should be decreased by a point.

TOTAL SCORE: _____/28

Mini-BESTest Instructions

Subject Conditions: Subject should be tested with flat-heeled shoes OR shoes and socks off.
Equipment: Temper® foam (also called T-foam™ 4 inches thick, medium density T41 firmness rating), chair without arm rests or wheels, incline ramp, stopwatch, a box (9" height) and a 3 meter distance measured out and marked on the floor with tape [from chair].
Scoring: The test has a maximum score of **28** points from **14 items** that are each scored from 0-2.
"0" indicates the lowest level of function and "2" the highest level of function.
If a subject must use an assistive device for an item, score that item one category lower.
If a subject requires physical assistance to perform an item, score "0" for that item.
For **Item 3** (stand on one leg) and **Item 6** (compensatory stepping-lateral) only include the score for one side (the worse score).
For **Item 3** (stand on one leg) select the best time of the 2 trials [from a given side] for the score.
For **Item 14** (timed up & go with dual task) if a person's gait slows greater than 10% between the TUG without and with a dual task then the score should be decreased by a point.

1. SIT TO STAND	Note the initiation of the movement, and the use of the subject's hands on the seat of the chair, the thighs, or the thrusting of the arms forward.
2. RISE TO TOES	Allow the subject two attempts. Score the best attempt. (If you suspect that subject is using less than full height, ask the subject to rise up while holding the examiners' hands.) Make sure the subject looks at a non-moving target 4-12 feet away.
3. STAND ON ONE LEG	Allow the subject two attempts and record the times. Record the number of seconds the subject can hold up to a maximum of 20 seconds. Stop timing when the subject moves hands off of hips or puts a foot down. Make sure the subject looks at a non-moving target 4-12 feet ahead. Repeat on other side.
4. COMPENSATORY STEPPING CORRECTION-FORWARD	Stand in front of the subject with one hand on each shoulder and ask the subject to lean forward (Make sure there is room for them to step forward). Require the subject to lean until the subject's shoulders and hips are in front of toes. After you feel the subject's body weight in your hands, very suddenly release your support. The test must elicit a step. NOTE: Be prepared to catch subject.
5. COMPENSATORY STEPPING CORRECTION - BACKWARD	Stand behind the subject with one hand on each scapula and ask the subject to lean backward (Make sure there is room for the subject to step backward.) Require the subject to lean until their shoulders and hips are in back of their heels. After you feel the subject's body weight in your hands, very suddenly release your support. Test must elicit a step. NOTE: Be prepared to catch subject.
6. COMPENSATORY STEPPING CORRECTION- LATERAL	Stand to the side of the subject, place one hand on the side of the subject's pelvis, and have the subject lean their whole body into your hands. Require the subject to lean until the midline of the pelvis is over the right (or left) foot and then suddenly release your hold. NOTE: Be prepared to catch subject.
7. STANCE (FEET TOGETHER); EYES OPEN, FIRM SURFACE	Record the time the subject was able to stand with feet together up to a maximum of 30 seconds. Make sure subject looks at a non-moving target 4-12 feet away.
8. STANCE (FEET TOGETHER); EYES CLOSED, FOAM SURFACE	Use medium density Temper® foam, 4 inches thick. Assist subject in stepping onto foam. Record the time the subject was able to stand in each condition to a maximum of 30 seconds. Have the subject step off of the foam between trials. Flip the foam over between each trial to ensure the foam has retained its shape.
9. INCLINE EYES CLOSED	Aid the subject onto the ramp. Once the subject closes eyes, begin timing and record time. Note if there is excessive sway.
10. CHANGE IN SPEED	Allow the subject to take 3-5 steps at normal speed, and then say "fast". After 3-5 fast steps, say "slow". Allow 3-5 slow steps before the subject stops walking.
11. WALK WITH HEAD TURNS-HORIZONTAL	Allow the subject to reach normal speed, and give the commands "right, left" every 3-5 steps. Score if you see a problem in either direction. If subject has severe cervical restrictions allow combined head and trunk movements.
12. WALK WITH PIVOT TURNS	Demonstrate a pivot turn. Once the subject is walking at normal speed, say "turn and stop." Count the number of steps from "turn" until the subject is stable. Imbalance may be indicated by wide stance, extra stepping or trunk motion.
13. STEP OVER OBSTACLES	Place the box (9 inches or 23 cm height) 10 feet away from where the subject will begin walking. Two shoeboxes taped together works well to create this apparatus.
14. TIMED UP & GO WITH DUAL TASK	*Use the TUG time to determine the effects of dual tasking. The subject should walk a 3 meter distance. TUG:* Have the subject sitting with the subject's back against the chair. The subject will be timed from the moment you say "Go" until the subject returns to sitting. Stop timing when the subject's buttocks hit the chair bottom and the subject's back is against the chair. The chair should be firm without arms. *TUG With Dual Task*: While sitting determine how fast and accurately the subject can count backwards by threes starting from a number between 100-90. Then, ask the subject to count from a different number and after a few numbers say "Go". Time the subject from the moment you say "Go" until the subject returns to the sitting position. Score dual task as affecting counting or walking if speed slows (>10%) from TUG and or new signs of imbalance.

Appendix F: Instructions to Panel of Experts for Survey Content Validation

Background Information: **Thank-you for agreeing to assist me with the development of this survey instrument!** The development of this survey was a unique contribution to the literature. By agreeing to participate, you agree to keep all information confidential and acknowledge that the initial and any subsequent drafts including the final survey tool are the intellectual property of Robert W. Nithman. Unfortunately, there was no compensation for your assistance but I was forever grateful for you sharing your time and expertise! With your permission, however, I will acknowledge you by listing your name when this questionnaire was disseminated.

Please type &/or sign your name acknowledging your acceptance of these conditions.

____ __________________

NAME /SIGNATURE DATE

Study Purpose: My goal was two-fold: 1) to quantify the behavioral intention of older adults to use technology applications and 2) to measure the impact of a telerehabilitation experience on baseline attitudes and beliefs of older adults towards technology. The theoretical foundation of this survey was based upon the Technology Acceptance Model (TAM): "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology" (Davis, 1989). Because I am *not* building a telehealth software application, my research was focused mainly on <u>perceived usefulness</u> and attitudes towards telerehabilitation rather than perceived ease of use. As background information to you, there lacks an existing survey instrument to adopt/"borrow" for some of my broader PhD work; existing surveys in the telehealth/telemedicine literature could possibly be modified but they lack methodologic rigor for me to use as a foundation for my research.

Definitions: **Telehealth** was the use of computerized videoconferencing systems transmitted over the internet for purposes related to connecting medical professionals with potential or actual patient/clients. **Telerehabilitation** was similar to telehealth but uses videoconferencing systems for rehabilitation services. Physical therapy was one example of a rehabilitation service.

Timelines/dates: Please complete each review within 7 days of receiving each iteration ☺. Once feedback from all reviewers was received from draft 1, I will compile all information and email draft 2 for your review and comment. Your time commitment will not exceed one month and it was limited to reviewing no more than 2 drafts of this survey.

Your Tasks:

Review #1

1) Familiarize yourself with each of the seven constructs.
   - I have provided operational definitions for each construct as well as supportive articles representing the theoretical framework of an individual's behavioral intention to use a technology system.
2) Review each item for relevance to each construct.
3) Add, edit, move, or delete any items for clarity, consistency, etc. (in track changes within the document -or- hand written).
4) Review the description of the Likert scale for relevance to its corresponding construct. For example, was the description range "not useful" to "very useful" – or- "disagree" to "strongly agree" more appropriate for a section?
   - Please note that the 0-7 scale will not change – I have adopted it due to its use in other technology acceptance publications.

Review #2

1) Repeat the above steps as appropriate.
2) Label each item as "essential," "useful but not essential," or "not necessary" to the performance of each construct.

Please email me each review – however, if you need to fax, please let me know and I will provide my fax number. IF YOU HAVE ANY QUESTIONS ALONG THE WAY, please don't hesitate to call or text me day or evening. My cell was **(412) 901-9944**.

THANK-YOU in advance for your time and efforts!!!

