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Review Article

Digital Health Interventions among People Living with Frailty: A Scoping Review

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A B S T R A C T

Objectives: Digital health interventions (DHIs) are interesting resources to improve various health conditions. However, their use in the older and frail population is still sparse. We aimed to give an overview of DHI used in the frail older population.
Design: Scoping review with PRISMA guidelines based on Population, Concept, and Context.
Setting and participants: We included original studies in English with DHI (concept) on people described as frail (population) in the clinical or community setting (context) and no limitation on date of publication. We searched 3 online databases (PubMed, Scopus, and Web of Science).
Measures: We described DHI in terms of purpose, delivering, content and assessment. We also described frailty assessment and study design.
Results: We included 105 studies that fulfilled our eligibility criteria. The most frequently reported DHIs were with the purpose of monitoring (45; 43%), with a delivery method of sensor-based technologies (59; 56%), with a content of feedback to users (34; 32%), and for assessment of feasibility (57; 54%). Efficacy was reported in 31 (30%) studies and usability/feasibility in 57 (55%) studies. The most common study design was descriptive exploratory for new methodology or technology (24; 23%). There were 14 (13%) randomized controlled trials, with only 4 of 14 studies (29%) showing a low or moderate risk of bias. Frailty assessment using validated scales was reported in only 47 (45%) studies.
Conclusions and Implications: There was much heterogeneity among frailty assessments, study designs, and evaluations of DHIs. There is now a strong need for more standardized approaches to assess frailty, well-structured randomized controlled trials, and proper evaluation and report. This work will contribute to the development of better DHIs in this vulnerable population.

Frailty is a condition of vulnerability to stressors of the older population that increases the risk of poor health outcomes.[1,2] The prevalence of frailty in the population varies considerably depending on how frailty is measured. In an analysis of the English Longitudinal Study on Aging using 35 frailty scores, the mean prevalence of frailty was 29% in women (range: 1%-72%) and 23% in men (1%-65%).[3] Frailty is a process that tends to increase over time,[4] but unlike disability, frailty is reversible with treatment.[5] Therefore, frailty must be detected and treated. To detect frailty, there are many validated frailty scores, based on different concepts. Two main underlying concepts are the frailty phenotype, a physiological model focused on physical frailty using 5 variables,[2] and the deficit accumulation model, calculating a frailty index comprising at least 30 variables from different domains such as comorbidity, disability, cognition, mood, and social.[6] Between 2015 and 2050, the number of people aged 60 or older will increase

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from 900 million to 2 billion, representing up to 22% of the global population.[7] People living with frailty (PLF) are prone to accidents and injuries and therefore have one of the highest health expenses in developed countries.[8]

Many digital health interventions (DHIs) are specifically designed to detect, monitor, and provide care and support for PLFs. There is a wide range of DHIs, such as Internet based or mediated with software and applications.[9] Digital technologies have opened doors to previously inaccessible areas in health care. For instance, "My Day for Seniors" on Alexa, which acts as a vocal assistant, has been used as a virtual screening tool for possible COVID-19 symptoms, because it was designed as daily questionnaires for the older population, although not specifically for PLF.[10]

Kampmeijer et al[11] conducted a systematic review of DHI in the older population and found 45 studies using smartphone applications, websites, connected devices, video consultations, and webinars. They found that one of the biggest barriers to DHI was insufficient support for older people.[11] Despite the fact that specific digital technologies have been used in the frail population, there are no scoping reviews focused on the frail population, who is more likely to be excluded from the digital world than the older general population.[12]

The main objective of this study was to provide a broad overview of DHIs used for PLF, to identify gaps in the literature and to describe the robustness of the digital approaches. Our objective being broad, we chose to carry out a scoping review rather than a systematic review.[13]

Methods

Before starting the review, a protocol based on PRISMA-ScR tool[14] was developed and registered on the Open Science Framework (OSF) registry.[15]

Eligibility Criteria, Information Sources, Search and Selection of Sources of Evidence

We included original studies in English with no limitations on the date of publication. We focused our inclusion criteria on population, concept, and context.[16] Population was identified as any study that specifies frail population or mentions the related terms for frail, frailty, or frailty syndrome. Concept was any DHI specifically for frail persons and with a participant interaction with or without comparison group. Context included all clinical and community-dwelling settings. We excluded publications without reported results, protocols, editorials, comments, perspectives, reviews, and correspondence (Supplementary Table 1). We searched 3 electronic databases (PubMed, Scopus, and Web of Science) (Supplementary Table 2). We accessed all databases on April 19, 2020.

