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Effectiveness of Ambulatory Telemedicine Care in Older Adults: A Systematic Review

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Conflicts of Interest

There are no Conflicts of Interest pertaining to this manuscript.

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Abstract

Background: Disparities in healthcare access and delivery caused by transportation and health workforce difficulties negatively impact individuals living in rural areas. These challenges are especially prominent in older adults.

Design: We systematically evaluated the feasibility, acceptability and effectiveness in providing telemedicine searching the English-language literature for studies (January 2012 to July 2018) in the following databases: Medline (PubMed); Cochrane Library (Wiley); Web of Science; CINAHL; EMBASE (Ovid); and PsycINFO (EBSCO).

Participants: Older adults (mean age ≥65 and none were less than 60 years)

Interventions: Interventions consisted of live, synchronous, two-way video-conferencing communication in non-hospital settings. All medical interventions were included.

Measurements: Quality assessment using the Cochrane Collaboration's Risk of Bias Tool was applied on all included articles, including a qualitative summary of all articles.

Results: Of 6,616 citations, we reviewed the full text of 1,173 articles, excluding 1,047 that did not meet criteria. Of the 17 randomized controlled trials, the United States was the country with the most trials (6 [35%]) with cohort sizes ranging from 3–844 (median 35) participants. Risk of bias among included studies varied from low to high. Our qualitative analysis suggests that telemedicine can improve health outcomes in older adults and that it could be used in this population.

Conclusions: Telemedicine is feasible and acceptable in delivering care to older adults. Research should focus on well-designed randomized trials to overcome the high degree of bias observed in our synthesis. Clinicians should consider using telemedicine in routine practice to overcome barriers of distance and access to care.

Keywords

telemedicine; older adult; rural; effectiveness

INTRODUCTION

Despite improvements in life expectancy and advances in medical therapies[1], individuals residing in rural areas in the United States face increasing disparities in healthcare delivery[2–4]. Remote and distant communities demonstrate higher rates of the five leading causes of death in the US[5, 6], attributed in part to the lack of resources[2, 5] in the ambulatory setting[7], limited access to specialists and specialized resources, fewer transportation options, and socioeconomic disparities[8–12]. Rural healthcare is especially problematic in vulnerable populations including persons with disabilities[13], children[14], and older adults[11].

Information and communication technologies provide an opportunity to improve rural healthcare delivery in older adults, the fastest growing user group of technology[15], particularly in an era of burgeoning rural broadband and cellular connectivity[16]. While telemedicine or telehealth encompasses many different modalities of using technology to deliver care, synchronous, two-way video-conferencing (referred and defined in this manuscript as telemedicine or TMed) is a promising strategy in delivering rural healthcare[17–19] that may address the long-standing challenge of rural health service availability. As a result of the Telecommunications Act signed in 1996, infrastructure changes have helped support the feasibility and dissemination of TMed delivery, particularly for rural healthcare providers, patients, and communities[19] in the United States. With the expansion of high-speed broadband access to over 96% of the population[20], there is now improved capability for TMed in surmounting the major barriers faced by rural residents and narrowing the rural-urban divide in healthcare utilization[17]. TMed has now become increasingly adopted, particularly in capitated and shared risk health care financing systems[21–23], and emerging legislation[24, 25] promises to further widespread dissemination.

While a number of observational studies and single-site pilot studies suggest that TMed may have long-term cost-effectiveness[26–30], may reduce hospital utilization[26, 31–33] or emergency department visits[34, 35], data in ambulatory settings have been less commonly evaluated. Older adults have less experience with emerging technologies and have considerable sensory, memory and other aging-related barriers to engaging in TMed[36, 37]. Older adults' multiple co-morbidities may also require in-person rather than remote-based care. The purpose of this review is to conduct a systematic evaluation of the evidence regarding TMed interventions conducted in older adults in non-hospital settings. Although the intent of our review is to consider implications for rural health care, we evaluated both rural and urban studies extending past the domestic United States to assess the feasibility, acceptability, and effectiveness of TMed in this population.

METHODS

We conducted a systematic review according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[38]. See Supplemental Appendix #1 for a checklist of each component.

Study Protocol

We reviewed all English-language studies published from the year of CMS's TMed coverage determination (January 2012) to July 2018[36, 39–44] Database searches were conducted in June 2017, and repeated in February and July 2018. The final search update covered the full date range and records found in the previous searches were removed, based on the methods described by Bramer and Bain[45]. We present the aggregate results of all searches below.

With the assistance of two reference librarians (HBB, PJB), the search included subject headings and keywords to capture the concepts of telemedicine and older adults in English language articles. The search strategy was adjusted for the syntax appropriate to each database. The following electronic databases were searched: Medline (PubMed); Cochrane Library (Wiley); Web of Science; CINAHL; EMBASE (Ovid); and PsycINFO (EBSCO). See Supplemental Appendix 2 for our full search strategy. As our focus was on peer-reviewed publications, we deliberately omitted any grey literature including websites, conference proceedings, abstract submissions or clinical trial registries. Bibliographies of identified systematic reviews and all included manuscripts were reviewed manually by the lead author (JAB) for additional studies.