Bob

SURVEY **DRAFT** 1
(*emailed to panel of experts*)

CONSTRUCT 1 **Performance Expectancy / Perceived Usefulness** – the degree to which an individual believes that using the system will help him or her attain gains / can improve one's quality of life. (Cimperman, 2013); …enhance his or her performance (Davis, 1989; Venkatesh, 2003); …extent which the person feels the technology will assist them. (Wade, 2012)	
Telerehabilitation could be a convenient way to access a physical therapist.	*not useful* *very useful* **0 1 2 3 4 5 6 7**

Using a computer to access a physical therapist was as good as seeing them face-to-face.	*not useful* *very useful* **0 1 2 3 4 5 6 7**
Telerehabilitation could help to better understand my risk of falling.	*not useful* *very useful* **0 1 2 3 4 5 6 7**
Telerehabilitation will improve access to regular testing of my walking ability and balance. (Wade)	*not useful* *very useful* **0 1 2 3 4 5 6 7**
Using telerehabilitation equipment will make it easier to do regular testing. (Wade)	*not useful* *very useful* **0 1 2 3 4 5 6 7**
Using telerehabilitation will save time in having regular testing. (Wade)	*not useful* *very useful* **0 1 2 3 4 5 6 7**
I will find the telerehabilitation equipment useful in my regular testing. (Wade)	*not useful* *very useful* **0 1 2 3 4 5 6 7**
CONSTRUCT 2 **Effort Expectancy** – the degree to which a person believes that using a system would be free from effort. (Venkatesh, 2003) The degree of ease associated with using the system. (Cimperman, 2013)	
Use of a computer will improve communication with my physical therapist.	*not useful* *very useful* **0 1 2 3 4 5 6 7**
Telerehabilitation equipment was easy to use. (Wade)	*Little effort* *significant effort* **0 1 2 3 4 5 6 7**
Learning to use the telerehabilitation equipment was easy for me. (Wade)	*Little effort* *significant effort* **0 1 2 3 4 5 6 7**
My interaction with the telerehabilitation equipment was clear and understandable. (Wade)	*not useful* *very useful* **0 1 2 3 4 5 6 7**
It was easy for me to become skillful at using the telerehabilitation equipment. (Wade)	*disagree* *strongly* *agree* **0 1 2 3 4 5 6 7**

CONSTRUCT 3 **Social Influence** – the degree to which an individual perceives that important others believe he or she should use the system; the influence of important others on an older users' decision to use home telemedicine services (HTS). (Cimperman, 2013) The person's perception that most people who are important to him think he should or should not perform the behavior in question. (Venkatesh, 2003)	
How likely I would ask somebody I know who already uses the system for opinion and recommendations. (Cimperman)	*not likely* *very likely* **0 1 2 3 4 5 6 7**
The opinion of my friends will influence my intension to use a computer to access a physical therapist.	*not likely* *very likely* **0 1 2 3 4 5 6 7**
The opinion of my family will influence my intension to use a computer to access a physical therapist.	*not likely* *very likely* **0 1 2 3 4 5 6 7**
The opinion of others will affect my intension to use a computer to assess my risk of falling.	*not likely* *very likely* **0 1 2 3 4 5 6 7**
CONSTRUCT 4 **Facilitating Condition** – the extent to which to which an individual believes that an infrastructure exists to support use of the system; this includes technical support, price, and organizational support. (Cimperman, 2013) The degree to which an innovation was perceived as being consistent with existing values, needs, and experiences of potential adopters. (Venkatesh, 2003)	
I believe the benefit of consistently accessing a physical therapist outweighs the cost of purchasing a computer or tablet.	*disagree* *strongly* *agree* **0 1 2 3 4 5 6 7**
I believe the benefit of consistently accessing a physical therapist	*disagree* *strongly* *agree* **0 1 2 3 4 5 6 7**

outweighs the cost of internet service in my home.	
I believe that technology advancements are important to meeting my healthcare needs.	*not useful* *very useful* **0 1 2 3 4 5 6 7**
I believe that any healthcare provider who uses a computer with their patients will also provide technical support to me.	*disagree* *strongly agree* **0 1 2 3 4 5 6 7**
CONSTRUCT 5 **Perceived Security** – the level to which transacting with the system was perceived as secure, enabling data integrity and reliability. (Cimperman, 2013)	
Telerehabilitation could increase the amount of one-on-one time with my physical therapist.	*not useful* *very useful* **0 1 2 3 4 5 6 7**
Telerehabilitation could enhance the security and confidentiality of my conversations with my physical therapist.	*not useful* *very useful* **0 1 2 3 4 5 6 7**
The internet can be secure if healthcare providers take the appropriate precautions.	*disagree* *strongly agree* **0 1 2 3 4 5 6 7**
Telerehabilitation could be a reliable method of accessing a physical therapist.	*not useful* *very useful* **0 1 2 3 4 5 6 7**
Computer use improves the accuracy of medical assessments.	*not useful* *very useful* **0 1 2 3 4 5 6 7**
CONSTRUCT 6 **Computer Anxiety** – a negative affective reaction toward computers such as an apprehension or fear of using computers. (Cimperman, 2013) / Self-efficacy – the belief that one has the capability to perform an action.(Cimperman, 2013)	

My computer anxiety will reduce once I get to know the telerehabilitation therapist.	*disagree* *strongly agree* **0 1 2 3 4 5 6 7**
Telerehabilitation was easy to learn once instructions are provided.	*disagree* *strongly agree* **0 1 2 3 4 5 6 7**
CONSTRUCT 7 **Physician's Opinion** – can be regarded as an expert power influence similar to the context of a manager/employee, salesperson/customer, or in the HJTS context, doctor/patient relationship. (Cimperman, 2013)	
My physician(s) *would* recommend telerehabilitation	*disagree* *strongly agree* **0 1 2 3 4 5 6 7**
My physician *should* recommend telerehabilitation	*disagree* *strongly agree* **0 1 2 3 4 5 6 7**
The opinion of my physician(s) would influence my intension to use a computer to access a physical therapist.	*disagree* *strongly agree* **0 1 2 3 4 5 6 7**
Overall, healthcare providers that I trust value technology advancements.	*disagree* *strongly agree* **0 1 2 3 4 5 6 7**

DRAFT

Appendix G: Participant Fall Risk Follow-up Letter

MIDWESTERN UNIVERSITY

COLLEGE OF HEALTH SCIENCES
PHYSICAL THERAPY PROGRAM
19555 N. 59th Avenue
Glendale, AZ 85308
Phone: 623/572-3920
Fax: 623/572-3929
www.midwestern.edu

Date:

Dear:

Thank-you for your participation in my research entitled: "The Use of Telehealth for Fall Risk Screening." Almost 3 million adults age 65+ are treated in the emergency room for fall-related injuries. My research goal is to greatly reduce this statistic!

Using outcomes from your balance and mobility tests as well as the information that you provided about your history of falls, I have quantified your individual fall risk with recommendations below. If you, your physician, or physical therapist would like to specifically reference the criteria that this study used, here is the *Centers for Disease Control and Prevention* (CDC) website for the STEADI Toolkit: https://www.cdc.gov/steadi/ .

Your risk of falling is *currently*:	**CDC Recommendations:**
☐ Low	1) Seek recommendations on Calcium / Vit D from a qualified health professional; 2) Participate in a group exercise program for strength & balance.
☐ Moderate	1) Review medications with your physician(s); 2) Seek recommendations on Calcium / Vit D from a qualified health professional; 3) Refer to PT to improve gait, strength, & balance –OR- participate in a group exercise program for strength & balance
☐ High	1) Seek a multifactorial risk assessment that includes review of medications, vision, strength, Blood Pressure, footwear, walking devices, etc; 2) Refer to PT to enhance mobility and improve strength, & balance; 3) Seek recommendations on Calcium / Vit D from a qualified health professional; 4) address needs from physical exam and optimize home safety.

The above information is meant to serve as a resource and provide educational information based upon how you presented on the day of research. Please note that the information gained about your individual fall risk is limited based upon the confines of the study parameters and was intended to screen, not diagnose. There are numerous factors that can contribute to a fall or fall-related fracture;

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www.midwestern.edu

therefore, it is suggested that you bring this form with you to your family physician or physical therapist, as a more complete assessment is recommended if you are listed as having "moderate" or "high" fall risk. Even if your risk level is "low," it is recommend that you have your fall risk reevaluated at least annually.

Once again, I thank-you for your time and participation! If you or your designated health professionals have any questions, I can be reached at 623-572-3927 or bnithman@midwestern.edu .

Yours in health,

Robert W. Nithman, PT, DPT, GCS, COS-C
PhD Candidate
Associate Professor, Doctor of Physical Therapy Program

Appendix H: Collective Comments from TR Survey Panel of Experts

Panelist	Review #1 comments	Review #2 comments
DB	N/A - Withdrew from panel	N/A - Withdrew from panel
KB (4)	Q1b: questioned need for specificity of “computer” use Q1c: suggested rephrase to emphasize the reader/use – help “me” Q1f: suggested change from “in having regular testing” to “by providing testing at regular intervals.” Q1g: suggested change form “useful” to “ easy to use.” Q2b: suggested change from “easy” to “simple enough.” Q2d: suggested change from “interaction with” to “use of.” Q2e: suggested change from “skillful” to “competent and successful.” Q5b: Commented that user should be told that the system was secure. Q5c: Commented that this question should parallel any changes to Q5b. Q5e: commented that older adults are used to F2F care. Q6a: Commented that “computer anxiety” could be substituted by “insecurity” or “apprehension.” Overall comment: “tried to look at this survey from the perspective of her family/friends.	Q1f: Suggested rephrase from “in having regular testing” to “by providing testing at regular intervals.” Q2b: Suggested change from “simple enough” to “simple for me.” Q2c: Suggested change from “Learning to use the TR equipment…” to “It was easy to learn to use the TR equipment.” Q2e: Suggested change from “skillful” to “competent.” Q3a: Suggested deletion of “How likely” and change from “the system” to “telerehabilitation.” Q4a: Suggested change from “I believe the benefit of consistently accessing” to “I believe having access.” Q4d: Suggest delete “any,” plural provider(s), and delete “who use a computer with their patients.” Q5f: Suggested to add this item (approved unanimously by all raters) Q6a: Suggested change from “My computer anxiety” to “Any apprehension or anxiety about computers.” Q6c: Suggested to add this item – “Greater access to a PT was a good reason to start using a computer. (approved unanimously by all raters)

SC (5)	Q1a: Commented about the use of “access” throughout the survey vs. “visit” or “seeing.” Suggested change to strongly disagree <–> strongly agree Likert scale for all items constructs 1 through 7. Constructs 1-2: Questioned how participants would know if TR equipment was useful, easy to use, etc. Q3a: Questioned about potential HIPAA violations with prospective end-users asking other people. Q3bcd: Change from “intension” to “intention.” Q4a: Commented about situational insurance coverage for PT services. Q4c: Questioned ‘what type of advancements?’ Q6b: Commented that this item sounds as though all participants will get was an instruction book. Q6c: Suggested to add this item – “I would prefer a class to teach me how to use the program/equipment (not approved by raters).	No comments or proposed edits.
MF (6)	Q1c: Commented that “falling” seemed too specific. Q1de: Commented that possible redundancy with these two items. Q1g: Suggested deletion of “equipment.” Suggested change to strongly disagree <–> strongly agree Likert scale for all items constructs 1 through 7 Q2e: Commented to correct text wrap issue with Likert scale.	No comments or proposed edits.