After database search, search results were imported into an open source online tool (CADIMA).[17] Then, 2 coauthors (N.L. and G.A.) performed screening by titles and abstracts independently. Full-text screening and selection of included articles was performed in parallel and blinded by 2 coauthors (N.L. and C.G.). Disagreements were discussed and solved with a third coauthor (G.A.).

Data Extraction Process

Data extraction format was created in Microsoft Excel adapting to the template used by Joanna Briggs Institute.[18] The data extraction form was tested on a small sample of studies and modified based on the feedback of the team. Two authors (N.L. and C.G.) categorized key components of DHI and extracted data independently. The results of data extraction were compared, and if there was any discrepancy, they were discussed and resolved with a third coauthor (G.A.).

Definitions Used for Data Extraction

We extracted data on purpose, mode of delivery, content, and assessment of DHI. The categorizations were not mutually exclusive. Therefore, it is possible that a study reported more than 1 category, for example, more than 1 purpose within a group of DHI delivery.

The purpose of DHI was categorized into frailty detection, monitoring, enhancing health status, communication, care and support, rehabilitation, prevention of falls, and assessing health status.

We also extracted the way of delivering DHI into sensor-based technologies, videoconferencing methods, game-based technologies, mobile applications, web interventions, and other technologies, such as robots and pillbox.

The content of DHI was categorized into goal setting, feedback, rewards, educational information, and self-reporting.

The assessment of DHI was categorized into efficacy, accuracy, usability and feasibility, and user experiences. Full definitions of purposes, content, and assessment are shown in Supplementary Table 3.

We also extracted the following items: first author, year of publication, country, main objectives, and study design. The study design was categorized with the following criteria. Randomized controlled trials (RCTs) were experimental studies (the DHI was decided by the researcher) with randomization. Quasi-experimental studies were defined as experimental studies in which treatment allocation was not randomized. Descriptive exploratory studies were defined as an experimental study where a novel numerical intervention was applied to a small number of participants to test the technical aspects. Validation studies were defined as experimental studies that tested a new application in a small number of participants for acceptability and utility, if they used qualitative research tools such as focus groups, they were defined as qualitative studies. Cross-sectional analysis was defined as an observational study (the DHI was not decided by the researcher but by the participant) where the exposure and the outcome were assessed at the same time. A longitudinal study was defined as an observational study where the exposure and the outcome were analyzed in 2 or more time points.

The population was described with the size of the study sample, the age and sex of the participants, the frailty assessment tools, and frailty status. The concept was described with the purpose of DHI, the method of delivery, the content, and the assessment of DHI. The context was categorized into a clinical or community environment.

Critical Appraisal of Individual Sources of Evidence and Reporting Efficacy

The sources of evidence were described in a general context (quantitative and qualitative studies) and in a more specific assessment for RCT, longitudinal, and cross-sectional observational studies. The Cochrane Risk of Bias Tool for Randomized Trials (RoB 2),[19] the Newcastle-Ottawa Scale,[20] and an adaptation of this scale for cross-sectional studies[21] were used for assessing RCT, longitudinal observational, and cross-sectional studies, respectively. Two researchers performed the critical appraisal (N.L. and G.A.).

We further analyzed results in terms of efficacy, accuracy, or feasibility in RCTs and cross-sectional or longitudinal studies that reported frailty assessment with a validated score.