Selection Criteria

We used the Patients, Intervention, Controls, Outcomes (PICO) framework to refine our criteria. Inclusion criteria consisted of: English language studies; human studies; studies with a mean participant age of 65 years and corresponding one standard deviation or range required to exceed 60 years, as conducted in our previous work[46]; and ambulatory TMed care delivered either in-home, or in an assisted living or long-term care setting on the receiving end of the intervention (not acute or hospital settings). For inclusiveness, participants were eligible if they had any co-morbid physical and mental health conditions were included. Interventions were considered only if TMed was defined as live, real-time, synchronous, two-way video-conferencing on both the receiving and delivery end, as this is the most common type used within clinical settings and one that is most fully reimbursed.[47] This is in contrast to other modalities of telehealth, including remote monitoring, e-consultations or store-and-forward, whose feasibility, acceptability and preliminary effectiveness have been reviewed elsewhere.[48–50] Inclusion criteria also required a focus on patient care with a health care provider or trained staff (i.e., physician, associate provider [advanced practice registered nurse or physician's assistant], physical/occupational therapist, psychologists, social workers or dietitians, etc.) on one end, and a patient on the receiving end. We also included peer-to-peer therapy for medical conditions, as it ultimately resulted in delivering patient care. We excluded any TMed (video-conferencing) related to remote medical education. Studies involving social media (i.e., Facebook or Twitter) were excluded. Initially, all study types (randomized controlled (RCT) trials, observational or qualitative studies, etc.) were included as the study team was concerned that the number of high-quality RCTs would be limited. Following full-text review and identification of a sufficient amount of eligible RCTs (N=17), our review protocol was modified to include only RCTs.

Data Extraction

Searches were combined using Endnote X8 (Thomson Reuters, New York). Two sets of reviewers extracted data from the full-text articles identified in each search. Each set of reviewers conducted a test review for quality assurance purposes by manually conducting a title/abstract review of 200 citations, for which concordance was required to exceed 80%. Discrepancies between reviewers were adjudicated by the senior author (JAB), an approach previously used[46].

A total of 9,185 citations were identified using our full search criteria (see Figure 1). An additional 535 studies were identified from related systematic reviews during the search process. Pairs of reviewers manually reviewed citation titles and abstracts for inclusion criteria. Following initial title/abstract screening, discrepancies were reconciled before proceeding to full-text review. A second-level screening applied a hierarchical method of exclusion on the remaining full-text studies.

Quality Review

The Cochrane Collaboration's Risk of Bias Tool was used to evaluate bias for all included studies as conducted in our group's previous work[46]. This tool focuses on the following: sequence generation; allocation concealment; blinding; incomplete outcome data; selective outcome reports; and other sources of bias. Two reviewers (LMS, PRD) assessed each of the included studies, rating them as high, low or unclear risk of bias for each criterion. The senior author (JAB) adjudicated if any decisions differed.

Study-Level Outcomes

The primary outcomes were chosen *a priori* and intentionally left broad to ensure all potential effectiveness measures were captured. Our evaluation focused on effectiveness outcomes and acceptability of the intervention. All study data were extracted using a standardized data collection form, which included: publication year; country of origin; funding source; telemedicine modality (process, transmitting/receiving end, device used); study aim; number of study participants; mean age (and range); socioeconomic status (education, place of residence; function or frailty indicators; primary medical condition evaluated; sex-distribution; study setting; and description of the intervention and control groups. We qualitatively evaluated the study's primary outcomes, video-contact time, and the estimate of effect and presented study limitations. Significant methodological heterogeneity precluded meta-analysis.

RESULTS

We present our PRISMA flow diagram in Figure #1. In total, our search strategy identified 9,720 total citations (Supplemental Appendix 2), of which 6,616 were reviewed after duplicates were removed. After initial title and abstract screening, 1,173 citations required full-text review. Non-RCT and asynchronous communications were the most common reasons for exclusion. The final count of included articles consisted of 17 studies, all of which were based on unique study populations.

Risk of Bias Assessment

Table 1 indicates the bias assessment according to the Cochrane Collaboration's Risk of Bias Tool[51] of all included studies according to the authors' judgment. Subjective methodological quality of all included studies was considered low to intermediate based on the proportion of studies found to have a "high" risk of bias according to the Cochrane Tool. Methodological problems in the included studies consisted of non-blinded data collectors, outcome assessors, and treatment allocation. As expected, blinding of study participants and healthcare providers was not possible due to the nature of TMed interventions and hence we did not evaluate these components of the tool.

Study Characteristics

The majority of the included RCTs were based in the United States (n=6), with Europe and South Korea both consisting of five and four studies, respectively (Supplemental Appendix 3). Only four studies focused in whole or in part on rural participants[52–55]. The majority of studies were funded by governmental or public agencies. Computers of all types (desktop, tablet, laptop) were used and included studies focused on effectiveness and participant perception of TMed usage. Study cohort number ranged from small pilot trials (n=3) to a larger, multi-site trial of 844 participants.