	Q3d: Questioned if this item was redundant with items Q3a,b,c. Q4d: Suggested change from “uses a computer with their patients” to “provides TR.” Q5e: Commented that the item was vague.	
GH (3)	Suggested change to strongly disagree <–> strongly agree Likert scale descriptions for all items constructs 1 through 7 Proposed need to place instructions at beginning of survey. Q3: Provided alternative phrasing if the decision was to use other Likert scale descriptors; for ex,” Rate the likelihood that the opinion of your friends will influence your intension to use a computer to access a physical therapist.”	No comments or proposed edits.
HM (1)	Made several comments and rankings that were in favor of telerehabilitation and technology advancements, but not suggested edits to items or Likert scale descriptions.	Made note of a typo in the description of the facilitating condition construct – “to which” was stated twice.
KS (2)	Q1e: Questioned if participants will know what was meant by “testing.” Q2c: Suggested rephrasing to “It was easy to learn to use the telerehabilitation equipment.” Q2d: Questioned how to quantify “clear and understandable.” Q3a: Suggested deletion of “how likely” in favor of a different Likert description.	Q6c: Suggested addition of this item – “My apprehension about computers will limit my use of this technology?” (motion not approved in favor of a different item)

	Q4: Commented that items might be a little lengthy for the survey. Q6a: Commented that developing an interpersonal relationship with a therapist was different than computer anxiety.	
JS (7)	Missed deadline for comment and proposal submissions.	Commented agreement with "strongly disagree" to "strongly agree" Likert scale description. Q1b: Questioned whether computer access meant video access. Q1ef: Commented that items were similar. Q1g: Commented about possible redundancy with Q1a. Q2e: Commented that this item might be redundant with other items in construct 2. Q3bcd: Corrected spelling of "intention." Q4c" Suggested change from "important to" to "important in." Q5a: Suggested moving this item to construct 1. Q5c: Questioned whether providers or the system was "set up with proper precautions" or leave as "if healthcare providers take appropriate precautions"? Q5e: Suggested edit from "improves" to "could improve." Q5f: Commented on redundancy with Q1b. Q6a: Suggested edit from "any" to "my." Q6: Suggested adding a 3rd item to this construct about technology experience. Q7a: Suggested edit of "would" to "may." Q7ab: Questioned redundancy of both items.

		Q7c: Corrected spelling of "intention." Q7d: Commented that this item was a "great comparison question for other constructs."

Appendix I: FINAL Version Telerehabilitation Survey Instrument (Pre-Test)

NAME:___________________________________ DOB:___________________________

The following pages contain a number of statements about the use of telerehabilitation. *Telerehabilitation* was defined as rehabilitation services delivered through the use of real-time audio and video telehealth technologies. Please rate how much you personally agree or disagree with these statements. Please circle the number that BEST reflects how YOU feel or think personally. Please answer ALL questions using the following scale:

(0) Strongly DISAGREE
(1)
(2)
(3)
(4)
(5)
(6)
(7) Strongly AGREE

1. Performance Expectancy / Perceived Usefulness	
Telerehabilitation could be a convenient way to access a physical therapist.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
Using a computer to access a physical therapist will be as good as seeing them face-to-face.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
Telerehabilitation could help me to better understand my risk of falling.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
Telerehabilitation will improve access to regular testing of my walking ability and balance.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
Using telerehabilitation equipment will make it easier to do regular testing.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**

Using telerehabilitation will save time by providing testing at regular intervals.	*Strongly Disagree* **0**	**1**	**2**	**3**	**4**	**5**	*Strongly Agree* **6**	**7**
I will find the telerehabilitation equipment useful in my regular testing.	*Strongly Disagree* **0**	**1**	**2**	**3**	**4**	**5**	*Strongly Agree* **6**	**7**
2. Effort Expectancy								
Use of a computer will improve communication with my physical therapist.	*Strongly Disagree* **0**	**1**	**2**	**3**	**4**	**5**	*Strongly Agree* **6**	**7**
Telerehabilitation equipment will be simple for me to use.	*Strongly Disagree* ***0***	***1***	***2***	***3***	***4***	***5***	*Strongly Agree* ***6***	***7***
It will be easy to learn to use the telerehabilitation equipment.	*Strongly Disagree* ***0***	***1***	***2***	***3***	***4***	***5***	*Strongly Agree* ***6***	***7***
My interaction with the telerehabilitation equipment will be clear and understandable.	*Strongly Disagree* **0**	**1**	**2**	**3**	**4**	**5**	*Strongly Agree* **6**	**7**
It will be easy for me to become competent at using the telerehabilitation equipment.	*Strongly Disagree* **0**	**1**	**2**	**3**	**4**	**5**	*Strongly Agree* **6**	**7**
3. Social Influence								
I would ask somebody I know who already uses telerehabilitation for opinion and recommendations.	*Strongly Disagree* **0**	**1**	**2**	**3**	**4**	**5**	*Strongly Agree* **6**	**7**
The opinion of my friends will influence my intention to use a computer to access a physical therapist.	*Strongly Disagree* **0**	**1**	**2**	**3**	**4**	**5**	*Strongly Agree* **6**	**7**
The opinion of my family will influence my intention to use a computer to access a physical therapist.	*Strongly Disagree* **0**	**1**	**2**	**3**	**4**	**5**	*Strongly Agree* **6**	**7**
The opinion of others will affect my intention to use a computer to assess my risk of falling.	*Strongly Disagree* **0**	**1**	**2**	**3**	**4**	**5**	*Strongly Agree* **6**	**7**
4. Facilitating Condition								

I believe having access to a physical therapist outweighs the cost of purchasing a computer or tablet.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
I believe the benefit of consistently accessing a physical therapist outweighs the cost of internet service in my home.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
I believe that technology advancements are important to meeting my healthcare needs.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
I believe that healthcare providers will also provide technical support to me.	*Strongly Disagree* *Strongly Agree* ***0 1 2 3 4 5 6 7***
5. Perceived Security	
Telerehabilitation could increase the amount of one-on-one time with my physical therapist.	*Strongly Disagree* *Strongly Agree* ***0 1 2 3 4 5 6 7***
Telerehabilitation could enhance the security and confidentiality of my conversations with my physical therapist.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
The internet can be secure if healthcare providers take the appropriate precautions.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
Telerehabilitation could be a reliable method of accessing a physical therapist.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
Computer use improves the accuracy of medical assessments.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
Computer use is as good as face-to-face medical assessments.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
6. Computer Anxiety	
Any apprehension or anxiety about computers will reduce once I get to know the telerehabilitation therapist.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**

Telerehabilitation will be easy to learn once instructions are provided.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
Greater access to a physical therapist is a good reason to start using a computer	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
7. Physician's Opinion	
My physician(s) *would* recommend telerehabilitation	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
My physician *should* recommend telerehabilitation	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
The opinion of my physician(s) would influence my intention to use a computer to access a physical therapist.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**
Overall, healthcare providers that I trust value technology advancements.	*Strongly Disagree* *Strongly Agree* **0 1 2 3 4 5 6 7**

Have you ever received or observed telehealth or telemedicine: ☐ yes ☐ no

*If yes, please explain:

____
____
____
____
____
____

Comments about Telehealth or Telerehabilitation:

____
____
____
____
____
____

Appendix J: Supplemental Correlation Data

Correlations

		[redacted]	STEADI Risk Category TH (1=HIGH risk 2=mod risk 3=low risk)	STEADI 2-tired risk TH (1=mod/high, 2=low)	STEADI Risk Category F2F (1=HIGH risk 2=mod risk 3=low risk)	STEADI 2-tired risk F2F (1=mod/high, 2=low)	RISK Stay Indep Questionairre (1=y, 2=n; 4 or more = risk)	FALL HISTORY (1=Y, 2=N)	12mo Fall History (1=Y, 2=N)	Prospective Falls 6-months (1=Y, 2=N)	Fracture History (1-yes) (2-no)	12mo Emergent Care (1=Y, 2=N)	Assistive Device (1-yes) (2-no)	Med Changes 6 mo (1-yes) (2-no)
Spearman's rho	STEADI Risk Category TH (1=HIGH risk 2=mod risk 3=low risk)	Correlation Coefficient	1.000	.866**	.981**	-.851**	.314	.432**	.380*	.279	.156	.245	.389*	.000
		Sig. (2-tailed)	.	.000	.000	.000	.051	.006	.017	.100	.344	.132	.014	1.000
		N	39	39	39	39	39	39	39	36	39	39	39	39
	STEADI 2-tired risk TH (1=mod/high, 2=low)	Correlation Coefficient	.866**	1.000	-.833**	.945**	.181	.332*	.146	.175	.090	.189	.225	.081
		Sig. (2-tailed)	.000	.	.000	.000	.269	.039	.374	.306	.587	.249	.169	.626
		N	39	39	39	39	39	39	39	36	39	39	39	39
	STEADI Risk Category F2F (1=HIGH risk 2=mod risk 3=low risk)	Correlation Coefficient	.981**	.833**	1.000	.882**	.339*	.404*	.341*	.292	.168	.255	.395*	.021
		Sig. (2-tailed)	.000	.000	.	.000	.035	.011	.033	.084	.308	.117	.013	.897
		N	39	39	39	39	39	39	39	36	39	39	39	39
	STEADI 2-tired risk F2F (1=mod/high, 2=low)	Correlation Coefficient	.851**	.945**	.882**	1.000	.233	.295	.097	.208	.115	.211	.248	.113
		Sig. (2-tailed)	.000	.000	.000	.	.153	.068	.558	.223	.484	.198	.128	.495
		N	39	39	39	39	39	39	39	36	39	39	39	39
	RISK Stay Indep Questionairre (1=y, 2=n; 4 or more = risk)	Correlation Coefficient	.314	.181	.339*	.233	1.000	.368*	.488**	.159	.114	.189	.495**	.041
		Sig. (2-tailed)	.051	.269	.035	.153	.	.021	.002	.355	.490	.250	.001	.805
		N	39	39	39	39	39	39	39	36	39	39	39	39
	FALL HISTORY (1=Y, 2=N)	Correlation Coefficient	.432**	.332*	.404*	.295	.368*	1.000	.668**	.385*	.298	.275	.298	.107
		Sig. (2-tailed)	.006	.039	.011	.068	.021	.	.000	.021	.065	.091	.065	.516
		N	39	39	39	39	39	39	39	36	39	39	39	39
	12mo Fall History (1=Y, 2=N)	Correlation Coefficient	.380*	.146	.341*	.097	.488**	.668**	1.000	.273	.190	.276	.319*	.024
		Sig. (2-tailed)	.017	.374	.033	.558	.002	.000	.	.108	.246	.089	.048	.887
		N	39	39	39	39	39	39	39	36	39	39	39	39
	Prospective Falls 6-months (1=Y, 2=N)	Correlation Coefficient	.279	.175	.292	.208	.159	.385*	.273	1.000	.009	.222	.322	.072
		Sig. (2-tailed)	.100	.306	.084	.223	.355	.021	.108	.	.960	.193	.055	.678
		N	36	36	36	36	36	36	36	36	36	36	36	36
	Fracture History (1-yes) (2-no)	Correlation Coefficient	.156	.090	.168	.115	.114	.298	.190	.009	1.000	.259	.101	.177
		Sig. (2-tailed)	.344	.587	.308	.484	.490	.065	.246	.960	.	.112	.541	.280
		N	39	39	39	39	39	39	39	36	39	39	39	39
	12mo Emergent Care (1=Y, 2=N)	Correlation Coefficient	.245	.189	.255	.211	.189	.275	.276	.222	.259	1.000	.259	.004
		Sig. (2-tailed)	.132	.249	.117	.198	.250	.091	.089	.193	.112	.	.112	.982
		N	39	39	39	39	39	39	39	36	39	39	39	39
	Assistive Device (1-yes) (2-no)	Correlation Coefficient	.389*	.225	.395*	.248	.495**	.298	.319*	.322	.101	.259	1.000	.105
		Sig. (2-tailed)	.014	.169	.013	.128	.001	.065	.048	.055	.541	.112	.	.525
		N	39	39	39	39	39	39	39	36	39	39	39	39
	Med Changes 6 mo (1-yes) (2-no)	Correlation Coefficient	.000	.081	.021	.113	.041	.107	.024	.072	.177	.004	.105	1.000
		Sig. (2-tailed)	1.000	.626	.897	.495	.805	.516	.887	.678	.280	.982	.525	.
		N	39	39	39	39	39	39	39	36	39	39	39	39

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

REFERENCES

1. National Center for Injury Prevention and Control. *Activity Report 2001 CDC's Unintentional Injury Prevention Program.* Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control;2002. http://stacks.cdc.gov/view/cdc/13425/cdc_13425_DS1.pdf.

2. Lee AC, Harada N. Telehealth as a means of health care delivery for physical therapist practice. *Phys Ther.* 2012;92(3):463-468.

3. Kekana M, Noe P, Mkhize B. The practice of telemedicine and challenges to the regulatory authorities. *S Afr J Bioeth Law.* 2010;3(1):33-37.

4. Louis AA, Turner T, Gretton M, Baksh A, Cleland JG. A systematic review of telemonitoring for the management of heart failure. *Eur J Heart Fail.* 2003;5(5):583-590.

5. Krupinski EA, Weinstein RS. Telemedicine in an academic center--the Arizona Telemedicine Program. *Telemed J E Health.* 2013;19(5):349-356.

6. Lee BR, Cadeddu JA, Stoianovici D, Kavoussi LR. Telemedicine and surgical robotics: urologic applications. *Rev Urol.* 1999;1(2):104-110.

7. Reese RM, Jamison R, Wendland M, et al. Evaluating interactive videoconferencing for assessing symptoms of autism. *Telemed J E Health.* 2013;19(9):671-677.

8. Kairy D, Lehoux P, Vincent C, Visintin M. A systematic review of clinical outcomes, clinical process, healthcare utilization and costs associated with telerehabilitation. *Disabil Rehabil.* 2009;31(6):427-447.

9. Mostyn A, Meade O, Lymn JS. Using audience response technology to provide formative feedback on pharmacology performance for non-medical prescribing students--a preliminary evaluation. *BMC Med Educ.* 2012;12:113.

10. Billings M, Elrod M, Greenfield B, et al. Are you ready for telehealth? Best lessons learned from models of care. Paper presented at: American Physical Therapy Association Combined Sections Meeting; January 21-24, 2013; San Diego, CA.

11. Shaw DK, Bierwas D, Nithman RW. Performing research in the real world; one group's home health experience. *Q Rep.* 2011;46(3):24-25.

12. Telemedicine frequently asked questions. American Telemedicine Association website. http://www.americantelemed.org/learn/what-is-telemedicine/faqs. Accessed April 25, 2013.

13. Stronge AJ, Rogers WA, Fisk AD. Human factors considerations in implementing telemedicine systems to accommodate older adults. *J Telemed Telecare.* 2007;13(1):1-3.

14. *WHO Global Report on Falls Prevention in Older Age.* Geneva, Switzerland: World Health Organization; 2007. http://www.who.int/ageing/publications/Falls_prevention7March.pdf. Accesed March 3, 2014.

15. Stevens J. The costs of fatal and non - fatal falls among older adults. *Inj Prev.* 2006;12(5):290-295.

16. Burns ER, Stevens JA, Lee R. The direct costs of fatal and non-fatal falls among older adults—United States. *J Safety Res.* 2016;58:99-103.

17. Englander F, Hodson TJ, Terregrossa RA. Economic dimensions of slip and fall injuries. *J Forensic Sci.* 1996;41(5):733-746.

18. Office of the Actuary - Centers for Medicare & Medicaid Services. Estimated financial effects of the “Patient Protection and Affordable Care Act of 2009,” as proposed by the

Senate Majority Leader [memorandum]. Baltimore, MD: Department of Health and Human Services; 2010:34 p.

19. PubMed Database. U.S. National Library of Medicine, National Institutes of Health

20. Centers for Disease Control. STEADI Toolkit for Healthcare Providers 2013; http://www.cdc.gov/homeandrecreationalsafety/Falls/steadi/index.html. Accessed March 16, 2014.

21. Finkelstein SM, Speedie SM, Potthoff S. Home telehealth improves clinical outcomes at lower cost for home healthcare. *Telemed J E Health.* Apr 2006;12(2):128-136.

22. De San Miguel K, Smith J, Lewin G. Telehealth remote monitoring for community-dwelling older adults with chronic obstructive pulmonary disease. *Telemed J E Health.* Sep 2013;19(9):652-657.

23. Bureau of Labor Statistics. Physical therapists. *Occupational Outlook Handbook. 2015-16 ed*. Washington, DC: US Department of Labor; 2015. http://www.bls.gov/ooh/Healthcare/Physical-therapists.htm. Accessed March 23, 2015.

24. ABC News. Church Attendance: Who Goes, How Often? 2002; http://abcnews.go.com/images/PollingUnit/875a2ChurchAttendance.pdf Accessed April 7, 2015.

25. Gellis ZD, Kenaley B, McGinty J, Bardelli E, Davitt J, Ten Have T. Outcomes of a telehealth intervention for homebound older adults with heart or chronic respiratory failure: a randomized controlled trial. *Gerontologist.* Aug 2012;52(4):541-552.