Results

Search Results

We found 2392 articles from 3 databases (PubMed (n=302), Scopus (n=1661), and Web of Science (n=429). We removed 578 duplicates and 1336 articles after title and abstract screening. Among the

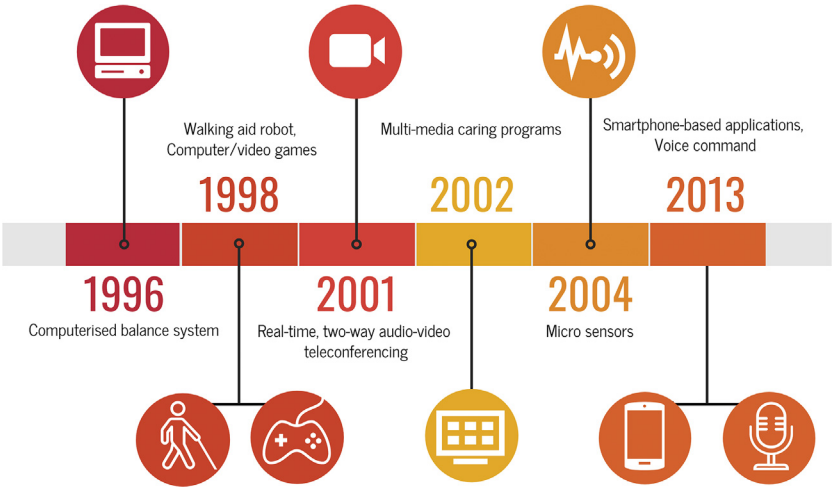

Fig. 1. Digital health interventions for people living with frailty over the years (based on the year of publication).

remaining 478 articles eligible for full text screening, we excluded 373 articles. Most common reasons were that they were not about DHI (n=102), they did not have results on the interventions (n=91), and they did not specify or mention frailty in the participants (n=79). Finally, we included 105 articles for this scoping review (Supplementary Figure 1 and Supplementary Table 4).

Characteristics of Included Studies

The total number of participants was 13,104, with the age of participants ranging from 29 to 93 years. We included articles published in peer-reviewed journals (n=89) as well as those presented in international conferences (n=16).

Context was described as follows: 28 (27%) studies were based in clinical settings, 68 (65%) were in community settings, 2 (2%) in both contexts, and 7 (7%) did not report context. Among participants in community settings, 37 (35%) lived in their homes without help, 7 (7%) were community dwelling needing help, 7 (7%) lived in retirement homes, 13 (12%) lived in nursery homes, and 4 (4%) reported community dwelling without other information. Forty-eight studies (46%) were performed in participants needing long-term care services, 18 (17%) were based on participants with cognitive impairment, 6 (6%) were based on participants with disability, and 37 (35%) were based on participants with other chronic conditions (Supplementary Table 4).

In the 1990s, DHI began to appear along with computerized scale systems. Then, other DHI appeared such as robots and games. In the 2000s and beyond, real-time teleconferencing and multimedia programs appeared, followed by sensors. In the 2010s and beyond, the most important tool that emerged was the use of smartphones and, more recently, vocal biomarkers (Figure 1).

Geographical Distribution and Years of Publication

There were overall 22 countries, which contributed to at least 1 individual study. The United States of America was the most represented country (24; 23%). By continent, Europe leads the geographical distribution (56; 53%), followed by America (30; 29%), Asia (10; 10%), and Oceania (2; 2%) (Supplementary Figure 2). Studies were published between 1996 and 2020. The numbers of records per year were below 5 in earlier years. From 2012, the number started to climb above 5 and reached the peak in 2017 (Supplementary Figure 3).

Frailty Assessment

Frailty assessment was reported in 47 (45%) and 17 (16%) with and without using a validated tool respectively (Table 1). The most frequent tool was the Phenotype of Frailty score (23; 22%). Among the 64 studies that reported frailty assessment, 27 (42%) described the population as mixed (frail, prefrail, and nonfrail), 24 (38%) as frail, 3 (5%) as prefrail, and in 10 (17%) it was unclear.

Purposes, Delivering, and Assessment

Purposes of DHI included monitoring (45; 43%), communication (41; 39%), care and support (40; 38%), assessing health status (37; 35%), frailty detection (30; 29%), enhancing health status (29; 28%), prevention of falls (11; 11%), and rehabilitation (7; 7%).