Participant Characteristics

Participants were older adults ranging from a mean age of 65.1 years to 86.45 years, although the ranges (when reported) consisted of adults aged 60 to >90 years (Table 3). Socioeconomic status was indicated in nine studies, and patient frailty or functional status was inconsistently reported using different indices. Most interventions focused on a spectrum of chronic disease entities including neurological disorders, depression, chronic obstructive pulmonary disease, diabetes, or high-risk older adults with different baseline characteristics. Studies varied in the sex-distribution of participants. Most interventions occurred in the participant’s home, with others delivered in nursing facilities or community centers.

Intervention & Outcomes

Table 4 outlines the intervention description and control group of all included studies. All intervention-based groups used synchronous video-conferencing modalities. Control groups varied by studies predominantly consisting of standard, in-person, clinical care or usual health promotion care for the specific disease entity. Study duration varied from 2 weeks[55] to 5 years[54]. One study[56] did not report their study duration. Most primary outcome measures consisted of disease-specific outcome measures, including re-hospitalizations, non-fatal events, or clinical complications. Video contact time was ranged from monthly to three times per week. Only three studies commented on technical limitations of their video-delivery[57–59], of which experienced considerable difficulty[59].

The main outcomes also varied between studies (Table 4). A number of studies (n=7) demonstrated similar outcomes compared to a corresponding control group; others demonstrated considerable acceptability, adherence and self-reported function. A number of studies (n=4) focused on fall, exercise or strength-based measures and demonstrated improvements. Three studies suggested that telemedicine could lead to improved cognitive function. All but one study demonstrated feasibility in their older adult population. However, improvements in utilization parameters were only observed in one study, while 5 studies demonstrated no differences. Each study had a number of major limitations, the main ones which are listed in the accompanying table (Supplemental Appendix 3).

DISCUSSION

We identified a number RCTs supporting TMed's feasibility, acceptability and effectiveness across diverse health conditions, healthcare settings, and patient populations. Our data demonstrate that TMed can potentially be a useful modality of health service delivery. However, there were limitations with respect to the findings due to heterogeneity in study design, the plurality of underpowered studies in each arm, and other methodological limitations. This underscores the need for well-designed trials to minimize bias and provide definitive evidence of TMed use among ambulatory older adults.

Our review fills a gap as it focuses on trials conducted outside of the hospital setting. A number of included studies demonstrated equivalent outcomes highlighting the potential for telemedicine to address geographic barriers while delivering comparable health outcomes. Hospitals aim to achieve improved efficiency, prompting smaller systems in more remote areas to use telestroke and teleintensive care programs that are successful and sustainable[60–62]. Yet, there is less emphasis on ambulatory or skilled nursing facility care. Our results suggest that policymakers should promote further ambulatory coverage by eliminating barriers for both providers and patients, alike.

There is a critical need for high-quality studies investigating the impact of TMed interventions in older adults. The IDEATel study[54, 63] integrated early TMed and remote monitoring with web-based informatics using a home-installed, low-bandwidth, TMed device. While their cohort exceeding 800 Medicare beneficiaries, the authors found that TMed was acceptable[64], usable in lower socioeconomic[65], ethnic[66] and older adult populations[67], and improved diabetes self-management[68]. Their data suggested a need for implementation strategies for future dissemination. The other three high methodologically high quality studies demonstrated sample size concerns[69, 70] and a sample consisting predominantly of males[71]. Additional, adequately powered studies focusing on diverse populations are needed.

Our findings demonstrate that TMed interventions are feasible and acceptable among older adults and that similar outcomes are achievable compared to usual, in-person care. Few studies, though, focused specifically on rural adults and the results were mixed. While TMed may provide a unique opportunity to reach isolated, low-resource populations with limited access to in-person medical services, well-designed, high-quality studies are needed. It is unclear whether the considerable bias and misperception related to older adults' use of technology[72] play a role. Providers are often hesitant in recommending technologies in older adults due to potential physical, sensory, cognitive and visual-spatial abnormalities[73–75]. The population of older adults in the U.S. is rapidly growing[76] with a workforce available to provide care for this demographic insufficient. TMed may help provide effective care, particularly in rural and underserved areas, and executing the Institute of Medicine's recommendation to advance TMed resources[77] is strongly supported by our observations.

Despite numerous limitations in study quality, our approach had a number of strengths supporting our conclusions. By using the PRISMA criteria, we reduced inherent bias and error that are present in conducting systematic reviews. Including research librarians increases the validity of our process. Our data substantiates that there are insufficient, well-designed RCTs in the use of TMed. The methodological inconsistencies in these trials provide an opportunity to focus on addressing these gaps in future work.

We acknowledge several limitations. First, many studies focused on specific diseases, and not multimorbid, frail older adults that often require a range of medical and social services[78], impeding generalizability. The majority of studies did not highlight functional or socioeconomic status suggesting a need for future studies to report on these parameters. Second, laptops and computers which may have larger screens rather than tablets or smartphone technologies were used which are more affordable, widely available, but whose user interfaces may not necessarily be tailored to older adults - an important factor in usability[79]. Software and peripherals differ that may impact user experience and intervention effectiveness, which may increase the reach of future interventions. Data are needed to evaluate these devices, expanding upon traditional healthcare delivery to non-healthcare settings, beyond research or health centers. While our focus was on non-hospital based, only two RCTs were in nursing facilities[53, 80]. Observational studies exist[81, 82]; yet, the lack of rigorous studies in older adults have considerable implications as they are sicker, require increased medical assessment and acuity[78], ultimately leading to increased utilization. Research to evaluate TMed interventions in such facilities are needed. Few studies described technological issues, particularly in areas with poor bandwidth, likely due to the urban-rural divide observed. Our findings are also prone to publication bias. Lastly, the heterogeneity of interventions and outcomes prevented us from conducting a formal meta-analysis, with some studies lacking formal statistical comparisons.