26. Baranowski T, Cullen KW, Nicklas T, Thompson D, Baranowski J. Are current health behavioral change models helpful in guiding prevention of weight gain efforts? *Obes Res.* Oct 2003;11 Suppl:23S-43S.

27. Evans WD. How social marketing works in health care. *British Medical Journal.* 2006;332(7551):1207–1210.

28. Qiu WQ, Dean M, Liu T, et al. Physical and mental health of homebound older adults: an overlooked population. *J Am Geriatr Soc.* Dec 2010;58(12):2423-2428.

29. Stalenhoef PA, Diederiks JPM, Knottnerus JA, Kester ADM, Crebolder HFJ. A risk model for the prediction of recurrent falls in community-dwelling elderly: a prospective cohort study. *J Clin Epidemiol.* 2002;55(11):1088-1094.

30. Russell TG, Buttrum P, Wootton R, Jull GA. Internet-based outpatient telerehabilitation for patients following total knee arthroplasty: a randomized controlled trial. *J Bone Joint Surg Am.* Jan 19 2011;93(2):113-120.

31. Robert W. Sandstrom, Helen Lohman, Bramble JD. *Health Services: Policy and Systems for Therapists.* 2nd ed. Upper Saddle River, NJ: Person Education, Inc; 2009.

32. Feasible [definition]. Cambridge Dictionaries Online website. http://dictionary.cambridge.org/us/dictionary/american-english/feasible. Accessed February 15, 2015.

33. Neufeld J, Case R. Walk-in telemental health clinics improve access and efficiency: a 2-year follow-up analysis. *Telemed J E Health.* 2013;19(12):938-941.

34. Hu PJ, Chau PY, Sheng ORL, Tam KY. Examining the technology acceptance model using physician acceptance of telemedicine technology. *J Manag Inf Syst.* 1999;16(2):91-112.

35. Avin KG, Hanke TA, Kirk-Sanchez N, et al. Management of falls in community-dwelling older adults: a clinical guidance statement from the Academy of Geriatric Physical

Therapy of the American Physical Therapy Association. *Phys Ther.* Jun 2015;95(6):815-834.
36. Centers for Disease Control. Important Facts About Falls. https://www.cdc.gov/homeandrecreationalsafety/falls/adultfalls.html. Accessed February 1, 2016.
37. Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice.* 3rd ed. Upper Saddle River, NJ: Pearson Prentice Hall; 2009.
38. Spagnuolo DL, Jurgensen SP, Iwama AM, Dourado VZ. Walking for the assessment of balance in healthy subjects older than 40 years. *Gerontology.* 2010;56(5):467-473.
39. Falls in nursing homes. Home & Recreational section of the Centers for Disease Control and Prevention website. 2013; http://www.cdc.gov/HomeandRecreationalSafety/Falls/nursing.html. Accessed March 31, 2013.
40. American Physical Therapy Association. PTNow: Tools to Advance Physical Therapist Practice. 2017; http://www.ptnow.org/Default.aspx. Accessed August 24, 2017.
41. Center for Rural Affairs. Healthcare in rural America [issue brief]. 2004:7 p. http://www.cfra.org/files/Health-Care-in-Rural-America.pdf. Accessed April 11, 2013.
42. Liddy C, Dusseault JJ, Dahrouge S, Hogg W, Lemelin J, Humbert J. Telehomecare for patients with multiple chronic illnesses: pilot study. *Can Fam Physician.* Jan 2008;54(1):58-65.
43. Pramuka M, van Roosmalen L. Telerehabilitation Technologies: Accessibility and Usability. *International Journal of Telerehabilitation.* Fall 09/04 2009;1(1):85-98.
44. Herr M, Latouche A, Ankri J. Homebound status increases death risk within two years in the elderly: results from a national longitudinal survey. *Arch Gerontol Geriatr.* 2013;56(1):258-264.
45. Vega S, Marciscano I, Holcomb M, et al. Testing a top-down strategy for establishing a sustainable telemedicine program in a developing country: the Arizona telemedicine program-US Army-Republic of Panama Initiative. *Telemed J E Health.* 2013;19(10):746-753.
46. Hilty DM, Ferrer DC, Parish MB, Johnston B, Callahan EJ, Yellowlees PM. The effectiveness of telemental health: a 2013 review. *Telemed J E Health.* 2013;19(6):444-454.
47. Locatis C, Ackerman M. Three principles for determining the relevancy of store-and-forward and live interactive telemedicine: reinterpreting two telemedicine research reviews and other research. *Telemed J E Health.* Jan 2013;19(1):19-23.
48. Turvey C, Coleman M, Dennison O, et al. ATA practice guidelines for video-based online mental health services. *Telemed J E Health.* 2013;19(9):722-730.
49. Shahid K, Kolomeyer AM, Nayak NV, et al. Ocular telehealth screenings in an urban community. *Telemed J E Health.* 2012;18(2):95-100.
50. Loehne HB. Telehealth for integumentary health. Paper presented at: Telehealth: The Next Generation of Healthcare...No Limits; March 25-26, 2010; Lake Oconee, GA.
51. Dehghan Nayeri N, Asadi Noghabi AA, Molaee S. The effect of telephone consultation on the quality of life of patients receiving interferon therapy: a quasi-experimental study. *Telemed J E Health.* Jul-Aug 2012;18(6):459-463.
52. Seibert PS, Whitmore TA, Patterson C, et al. Telemedicine facilitates CHF home health care for those with systolic dysfunction. *Int J Telemed Appl.* 2008:235031.

53. Khan SA, Omar H. Teledentistry in practice: literature review. *Telemed J E Health.* 2013;19(7):565-567.
54. Cimperman M, Brencic MM, Trkman P, Stanonik Mde L. Older adults' perceptions of home telehealth services. *Telemed J E Health.* Oct 2013;19(10):786-790.
55. Telemedicine in the Patient Protection and Affordable Care Act (2010). American Telemedicine Association website. http://www.americantelemed.org/docs/default-source/policy/telehealth-provisions-within-the-patient-protection-and-affordable-care-act.pdf?sfvrsn=14. Accessed January 14, 2013.
56. Accountable Care Organizations (ACO). Centers for Medicare & Medicaid Services website. http://www.cms.gov/ACO. Updated January 6, 2015. Accessed February 16, 2015.
57. (APTA) APTA. 2009; http://www.apta.org/. Accessed September, 2009.
58. Centers for Medicare & Medicid Services. Telehealth Services *Rural Health Fact Sheet Series* 2012(Dec):6 p. https://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNProducts/downloads/TelehealthSrvcsfctsht.pdf. Accessed July 11, 2017.
59. American Physical Therapy Association. APTA's Telehealth Position Statement. 2012. http://www.apta.org/uploadedFiles/APTAorg/About_Us/Policies/Practice/Telehealth.pdf#search=%22Telehealth%22. Accessed June 27, 2013.
60. American Physical Therapy Association. The Guide to Physical Therapist Practice 3.0. Alexandria, VA: American Physical Therapy Association; 2014: http://guidetoptpractice.apta.org/. Accessed July 1, 2017.
61. Hub RHI. 2016; https://www.ruralhealthinfo.org/states/united-states. Accessed July 13, 2017.
62. Kaiser Family Foundation. Trends in Health Care Costs and Spending [March 2009, Publication #7692-02]. https://kaiserfamilyfoundation.files.wordpress.com/2013/01/7692_02.pdf Accessed February 14, 2014.
63. Wang F, Luo W. Assessing spatial and nonspatial factors for healthcare access: towards an integrated approach to defining health professional shortage areas. *Health Place.* Jun 2005;11(2):131-146.
64. Harada N, Chiu V, Damron-Rodriguez J, Fowler E, Siu A, Reuben DB. Screening for balance and mobility impairment in elderly individuals living in residential care facilities. *Phys Ther.* Jun 1995;75(6):462-469.
65. Panzer VP, Wakefield DB, Hall CB, Wolfson LI. Mobility assessment: sensitivity and specificity of measurement sets in older adults. *Arch Phys Med Rehabil.* Jun 2011;92(6):905-912.
66. Bynum AB, Cranford CO, Irwin CA, Denny GS. Participant satisfaction in an adult telehealth education program using interactive compressed video delivery methods in rural Arkansas. *J Rural Health.* Summer 2003;19(3):218-222.
67. Shaw D, Nithman RW, Bierwas D. Real-Time Telerehabilitation as an Adjunct to Physical Therapy Following Total Knee Replacement. Paper presented at: American Physical Therapy Association. Combined Sections Meeting; February 8-11, 2012; Chicago, IL.