Delivering of DHI was reported as sensor-based technologies (59; 56%), other technologies, such as robots and electronic pillbox (43; 41%), videoconferencing technology (18; 17%), mobile applications (15; 14%), web-based technology (15; 14%), and game-based technology (6; 6%). The major purpose of the studies (where description was not mutually exclusive) in sensor-based technology studies was for frailty monitoring (32 studies). Videoconferencing technology was mostly used for communication purposes (16 studies). Among the studies using game-based technology, 4 were aimed at enhancing the health status. Of the studies that featured mobile applications, the most common purposes were frailty detection (7 studies) and monitoring (7 studies). Among those on web-based technology, the stated

Table 1
Validated Frailty Assessment Tools Used in the 105 Included Studies

Frailty Assessment Tools	Studies, n (%)
Phenotype of Frailty[2]	23 (22)
Frailty index[22]	11 (10)
Groningen Frailty Indicator[23]	5 (5)
Two or more frailty scores (Phenotype of Frailty,[2] Frailty Index,[22] Short Physical Performance Battery,[24] Clinical Frailty Scale[25])	3 (3)
Tilburg Frailty Indicator[26]	2 (2)
Edmonton Frailty Scale[27]	1 (1)
Clinical Frailty Scale[25]	1 (1)
Easycare-TOS[28]	1 (1)
Own definitions of frailty/use of scales not validated for frailty	17 (16)
Not reported	41 (39)

purpose in 13 studies was communication. Other technologies such as robots and pillboxes were used mainly for monitoring (22 studies) and care and support (22 studies). Figure 2 shows the number of studies for each group as we defined above, covering the modes of delivery and the purpose of DHI.

Content of DHI was found in 64 (61%) studies. Content was reported as feedback to users in 34 (32%) studies, educational information in 15 (14%) studies, self-reporting in 8 studies (8%), rewarding experiences in 4 studies (4%), and goal-setting for users in 3 studies (3%).

Assessment of DHI was reported as efficacy in 31 studies (30%), accuracy in 23 studies (22%), usability and feasibility studies in 57 studies (54%), user experiences, such as qualitative interviews and satisfaction surveys, in 24 studies (23%) and cost analysis in 7 studies (7%). Figure 3 summarizes findings on purpose, mode of delivery, and content of DHI.

Study Design and Quality of Evidence

We found that 24 (23%) were descriptive exploratory studies (new methodology or technology), 20 (19%) were validation studies, 16 (15%) were cross-sectional, 14 (13%) were RCT, 10 (10%) were quasi-experimental, 8 (8%) were qualitative research, 4 (4%) were observational longitudinal studies, and 9 (9%) were another type of study (Supplementary Table 4). The RCTs showed a wide range of low risk of bias (0%-100%). Only 4 of 14 studies (29%) showed a low or moderate risk of bias (Supplementary Figure 4). The quality of the cross-sectional studies ranged from 10% to 70%, with 9 of 16 studies (56%) scoring 5 of 10 stars or more (Supplementary Table 5). The quality of the longitudinal studies ranged from 22% to 89%, with 2 of 4 studies (50%) scoring 5 of 9 stars or more (Supplementary Table 6).

Efficacy, Accuracy, and Feasibility

RCT studies that showed good efficacy were an exercise program based on a game system,[29,30] another exercise program in a tablet and a night pad light to prevent falls.[31] Among cross-sectional studies, DHI that showed good frailty prediction or efficacy were a set of e-furniture (frailty assessment),[32] a balance quality tester (falls),[33] and a single wrist sensor (frailty detection).[34] A longitudinal study that showed good efficacy was a DHI with a light path for preventing falls[35] (Table 2).

Discussion

In this scoping review, we were able to map DHI in PLF. We found that DHIs have been used for many purposes and delivery means, with relatively few studies evaluating usability and feasibility. We found that despite the studies claimed to be for PLF, some studies did not report frailty assessment.