Our findings have a number of implications and provide a foundation for research priorities. The 2012 legislation covering TMed highlights an urgent need to develop novel, pragmatic interventions to evaluate TMed delivery, in both rural and non-rural populations. Currently, an Innovation Award is evaluating the impact of TMed on cost and reducible hospitalizations irrespective of locality in long-term care settings[83]. Understanding barriers and facilitators of effective TMed implementation strategies in systems as well as payment models to improve efficiency for both older adults and provider systems is helpful. We have an opportunity to integrate technology in older adults who traditionally are excluded from trials. Usability needs differ[79] and future trials should adapt delivery systems to different chronological and physiological groups. While a number of RCTs using TMed in non-hospital settings exist, well-designed, powered trials will provide guidance in using this technology in older adults, particularly in rural areas.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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ABBREVIATIONS

CMS	Centers for Medicare and Medicaid Services
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomized controlled trial
TMed	Telemedicine

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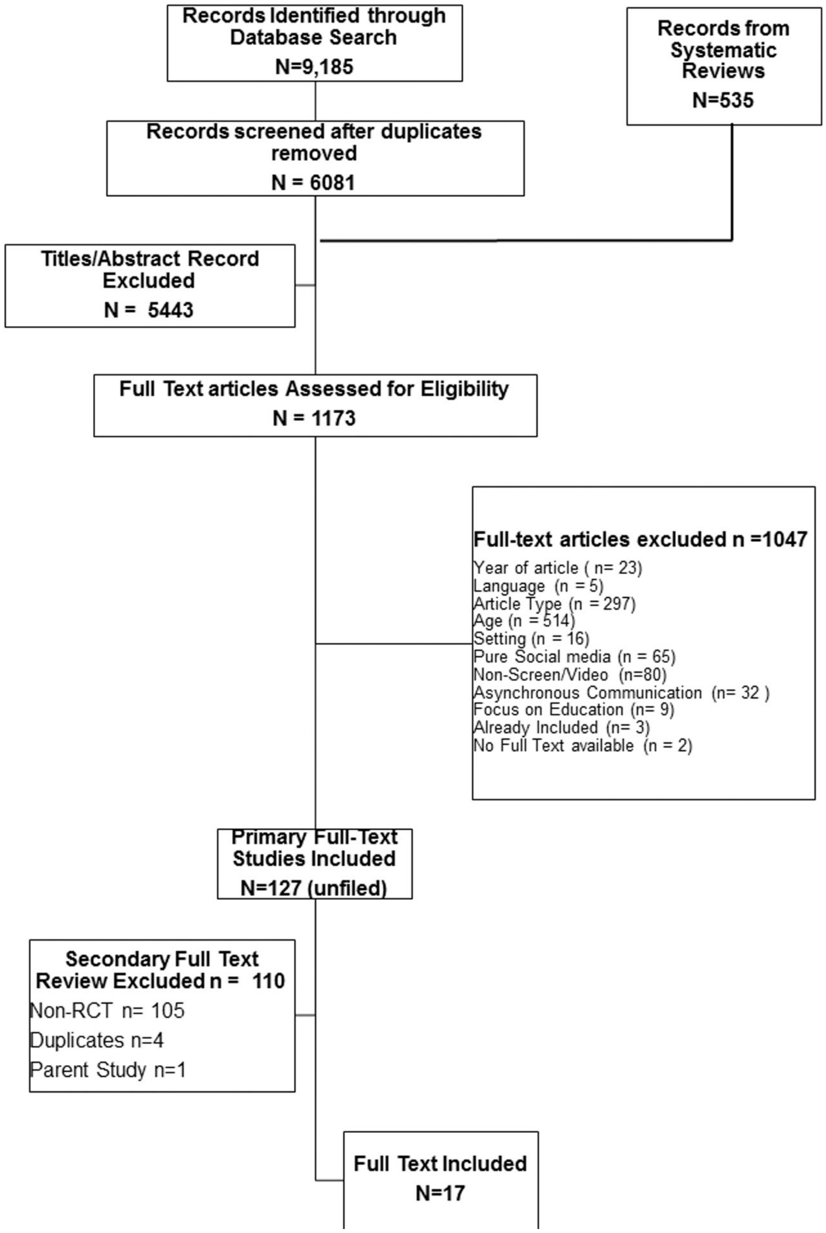

FIGURE 1:

Flow Diagram of Study Selection Process for the Systematic Review.

We reviewed n=36 systematic review bibliographies, which accounted for n=535 additional records of studies for review (accounted for in the flow diagram as ‘additional records identified through other sources.’). These articles were accounted for in the flow diagram.