68. Russell TG, Buttrum P, Wootton R, Jull GA. Low-bandwidth telerehabilitation for patients who have undergone total knee replacement: preliminary results. *J Telemed Telecare.* 2003;9 Suppl 2:S44-S47.
69. What are the reimbursement issues for telehealth? Health Resources and Services Administration website. http://www.hrsa.gov/healthit/toolbox/RuralHealthITtoolbox/Telehealth/whatarethereimbursement.html. Accessed June 12, 2013.
70. Library of Congress. Telehealth legislation in Thomas [online database]. Accessed April 1, 2013. Washington, DC: Library of Congress.
71. American Physical Therapy Association. APTA Guide for Professional Conduct. 2010:6 p. http://www.apta.org/.../APTAorg/.../Ethics/GuideforProfessionalConduct.pdf. Accessed June 26, 2013.
72. Selwyn N, Gorard S, Furlong J, Madden L. Older adults' use of information and communications technology in everyday life. *Ageing Soc.* 2003;23(5):561-582.
73. Van Volkom M, Stapley JC, Malter J. Use and perception of technology: sex and generational differences in a community sample. *Educ Gerontol.* 2013;39(10):729-740.
74. Olson K, O'Brien M, Rogers W, Charness N. Diffusion of technology: frequency of use for younger and older adults. *Ageing Int.* 2011;36(1):123-145.
75. Kahana E, Kahana B, Kercher K. Emerging lifestyles and proactive options for successful ageing. *Ageing Int.* 2003;28(2):155-180.
76. Cimperman M, Brenčič MM, Trkman P, Stanonik MdL. Older adults' perceptions of home telehealth services. *Telemed J E Health.* 2013;19(10):786-790.
77. Bürmann Genannt Siggemann C, Mensing M, Classen T, Hornberg C, Terschüren C. Specific health status has an impact on the willingness to use telemonitoring: data from a 2009 health survey in North Rhine-Westphalia, Germany. *Telemed J E Health.* Sep 2013;19(9):692-698.
78. Scott V, Votova K, Scanlan A, Close J. Multifactorial and functional mobility assessment tools for fall risk among older adults in community, home-support, long-term and acute care settings. *Age Ageing.* Mar 2007;36(2):130-139.
79. Panel on Prevention of Falls in Older Persons - American Geriatrics Society and British Geriatrics Society. Summary of the Updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons. *J Am Geriatr Soc.* Jan 2011;59(1):148-157.
80. Shaw DK. Overview of telehealth and its application to cardiopulmonary physical therapy. *Cardiopulm Phys Ther J.* Jun 2009;20(2):13-18.
81. Russell TG. Physical rehabilitation using telemedicine. *J Telemed Telecare.* 2007;13(5):217-220.
82. Hoffmann T, Russell T, Thompson L, Vincent A, Nelson M. Using the Internet to assess activities of daily living and hand function in people with Parkinson's disease. *NeuroRehabilitation.* 2008;23(3):253-261.
83. Venkatesh V. Determinants of perceived ease of use: integrating control, intrinsic motivation, and emotion into the Technology Acceptance Model. *Inf Syst Res.* 2000;11(4):342-365.
84. Kang HG, Mahoney DF, Hoenig H, et al. In situ monitoring of health in older adults: technologies and issues. *J Am Geriatr Soc.* Aug 2010;58(8):1579-1586.

85. Girard P. Military and VA telemedicine systems for patients with traumatic brain injury. *J Rehabil Res Dev.* 2007;44(7):1017-1026.
86. Reisman AB, Stevens DL. *Telephone Medicine: A Guide for the Practicing Physician.* Philadelphia, PA: American College of Physicians; 2002.
87. Genentech Inc. Telestroke Centers. 2013; http://www.activase.com/telestroke/stroke-centers.jsp. Accessed May 31, 2013.
88. Shaw DK. Telemedicine and cardiopulmonary rehabilitation: where do we stand? *J Cardiopulmonary Reahabil.* Jan-Feb 1999;19(1):59-60.
89. Keehan SP, Lazenby HC, Zezza MA, Catlin AC. Age estimates in the National Health Accounts [web exclusive]. *Health Care Financ Rev.* 2004;1(1):1-16.
90. Telehealth: just a call away [Executive Summary]. *Inf Edge.* 2005;11(3):1-8. http://integrisok.com/upload/docs/Telehealth/telehealthscottsdaleinstituteApril05final.pdf . Accessed April 27, 2013.
91. Committee on the Quality of Health Care in America of the Institute of Medicine. Crossing the quality chasm: a new health system for the 21st century [report brief]. 2000. http://iom.nationalacademies.org/~/media/Files/Report%20Files/2001/Crossing-the-Quality-Chasm/Quality%20Chasm%202001%20%20report%20brief.pdf
92. Yu TH-K, Wang DH-M, Wu K-L. Reexamining the red herring effect on healthcare expenditures. *J Bus Res.* 2015;68(4):783-787.
93. Peel NM, Russell TG, Gray LC. Feasibility of using an in-home video conferencing system in geriatric rehabilitation. *J Rehabil Med.* Mar 2011;43(4):364-366.
94. Young R, Willis E, Cameron G, Geana M. "Willing but unwilling": attitudinal barriers to adoption of home-based health information technology among older adults. *Health Informatics J.* Jun 2014;20(2):127-135.
95. Chang IC, Hsu H-M. Predicting medical staff intention to use an online reporting system with modified unified theory of acceptance and use of technology. *Telemed J E Health.* 2012;18(1):67-73.
96. Duyck P, Pynoo B, Devolder P, Voet T, Adang L, Vercruysse J. User acceptance of a picture archiving and communication system. Applying the unified theory of acceptance and use of technology in a radiological setting. *Methods Inf Med.* 2008;47(2):149-156.
97. Davis FD, Jr. *A Technology Acceptance Model for Empirically Testing New End-User Information Systems: Theory and Results* [PhD dissertation]. Cambridge, MA: Sloan School of Management, Massachusetts Institute of Technology; 1985.
98. Heinz M, Martin P, Margrett JA, et al. Perceptions of technology among older adults. *J Gerontol Nurs.* Jan 2013;39(1):42-51.
99. Demiris G, Rantz M, Aud M, et al. Older adults' attitudes towards and perceptions of "smart home" technologies: a pilot study. *Med Inform Internet Med.* Jun 2004;29(2):87-94.
100. Bendixen RM, Levy CE, Olive ES, Kobb RF, Mann WC. Cost effectiveness of a telerehabilitation program to support chronically ill and disabled elders in their homes. *Telemed J E Health.* 2009;15(1):31-38.
101. Switzer JA, Demaerschalk BM, Xie J, Fan L, Villa KF, Wu EQ. Cost-effectiveness of hub-and-spoke telestroke networks for the management of acute ischemic stroke from the hospitals' perspectives. *Circ Cardiovasc Qual Outcomes.* 2013;6(1):18-26.

102. Jen WY, Hung MC. An empirical study of adopting mobile healthcare service: the family's perspective on the healthcare needs of their elderly members. *Telemed J E Health.* Jan-Feb 2010;16(1):41-48.

103. Muncert ES, Bickford SA, Guzic BL, Demuth BR, Bapat AR, Roberts JB. Enhancing the quality of life and preserving independence for target needs populations through integration of assistive technology devices. *Telemed J E Health.* Jul-Aug 2011;17(6):478-483.

104. Chou C-C, Chang C-P, Lee T-T, Chou H-F, Mills ME. Technology acceptance and quality of life of the elderly in a telecare program. *Comput Inform Nurs.* Jul 2013;31(7):335-342.

105. Doherty ST, Oh P. A multi-sensor monitoring system of human physiology and daily activities. *Telemed J E Health.* 2012;18(3):185-192.

106. Courtney KL, Demiris G, Rantz M, Skubic M. Needing smart home technologies: the perspectives of older adults in continuing care retirement communities. *Informatics in primary care.* 2008;16(3):195-201.

107. Xie B. Effects of an eHealth literacy intervention for older adults. *J Med Internet Res.* 2011;13(4):e90.

108. Courtney KL. Privacy and senior willingness to adopt smart home information technology in residential care facilities. *Methods Inf Med.* 2008;47(1):76-81.

109. Carpenter BD, Buday S. Computer use among older adults in a naturally occurring retirement community. *Computers in Human Behavior.* 2007/11/01/ 2007;23(6):3012-3024.

110. Anderson A, Perrin A. Tech Adoption Climbs Among Older Adults. 2017. http://www.pewinternet.org/2017/05/17/tech-adoption-climbs-among-older-adults/. Accessed January 15, 2018.

111. Or CKL, Karsh B-T, Severtson DJ, Burke LJ, Brown RL, Brennan PF. Factors affecting home care patients' acceptance of a web-based interactive self-management technology. *J Am Med Inform Assoc.* Jan-Feb 2011;18(1):51-59.

112. Joe J, Chaudhuri S, Chung J, Thompson H, Demiris G. Older adults' attitudes and preferences regarding a multifunctional wellness tool: a pilot study. *Inform Health Soc Care.* Oct 17 2014:1-16.

113. Chutter M. Overview of the technology acceptance model: origins, developments and future directions. *Sprouts Work Pap Inf Syst.* 2009;9(37):9-37.

114. Theory of reasoned action. Wikipedia website. http://en.wikipedia.org/wiki/Theory_of_reasoned_action. Accessed February 28, 2015.

115. Wade R, Cartwright C, Shaw K. Factors relating to home telehealth acceptance and usage compliance. *Risk Manag Healthc Policy.* 2012;5:25-33.

116. Porter CE, Donthu N. Using the technology acceptance model to explain how attitudes determine Internet usage: the role of perceived access barriers and demographics. *J Bus Res.* 9// 2006;59(9):999-1007.

117. Holden RJ, Karsh B-T. The technology acceptance model: its past and its future in health care. *J Biomed Inform.* 07/15 2010;43(1):159-172.