Table #1:

Methodological Quality of Telemedicine Randomized Controlled Studies (n=17) - Cochrane Risk-of-Bias Tool[a]

Reference	Year	Overall Risk of Bias[b]	Sequence Generation	Allocation Concealment	Blinding		Incomplete Outcome Data	Selective Outcome Reporting	Other Sources of Bias
					Data Collectors	Outcome Assessors			
Burns[57]	2017	Low	High	High	Low	Unclear	High	High	Low
Burton[84]	2018	Low	High	High	Low	Unclear	Low	Low	Low
Comin-Colet[58]	2016	Low	High	High	High	Unclear	High	High	High
De Luca[80]	2015	Low	Low	Unclear	Low	Unclear	High	High	Low
Dichmann Sorknaes[52]	2013	Low	High	High	High	Unclear	High	High	High
Dy[53]	2013	Low	Unclear	Unclear	Unclear	Unclear	Low	Low	Low
Gandolfi[85]	2017	Low	High	Unclear	High	High	High	High	Low
Homma[59]	2016	Low	Low	Low	Unclear	Unclear	High	Low	Low
Hong[86]	2017	Low	High	High	Unclear	Unclear	High	High	High
Hong[69]	2018	High	High	High	High	High	High	High	Low
Ishani[71]	2016	High	High	High	High	High	High	High	Low
Jelcic[87]	2014	Low	Low	Low	High	High	High	High	Unclear
Orlandoni[88]	2016	Low	High	High	Unclear	Unclear	High	High	High
[c]Takahash[89]	2012	Low	High	High	High	High	High	High	High
[d]Trief[54]	2013	Unclear	Unclear	Unclear	High	High	High	High	Unclear
Tsai[70]	2017	High	High	High	High	High	High	High	High
Vahia[55]	2015	Low	Unclear	Unclear	Unclear	Unclear	Unclear	Low	Low
% High[e]	---	3 (17.6)	11 (64.7)	10 (58.8)	8 (47.1)	6 (35.2)	15 (88.2)	13 (76.5)	6 (35.2)

[a]Criteria for the author's judgment of a summary assessment: "Yes" indicates a low risk of bias; "No" indicates a high risk of bias; "Unclear" indicates an uncertain risk of bias according to the Cochrane Collaboration tool. Blinding of Participants and Healthcare providers were not included in this evaluation.

[b]A "Low" overall risk was assigned if all assessed domains were given a "Yes", other than for Blinding. A "High" overall risk was assigned if there were one more domains given a "No." Blinding of participants and healthcare providers was not taken into consideration when assessing a study's overall risk of bias.

[c]This paper is a secondary analysis of a previously conducted randomized controlled trial[89]

[d]This paper is a secondary analysis of a previously conducted randomized controlled trial[90]

[e] A percentage was calculated as the quotient of the number of “High” within a column and the total number of included citations.

Table 2:

Study Characteristics of Included Telemedicine Randomized Controlled Studies (n=17)

Reference Year	Telemedicine Model				Study Aim	# Participants	
	Process	Transmitting End	Receiving End	Device		Active	Control
Burns[57] 2017	Expert to patient	Hospital-based speech pathologist	Patient with regional speech pathologist	Videoconferencing unit with Pan-Tilt-Zoom camera and handheld medical camera system	Evaluating speech pathology telepractice for swallowing of head/ neck cancer patients	43	39
Burton[84] 2018	Expert to patient	Cognitive therapist	Patient	Video Therapy Analysis Lab with video set-up and peripherals	Comparability and feasibility of cognitive rehabilitation delivered by videoconferencing vs. in-person	3	3
Comin-Colet[58] 2016	Expert to patient	Nurse	Patient	Touchscreen computer, 3G access with videocall ability	Effectiveness of telemedicine check-ins & telemonitoring in improving CHF outcomes	81	97
De Luca[80] 2015	Expert to patient	Neurologist ± Psychologist	NH Resident	Videoconferencing-enabled PC and peripherals	Effectiveness of telehealth care model for managing NH residents	32	27
Dichmann Sorknaes[52] 2013	Expert to patient	Hospital-based nurses	Patient	Computer with web camera and microphone, and peripherals	Effectiveness of daily real-time video-consult vs. usual follow-up care in reducing readmission rates	132	134
Dy[53] 2013	Expert to expert	Endocrinologist	Nursing home nurse, dietician and patient	Laptop computer with secure videoconferencing and Skype freeware	Perception of telemedicine diabetes consultations by Skilled Nursing Facility Care Providers	12	11
Gandolfi[85] 2017	Expert to patient	Physio-therapist	Patient	Nintendo Wii console with web-camera & peripherals	Home virtual reality with in-clinic balance training in reducing instability in Parkinson's patients	38	38
Homma[59] 2016	Expert to patient	Physician	Patient	Videophone (details not specified)	Effectiveness of counseling with telemonitoring vs. printed media in modifying lifestyle	35	33
Hong[86] 2017	Expert to patient	Exercise Instructor	Patient	PC with Internet connection; 15.6 inch touchscreen LCD, 2mp webcam, speaker, microphone	Development of a tele-exercise program on effectiveness of sarcopenia-related health factors	11	12
Hong[69] 2018	Expert to patient	Exercise instructor	Patient	Tablet with video-conferencing software	Effectiveness of a tele-exercise program on risk factors for falls	15	15
Ishani[71] 2016	Expert to patient	Interdisciplinary care team	Patient	Touch screen computer with peripherals	Feasibility and effectiveness of telehealth and case management for chronic kidney disease patients	451	150
Jelcic[87] 2014	Expert to patient	Therapist	Patient	Skype for Windows with network camera	Effect of domain-specific cognitive training delivered	7[c] 10	10
Orlandoni[88] 2016	Expert to patient	Physician	Patient	Samsung Galaxy Tablet with videocall capabilities	Effectiveness of video consultation between	100	88

Reference Year	Telemedicine Model				Study Aim	# Participants	
	Process	Transmitting End	Receiving End	Device		Active	Control
					home visits on outcomes of home enteral nutrition		
[a]Takahashi 2012	Expert to patient	Registered nurse	Patient	Intel Health Guide with videoconferencing capabilities and peripherals	Effectiveness of reducing ED visits and hospitalizations in older adults using telemonitoring	102	103
[b]Trief[54] 2013	Expert to patient	Nurse case manager or dietician	Patient	Web-enabled computer with camera and peripherals	Adherence to diabetes care using telemedicine in Hispanic & African American patients	844	821
Tsai[70] 2017	Expert to patient	Physiotherapist based in tertiary hospital	Patient	Laptop computer with built-in camera (HP EliteBook 8560p) and peripherals	Effectiveness of videoconferencing tele-rehabilitation in improving physical fitness	19	17
Vahia[55] 2015	Expert to patient	UCSD Clinical evaluator	Patient	Tablet PC laptop, video camera, microphone and peripherals	Comparability of neuro-cognitive assessment via telepsychiatry vs. for older rural Latinos	11	11

Abbreviations: ER – emergency room; UCSD – University of California, San Diego;

[a]This paper is a secondary analysis of a randomized controlled trial[89]

[b]This paper is a secondary analysis of a previously published randomized controlled trial[90]

[c]Two intervention groups participated in this trial

Table 3:

Description of Study Population of Telemedicine Randomized Controlled Studies (n=17)

Study	Arm	Age ± SD	Age Range	Sample Size	Sex Distribution	Socioeconomic Status[c]	Baseline Functional or Frailty Status[d]	Study Duration	Setting	Disorders or Conditions
Burns[57]	Intervention	64 ± 7.58	61–66	43	37M:6F	NR	NR	~27 months	Local health facility	Head and neck cancer, post-treatment
	Control	65 ± 7.45	62–67	39	29M:10F	NR	NR			
Burton[84]	Intervention	71.33	66–80	3	0M:3F	15±1.7 years of education	MMSE 27.3±1.5	8 weeks	Video Therapy Analysis Lab, university campus	Early-stage dementia, subjective cognitive impairment
	Control	72.33	68–77	3	1M:2F	14.7±3.1 years of education	MMSE 24.3±6.4			
Comin-Colet[58]	Intervention	74 ± 11	NR	81	46M:35F	NR	Fragility 19 (24%)	6 months	Participant home	Congestive heart failure
	Control	75 ± 11	NR	97	59M:38F	NR	Fragility 25 (26%)			
De Luca[80]	Intervention	79.1±9.2	NR	32	11M:21F	100% residing in nursing home	ADL 5.5 (2.0,6.0) IADL 3.0 (2.0,5.0) MMSE 24.1 (16.1,26.1)	NR	Nursing home	Depression
	Control		NR	27	8M:19F	100% residing in nursing home	ADL 1.0 (1.0,2.0) IADL 2.0 (2.0,3.0) MMSE 21.3 (17.9, 24.1)			
Dichmann Sorknaes[52]	Intervention	71 ± 10	NR	132	53M:79F	8 (6%) with 12–13 years of school	NR	26 weeks	Participant home	Acutely-exacerbated COPD
	Control	72 ± 9	NR	134	51M:83 F	4 (3%) with 12–13 years of school	NR			
Dy[53]	Intervention	83	65–93	11	7M:16F	100% residing in nursing home	Anticipated ≥6 month residency	6 months	Skilled nursing facility	Type II Diabetes Mellitus
	Control			12		100% residing in nursing home	Anticipated ≥6 month residency			
Gandolfi[85]	Intervention	67.45 ± 7.18	NR	38	23M:15F	NR	MMSE 26.77±1.48 # Falls 0.58±1.44	7 weeks	Participant home	Parkinson's Disease
	Control	69.84 ± 9.41	NR	38	28M:10F	NR	MMSE 28.64±6.96 # Falls 1.84±5.29			
Homma[59]	Intervention	67.2 ± 1.5	NR	33	11M:22F	NR	NR	3 months	District community center	Any lifestyle disease (i.e. HTN, dyslipidemia, diabetes, obesity)
	Control	65.1 ± 1.3	NR	35	13M:22F	NR	NR			
Hong[86]	Intervention	82.2 ± 5.6	69–93	11	5M:6F	NR	8' TUG 9.2±5.7s	12 weeks	Residences in the community	Sarcopenia
	Control	81.5 ± 4.4		12	5M:7F	NR	8' TUG 10.9±4.8s			
Hong[69]	Intervention	78.1 ± 5.66	68–91	15	0M:15F	NR	8' TUG 9.55±4.03s	12 weeks	Participant home	Fall Risk Assessment Scale score > 14
	Control	81.54 ± 5.07		15	0M:15F	NR	8' TUG 8.27±2.27s			
Ishani[71]	Intervention	75.3 ± 8.1	NR	451	445M:6F	115 (25.5%) ≥4 year degree	Good/excellent health 288 (63.9%)	1 year	Participant home	Chronic Kidney Disease
	Control	74.3 ± 8.1		150	147M:3F	34 (22.7%) ≥4 year degree	Good/excellent health 107 (71.3%)			
Jelcic[87]	LSS-tele	86±5.1	NR	7	2M:5F	6±3.5 years of education	MMSE 23.7±2.8	3 months	Elderly Day care	Mild memory decline
	LSS-direct	82.7±6		10	3M:7F	6.7±3.3 years of education	MMSE 24.9±2.5			
	Control	82.3±5.9		10	1M:9F	8.7±3.7 years of education	MMSE 24.8±2.7			
Orlandoni[88]	Intervention	86.45 ± 7.03	NR	100	28M:72F	NR	Karnofsky index 42 ± 6.51	1 year	Participant home	Requires home enteral nutrition
	Control	84.36 ± 7.05		88	21M:67F	NR	Karnofsky index 42 ± 6.53			
[a]Takahashi	Intervention	80.3 ± 8.9	NR	102	50M:52F	NR	Grip strength 18.2±8.6 kg TUG 13.3±6.8 seconds Gait speed 0.70±0.38 m/s	1 year	4 sites within Mayo Clinic's Employee/Community Health	High-risk elderly adults[e]