118. Venkatesh V, Morris MG, Davis GB, Davis FD. User acceptance of information technology: toward a unified view. *MIS Q.* Sep 2003;27(3):425-478.

119. Peek ST, Wouters EJ, van Hoof J, Luijkx KG, Boeije HR, Vrijhoef HJ. Factors influencing acceptance of technology for aging in place: a systematic review. *Int J Med Inform.* Apr 2014;83(4):235-248.
120. Coughlin J, D'Ambrosio LA, Reimer B, Pratt MR. Older adult perceptions of smart home technologies: implications for research, policy & market innovations in healthcare. *Conf Proc IEEE Eng Med Biol Soc.* 2007;2007:1810-1815.
121. Hawley-Hague H, Boulton E, Hall A, Pfeiffer K, Todd C. Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: a systematic review. *Int J Med Inform.* Jun 2014;83(6):416-426.
122. Arnaert A, Klooster J, Chow V. Attitudes toward videotelephones: an exploratory study of older adults with depression. *J Gerontol Nurs.* Sep 2007;33(9):5-13.
123. Bonder BR, Dal Bello-Haas V. *Functional Performance in Older Adults.* 3rd ed. Philadelphia, PA: F.A. Davis; 2009.
124. Timed Up and Go Dual Task; Timed Up and Go (Cognitive); Timed Up and Go (Motor); Timed Upa and Go (Manual). Rehabilitation Measures Database. [online database]. 2014; https://www.sralab.org/rehabilitation-measures/timed-and-go. Accessed January 15, 2018.
125. Siggeirsdóttir K, Jónsson BY, Jónsson H, Iwarsson S. The timed 'Up & Go' is dependent on chair type. *Clinical Rehabilitation.* 2002;16(6):609-616.
126. Franchignoni F, Horak F, Godi M, Nardone A, Giordano A. Using psychometric techniques to improve the Balance Evaluation Systems Test: the mini-BESTest. *J Rehabil Med.* Apr 2010;42(4):323-331.
127. Padgett PK, Jacobs JV, Kasser SL. Is the BESTest at its best? A suggested brief version based on interrater reliability, validity, internal consistency, and theoretical construct. *Phys Ther.* Sep 2012;92(9):1197-1207.
128. Leddy AL, Crowner BE, Earhart GM. Utility of the Mini-BESTest, BESTest, and BESTest sections for balance assessments in individuals wth Parkinson dsease. *J Neurol Phys Ther.* 2011;35(2):90-97.
129. King L, Horak F. On the mini-BESTest: scoring and the reporting of total scores. *Phys Ther.* Apr 2013;93(4):571-575.
130. O'Hoski S, Winship B, Herridge L, et al. Increasing the clinical utility of the BESTest, mini-BESTest, and brief-BESTest: normative values in Canadian adults who are healthy and aged 50 years or older. *Phys Ther.* Mar 2014;94(3):334-342.
131. Padgett PK, Jacobs JV, Kasser SL. Is the BESTest at its best? A suggested brief version based on interrater reliability, validity, internal consistency, and theoretical construct. *Phys Ther.* 2012;92(9):1197-1207.
132. Duncan RP, Leddy AL, Cavanaugh JT, et al. Comparative utility of the BESTest, mini-BESTest, and brief-BESTest for predicting falls in individuals with Parkinson disease: a cohort study. *Phys Ther.* Apr 2013;93(4):542-550.
133. Choe CY, Chien CW, Hsueh IP, Sheu CF, Wang CH, Hsieh CL. Developing a short form of the Berg Balance Scale for people with stroke. *Phys Ther.* 2006;86(2):195-204.
134. Muir S, Berg K, Chesney B, Speechley M. Use of the Berg Balance Scale for predicting multiple falls in community-dwelling elderly people: a prospective study. *Phys Ther.* Apr 2008;88(4):449-459.

135. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. *Phys Ther.* Sep 2000;80(9):896-903.

136. Conradsson M, Lundin-Olsson L, Lindelof N, et al. Berg Balance Scale: intrarater test-retest reliability among older people dependent in activities of daily living and living in residential care facilities. *Phys Ther.* Sep 2007;87(9):1155-1163.

137. Mao HF, Hsueh IP, Tang PF, Sheu CF, Hsieh CL. Analysis and comparison of the psychometric properties of three balance measures for stroke patients. *Stoke.* Apr 2002;33(4):1022-1027.

138. Romero S, Bishop MD, Velozo CA, Light K. Minimum detectable change of the Berg Balance Scale and Dynamic Gait Index in older persons at risk for falling. *J Geriatric Physical Therapy.* Jul-Sep 2011;34(3):131-137.

139. Meeks S. Use of Tinetti POMA (and Berg) [web blog]. *geriatricspt@yahoogroups.com.* 2013 July 31.

140. Sharkey JR, Giuliani C, Haines PS, Branch LG, Busby-Whitehead J, Zohoori N. Summary measure of dietary musculoskeletal nutrient (calcium, vitamin D, magnesium, and phosphorus) intakes is associated with lower-extremity physical performance in homebound elderly men and women. *Am J Clin Nutr.* 2003;77(4):847-856.

141. Clinical Test of Sensory Interaction and Balance; Modified Clinical Test of Sensory Interaction and Balance. Rehabilitation Measures Database. [online database]. 2013; https://www.sralab.org/rehabilitation-measures/sensory-organization-test. Accessed January 17, 2018.

142. Cascardi KA. *The Relationship of Vestibulo-Ocular Reflex (VOR) Function to Falling in the Past Year Among Physically Active Community-Dwelling Adults 75 Years and Older* [PhD dissertation]. Cypress, CA, Trident University International; 2008.

143. Anacker SL, Di Fabio RP. Influence of Sensory Inputs on Standing Balance in Community-Dwelling Elders with a Recent History of Falling. *Phys Ther.* 1992;72(8):575-581.

144. Whitney SL, Hudak MT, Marchetti GF. The Dynamic Gait Index relates to self-reported fall history in individuals with vestibular dysfunction. *J Vestib Res.* 2000;10(2):99-105.

145. Marchetti G, Whitney S, Blatt P, Morris LO, Vance JM. Temporal and spatial characteristics of gait during performance of the Dynamic Gait Index in people with and people without balance or vestibular disorders. *Phys Ther.* May 2008;88(5):640-651.

146. Russell TG, Buttrum P, Wootton R, Jull GA. Internet-based outpatient telerehabilitation for patients following total knee arthroplasty: a randomized controlled trial. *J Bone Joint Surg Am.* 2011;93-A(2):113-120.

147. Weiner DK, Duncan PW, Chandler J, Studenski SA. Functional reach: a marker of physical frailty. *J Am Geriatr Soc.* Mar 1992;40(3):203-207.

148. Functional Reach Test / Modified Functional Reach Test. Rehabilitation Measures Database. [online database]. 2013; https://www.sralab.org/rehabilitation-measures/functional-reach-test-modified-functional-reach-test. Accessed January 17, 2018.

149. Thomas JI, Lane JV. A pilot study to explore the predictive validity of 4 measures of falls risk in frail elderly patients. *Arch Phys Med Rehabil.* 2005;86(8):1636-1640.

150. Middleton A, Fritz SL, Lusardi M. Walking speed: the functional vital sign. *J Aging Phys Act.* Apr 2015;23(2):314-322.

151. Fritz S, Lusardi M. White paper: "Walking speed: the sixth vital sign". *J Geriatr Phys Ther.* 2009;32(2):46-49.
152. Nithman RW. Gait speed: an interprofessional tool to guide prognosis and referral. *Ariz Geriatr Soc J.* 2015;20(1):3-6.
153. Or CK, Karsh B-T. A systematic review of patient acceptance of consumer health information technology. *J Am Med Inform Assoc.* 2009;16(4):550-560.
154. Tinetti Performance Oriented Mobility Assessment. Rehabilitation Measures Database [onlne database]. 2013; https://www.sralab.org/rehabilitation-measures/tinetti-performance-oriented-mobility-assessment. Accessed November 17, 2015.
155. Faber MJ, Bosscher RJ, van Wieringen PC. Clinimetric properties of the performance-oriented mobility assessment. *Phys Ther.* Jul 2006;86(7):944-954.
156. Sterke CS, Huisman SL, van Beeck EF, Looman CW, van der Cammen TJ. Is the Tinetti Performance Oriented Mobility Assessment (POMA) a feasible and valid predictor of short-term fall risk in nursing home residents with dementia? *Int Psychogeriatr.* 2010;22(2):254.
157. Pardasaney PK, Latham NK, Jette AM, et al. Sensitivity to change and responsiveness of four balance measures for community-dwelling older adults. *Phys Ther.* 2012;92(3):388-397.
158. Ward RE, Leveille SG, Beauchamp MK, et al. Functional performance as a predictor of injurious falls in older adults. *J Am Geriatr Soc.* Feb 2015;63(2):315-320.
159. Stookey AD, Katzel LI, Steinbrenner G, Shaughnessy M, Ivey FM. The short physical performance battery as a predictor of functional capacity after stroke. *J Stroke Cerebrovasc Dis.* Jan 2014;23(1):130-135.
160. Puthoff ML. Outcome measures in cardiopulmonary physical therapy: short physical performance battery. *Cardiopulm Phys Ther J.* 2008;19(1):17-22.
161. da Câmara SMA, Alvarado BE, Guralnik JM, Guerra RO, Maciel ÁCC. Using the Short Physical Performance Battery to screen for frailty in young-old adults with distinct socioeconomic conditions. *Geriatr Gerontol Int.* 2013;13(2):421-428.
162. 30 Second Sit to Stand. Rehabiltation Measures Database. [online database]. 2013; http://www.rehabmeasures.org/Lists/RehabMeasures/DispForm.aspx?ID=1122. Accessed November 17, 2015.
163. Moreland JD, Richardson JA, Goldsmith CH, Clase CM. Muscle weakness and falls in older adults: a systematic review and meta-analysis. *J Am Geriatr Soc.* Jul 2004;52(7):1121-1129.
164. Herman T, Giladi N, Hausdorff JM. Properties of the 'timed up and go' test: more than meets the eye. *Gerontology.* 2011;57(3):203-210.
165. Arnold CM, Faulkner RA. The history of falls and the association of the timed up and go test to falls and near-falls in older adults with hip osteoarthritis. *BMC Geriatr.* Jul 4 2007;7:17.
166. Russell TG, Hoffmann TC, Nelson M, Thompson L, Vincent A. Internet-based physical assessment of people with Parkinson disease is accurate and reliable: a pilot study. *J Rehabil Res Dev.* 2013;50(5):643-650.
167. Stevens JA, Phelan EA. Development of STEADI. *Health Promotion Practice.* 2013;14(5):706-714.
168. American Geriatrics Society, Society BG. AGS/BGS Clinical Practice Guideline: Prevention of Falls in Older Persons. American Geriatrics Society New York, NY; 2010.