Study	Arm	Age ± SD	Age Range	Sample Size	Sex Distribution	Socioeconomic Status[c]	Baseline Functional or Frailty Status[d]	Study Duration	Setting	Disorders or Conditions
							Barthel ADL Index 94.3±9.7			
	Control	80.2 ± 7.6	NR	103	44M:59F	NR	Grip strength 18.8±9.4 kg TUG 15.8±15.4 seconds Gait speed 0.70±0.35m/s Barthel ADL Index 94.6±8.7			
[b]Trief[54]	Intervention	70.79 ± 6.46	NR	844	308M:536F	9.69±4.11 years of education	Charlson comorbidity index 2.88±2.00	5 years	NY-state residences	Type II Diabetes Mellitus
	Control	70.86 ± 6.78	NR	821	311M:510F	9.85±4.13 years of education	Charlson comorbidity index 2.89±1.75			
Tsai[70]	Intervention	73 ± 8	NR	19	12M:7F	NR	6MWT: 363±66	8 weeks	Participant home	COPD
	Control	75 ± 9	NR	17	6M:11F	NR	6MWT: 383±93			
Vahia[55]	Intervention	70.1 ± 8.7	NR	11	NR	5.9±4.8 years of education	MMSE z-score (standard deviation, median) −0.73 (3.18,0)	2 weeks	Residences in Imperial County, California	Suspected cognitive impairment
	Control	71.4 ± 10.6	NR	11	NR	5.0±3.7 years of education	MMSE z-score (standard deviation, median) −1.02 (3.03,−0.45)			

Values represented are mean ± standard deviations, counts (percent), or median (interquartile range)

Abbreviations: ADL – Activities of Daily Living; IADL – instrumental activities of daily living; COPD – Chronic obstructive pulmonary disease; LSS – lexical-semantic stimulation; MMSE – mini mental status examination; NR – not reported; NY – New York. TUG – timed up and go; 6MWT – 6-minute walk test

[a]This paper is a secondary analysis of a randomized controlled trial[89]

[b]This paper is a secondary analysis of a previously published randomized controlled trial[90]

[C]socioeconomic status is defined as income, education, poverty, financial means, or Medicaid insurance status

[d]each article either did not report frailty/functional status or defined it differently – please refer to the individual article for their precise definition

Table 4:

Study Outcomes of Randomized Controlled Trials (n=17)

Study	Intervention	Control	Primary Outcomes	Video Contact Time	Main Findings
Burns[57]	Speech pathology care delivered by TMed	Standard, in-person speech pathology care	Cost, number, session length, efficiency; service	Telepractice sessions weekly; appointments as needed (1 hour each)	Significant reduction in number (p = 0.004) and duration (p = 0.024) of contact events required to manage cases by telepractice
Burton[84]	Cognitive rehabilitation using TMed	Face-to-face care	Goal performance (Canadian Occupational Performance Measure)	Videoconferencing 1x/week	Lower rates of session completion among telehealth group may suggest lack of feasibility or acceptance. No statistical testing reported.
Comin-Colet[58]	Telemonitoring with video-conferencing	Face-to-face encounters	Non-fatal heart failure events	NR	Significant decrease in non-fatal HF events (p<0.001) with lower readmission rates (p=0.007), among telehealth group
De Luca[80]	Telemonitoring. Neurological / psychological video-counseling	Standard in-home nursing care	Psychological well-being; MMSE, ADL, IADL, GDS, BANSS, BPRS, EUROQoL	Video-counseling 1x per week	Significant differences only reported within telehealth group, T0 to T1: GDS (p<0.01), BPRS (p=.04), heart rate (p=.02), SAP (p<0.001), DAP (p=0.03)
Dichmann Sorknaes[52]	Video consults one week post-discharge	Usual follow-up care	Total # of hospital readmissions	Teleconsulations daily for 1 week	No difference in # of hospital re-admissions (p=0.62)
Dy[53]	Standard care with TMed	Standard home nursing care	Diabetes care; HbA1c point-of-care glucose,	Weekly or biweekly teleconsulations	SNF nurses reported TMed were a good use of their time; skills were effective for consult delivery . No statistical testing reported.
Gandolfi[85]	Home-based Virtual Reality balance training	In-clinic sensory integration balance training	Gait and balance; Berg Balance Scale	Tele-rehab session 3x/week (50 minutes each)	Improved BBS scores for telerehab group (p = 0.04); significant Time × Group Interactions in Dynamic Gait Index for in-clinic (p = 0.04)
Homma[59]	Lifestyle, health reports delivered by videophone	Printed document reports	Health status, body mass index, steps/day satisfaction;SBP/DBP, cholesterol	Monthly videophone sessions (15–20 minutes each)	Similar degrees of health status improvement & satisfaction levels (not significant)
Hong[86]	Tele-exercise program with one-on-one remote instruction	Maintenance of usual lifestyle	Sarcopenia-related factors of health; total and AMM, chair sit-and-reach length, 2-min step, chair stand	Tele-exercise sessions 3x per week (20–40 min each)	Improved lower-limb muscle mass (p=0.017), AMM (p=0.032), total muscle mass (p=0.033), chair sit-and-reach length (p=0.019)
Hong[69]	Exercise by TMed	Nutrition, exercise education, activity and nutrition monitoring	Fall-related risk factors	Tele-exercise sessions 3x/week (20–40 min each)	Greater improvement in chair stand test (p<0.001), Berg Balance Scale (p=0.02)
Ishani[71]	Case management & care TMed	Usual kidney disease care	All-cause mortality, emergency department visits, nursing home admits	At least 1 video visit, with more as needed for acute care concerns	No significant difference between groups for any component of the primary outcome
Jelecic[87]	Lexical tasks to enhance semantic verbal processing by Skype	Unstructured cognitive stimulation	Global cognitive performance; lexical-semantic; semantically-related or unrelated episodic verbal memory	One hour each morning	Improvements in global cognitive domain (p=0.001); non-inferior to in-person

Study	Intervention	Control	Primary Outcomes	Video Contact Time	Main Findings
Orlandoni[88]	Nutritional assessment delivered by TMed	Standard home-visits with nutritional assessment	Incidence of metabolic and GI complications secondary to home enteral nutrition	At least 1 monthly video consultation (< 10 minutes on average)	Significantly lower incidence of metabolic and GI complications among video consultation group (both p<0.001); no significant difference in hospital admission rate
[a]Takahashi[89]	Hospice care with TMed	Usual end-of-life care	# of hospital and emergency room visits	NR	No difference in hospitalizations, ER visits; mortality in telemonitoring higher compared to usual care (p=0.008)
[b]Trief[54]	TMed for diabetic coaching (in Spanish if needed)	Usual diabetic care	Adherence to diabetes management; HbA1c, Diabetes Self-Care Activities scale	Tele-visits every 4–6 weeks	Self-reported adherence improved for intervention compared to control (p<0.001)
Tsai[70]	Group-based telerehabilitation program	Usual care without exercise training	Endurance exercise capacity (ESWT)	Telerehab sessions 3x per week (1 hour each)	Improvement in ESWT (p<0.001)
Vahia[55]	Neurocognitive testing using TMed	In-person neurocognitive testing	Various Neurocognitive tests	1 test session per modality, administered 2 weeks apart	No differences in cognitive scores (p=0.280)

Abbreviations: ADL - Activities of Daily Living; AMM – appendicular muscle mass; BANSS - Bedford Alzheimer Nursing Severity scale; BBS – berg balance scale; BPRS - Brief Psychiatric Rating Scale; DBP – diastolic blood pressure; DGI – Dynamic gait index; ER – emergency room; ESWT - endurance shuttle walk test; EUROQoL - standardized instrument as a measure of health outcomes and quality of life; GDS = Geriatric Depression Scale; HbA1c – hemoglobin A1c; HF – heart failure; HR - heart rate; IADL - Instrumental Activities of Daily Living Scale; IT – information technology; MMSE - Mini Mental State Examination; NR – not reported; PD – parkinson's disease; QoL - quality of life; SBP – systolic blood pressure; SNF – skilled nursing facility; TMed - telemedicine

[a]This paper is a upondary analysis of a Randomized Controlled Trial[89]

[b]This paper is a secondary analysis of a previously published randomized controlled trial[90]