169. Census Bureau. An aging nation: the older population in the United States. https://www.census.gov/prod/2014pubs/p25-1140.pdf. Accessed October 12, 2014.
170. Renfro M. Preventing Falls Concentrated Education Series. APTA Annual Conference 2012.
171. Rydwik E BA, Forsen L, Frandin K. Psychometric properties of Timed Up and Go in elderly people: a systematic review. *Phys Occup Ther Geriatr*. 2011;29(2):102-125.
172. 10 meter walk test. Rehabilitation Measures Database. [online database]. 2014; https://www.sralab.org/rehabilitation-measures/10-meter-walk-test. Accessed November 17, 2015.
173. Trochim WMK, Donnelly JP. *The Research Methods Knowledge Base.* 3rd ed. Mason, OH: CENGAGE Learning; 2008.
174. Heinrich-Heine-Universität Düsseldorf. G*Power 3 [software program]. 2012; http://www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3/. Accessed September 26, 2013.
175. Hicks LL, Boles KE, Hudson S, et al. Patient satisfaction with teledermatology services. *J Telemed Telecare.* 2003;9(1):42-45.
176. Kairy D, Tousignant M, Leclerc N, Cote AM, Levasseur M, Researchers TT. The patient's perspective of in-home telerehabilitation physiotherapy services following total knee arthroplasty. *Int J Environ Res Public Health.* Sep 2013;10(9):3998-4011.
177. Tousignant M, Boissy P, Moffet H, et al. Patients' satisfaction of healthcare services and perception with in-home telerehabilitation and physiotherapists' satisfaction toward technology for post-knee arthroplasty: an embedded study in a randomized trial. *Telemed J E Health.* Jun 2011;17(5):376-382.
178. Harada ND, Dhanani S, Elrod M, Hahn T, Kleinman L, Fang M. Feasibility study of home telerehabilitation for physically inactive veterans. *J Rehabil Res Dev.* 2010;47(5):465-475.
179. Lawshe CH. A quantitative approach to content validity. *Personnel psychology.* 1975;28(4):563-575.
180. Tinetti ME, Williams TF, Mayewski R. Fall risk index for elderly patients based on number of chronic disabilities. *Am J Med.* 1986;80(3):429-434.
181. Geriatric Examination Tool Kit. http://geriatrictoolkit.missouri.edu/. Accessed April 1, 2013.
182. Whitney JC, Lord SR, Close JCT. Streamlining assessment and intervention in a falls clinic using the Timed Up and Go Test and Physiological Profile Assessments. *Age Ageing.* 2005;34(6):567-571.
183. Viccaro LJ, Perera S, Studenski SA. Is Timed Up and Go better than gait speed in predicting health, function, and falls in older adults? *J Am Geriatr Soc.* 03/15 2011;59(5):887-892.
184. Rikli RE, Jones CJ. Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years. *Gerontologist.* Apr 2013;53(2):255-267.
185. Hausdorff JM, Rios DA, Edelber HK. Gait variability and fall risk in community-living older adults: a 1-year prospective study. *Arch Phys Med Rehabil.* Aug 2001;82(8):1050-1056.

186. Hornbrook MC, Stevens VJ, Wingfield DJ, Hollis JF, Greenlick MR, Ory MG. Preventing falls among community-dwelling older persons: results from a randomized trial. *Gerontologist.* Feb 1994;34(1):16-23.
187. Lewis CB, Kellems S. *The Prevention and Wellness Tool Kit.* Akron, OH: GREAT Seminars and Books, Inc.; 2007.
188. Viera AJ, Garrett JM. Understanding interobserver agreement: the kappa statistic. *Fam Med.* 2005;37(5):360-363.
189. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *New England journal of medicine.* 1988;319(26):1701-1707.
190. Montana Geriatric Education Center. Fall Prevention for Community-Dwelling Older Adults,. http://health.umt.edu/mtgec/documents/Fall%20Prevention%202014%20IPHARM.pdf; 2014; University of Montana.
191. Russell TG, Gillespie N, Hartley N, Theodoros D, Hill A, Gray L. Exploring the predictors of home telehealth uptake by elderly Australian healthcare consumers. *J Telemed Telecare.* Dec 2015;21(8):485-489.
192. Chumbler NR, Rose DK, Griffiths P, et al. Study protocol: home-based telehealth stroke care: a randomized trial for veterans. *Trials.* Jun 30 2010;11:74.
193. Chumbler NR, Li X, Quigley P, et al. A randomized controlled trial on Stroke telerehabilitation: The effects on falls self-efficacy and satisfaction with care. *J Telemed Telecare.* Apr 2015;21(3):139-143.
194. Russell TG, Buttrum P, Wootton R, Jull GA. Rehabilitation after total knee replacement via low-bandwidth telemedicine: the patient and therapist experience. *J Telemed Telecare.* 2004;10 Suppl 1:85-87.
195. Truter P, Russell T, Fary R. The validity of physical therapy assessment of low back pain via telerehabilitation in a clinical setting. *Telemed J E Health.* Feb 2014;20(2):161-167.
196. Russell TG, Hoffmann TC, Nelson M, Thompson L, Vincent A. Internet-based physical assessment of people with Parkinson disease is accurate and reliable: a pilot study. *J Rehabil Res Dev.* 2013;50(5):643-650.
197. Wolf SL, Catlin PA, Gage K, Gurucharri K, Robertson R, Stephen K. Establishing the reliability and validity of measurements of walking time using the Emory Functional Ambulation Profile. *Phys Ther.* Dec 1999;79(12):1122-1133.
198. Single Leg Stance. Rehabilitation Measures Database. [online database]. 2013; https://www.sralab.org/rehabilitation-measures/single-leg-stance-or-one-legged-stance-test. Accessed November 17, 2015.
199. Franchignoni F, Tesio L, Martino MT, Ricupero C. Reliability of four simple, quantitative tests of balance and mobility in healthy elderly females. *Aging (Milano).* Feb 1998;10(1):26-31.
200. Romberg Test (narrow stance). Rehabilitation Measures Database. [online database]. 2013; https://www.sralab.org/rehabilitation-measures/romberg-test. Accessed December 29, 2016.
201. Sharpened Romberg (Tandem Stance) . Rehabilitation Measures Database. [online database]. 2013; https://www.sralab.org/rehabilitation-measures/sharpened-romberg. Accessed December 29, 2016.
202. Smithson F, Morris ME, Iansek R. Performance on clinical tests of balance in Parkinson's disease. *Phys Ther.* Jun 1998;78(6):577-592.

203. Chan ACM, Pang MYC. Assessing Balance Function in Patients With Total Knee Arthroplasty. *Phys Ther.* 2015;95(10):1397-1407.
204. Mini Balance Evaluation Systems Test. Rehabilitation Measures Database. [online database]. 2014; https://www.sralab.org/rehabilitation-measures/mini-balance-evaluation-systems-test. Accessed December 18, 2016.
205. Federation State Boards of Physical Therapy. Physical Therapy Licensure Compact. http://www.fsbpt.org/FreeResources/PhysicalTherapyLicensurecompact.aspx. Accessed July 1, 2017.
206. Cohen J. *Statistical power analysis for the behavioral sciences.* Vol 2nd ed. . Hillsdale, NJ: Erlbaum; 1988.
207. Claes V, Devriendt E, Tournoy J, Milisen K. Attitudes and perceptions of adults of 60 years and older towards in-home monitoring of the activities of daily living with contactless sensors: an explorative study. *Int J Nurs Stud.* Jan 2015;52(1):134-148.
208. Grindrod KA, Li M, Gates A. Evaluating user perceptions of mobile medication management applications with older adults: a usability study. *JMIR mHealth and uHealth.* 2014;2(1):e11.