The role of DHI has been studied in the frail population with specific health conditions or issues such as palliative care in oncology,[39] renal replacement therapy,[40] chronic diseases,[41] dental hygiene,[42] mental health,[43] and falls.[44] Liu et al[45] published a systematic review on the readiness of the older population for smart home technologies. Rialle et al[46] reviewed recent health “smart” home projects and concepts. Karlsen et al[47] performed a qualitative review on telecare at home for community-dwelling older people. These studies focused either on particular interventions or on the frail population with specific underlying conditions.

We found 2 scoping reviews about mobile health applications.[48,49] Neither of these reviews focused on frailty but they rather included older people in general. We found 1 scoping review, with a primary interest on frailty, that focused on the functionality and mobility of prefrail and frail older people.[50] In addition, we also found systematic reviews on home-based telemedicine care services for frail older individuals with chronic diseases,[51] on analysis of gait characteristics in people with frailty,[52] and on ethical considerations in assistive technologies used in the care for frail older individuals.[53] Based on these literature findings, this scoping review is fulfilling the gaps to present a wider and, therefore, more comprehensive range of DHI for the frail population in general.

Frailty prevalence measured with the Phenotype of Frailty score was reported to be 15%, 10%, and 7.4% in the USA,[54] Europe,[55] and Japan,[56] respectively. We found that research work in digital health technologies for PLF were mostly concentrated in regions with a high frailty prevalence. Moreover, we found that the availability of DHI seemed to be limited to industrialized countries and regions. The pooled prevalence of frailty in community-dwelling older adults among upper middle-income countries was reported to be 13%. However, there was information of frailty status in only 1 study from a low-income country. Therefore, this review reveals the need for research in low-income countries that also have PLF often with digital literacy issues, who may be perhaps even more likely to be reluctant to use DHI.[57]

From 2012 onwards, we observed a rising trend in the number of publications. Moreover, 78% (n=82) of the studies were published after 2012. Because digital health has become a popular area of research over the decade, as recognized by the World Health Organization,[58] we believe that it is also important to describe the current and future contribution of DHI for vulnerable populations.

Researchers in the United Kingdom found that public digital websites for health and social care used limited visual representations for older people, which means they were not considered main users of those websites and therefore they were excluded.[59] An explanation for this exclusion can be the assumption that at an advanced age, the ability to use technology on computers, tablets, and smartphones may be reduced.[60]

O'Connor et al[61] reviewed qualitative research studies on patient engagement in DHI and identified 4 main determinants of success: motivation, personal values, recruitment approach, and quality of the DHI. When the goal of engagement is well defined with flexible methods for participants, involvement of the PLF in research is not only possible but also above all necessary to match what is important to end users.[62] Research priorities chosen by PLF focused on the prevention and management of frailty, the prevention of hospitalizations, and the adaptation of health care and housing systems to improve quality of life.[63] We hope that future research in digital health will not only include frail populations as the target of DHI, but will also involve them in the design and validation of digital tools intended for them.

We found out that 39% of studies did not specify frailty assessment or define frailty among their participants even though they used “frail” and its related terms throughout their studies. This may reflect the lack of knowledge about what frailty is to researchers. Additionally, in some studies, the concept of frailty was used in the context of other clinical conditions such as cancer or dementia. This is consistent with the findings from previous review papers[45,46] where the term *frailty* was loosely based on different concepts and tools, or simply assigned to old participants without mentioning a frailty assessment. We found great heterogeneity in reporting and choosing a frailty score and in the nature of the frailty assessment. This makes it difficult to screen and collect evidence about whether study participants were frail or not.

In this review, we found that DHIs were mostly used for monitoring and for providing care and support. PLF frequently have several comorbidities,[64] and DHIs should be personalized according to them.[65] Among several DHIs, sensors were featured most frequently for diagnosis and for monitoring and assessing health status in frail persons. Another type of DHI was video conferencing, which was mainly used for communication purposes as well as for other purposes such as providing care and support, and enhancing health status, for example, home-based tele-yoga to improve patients with chronic

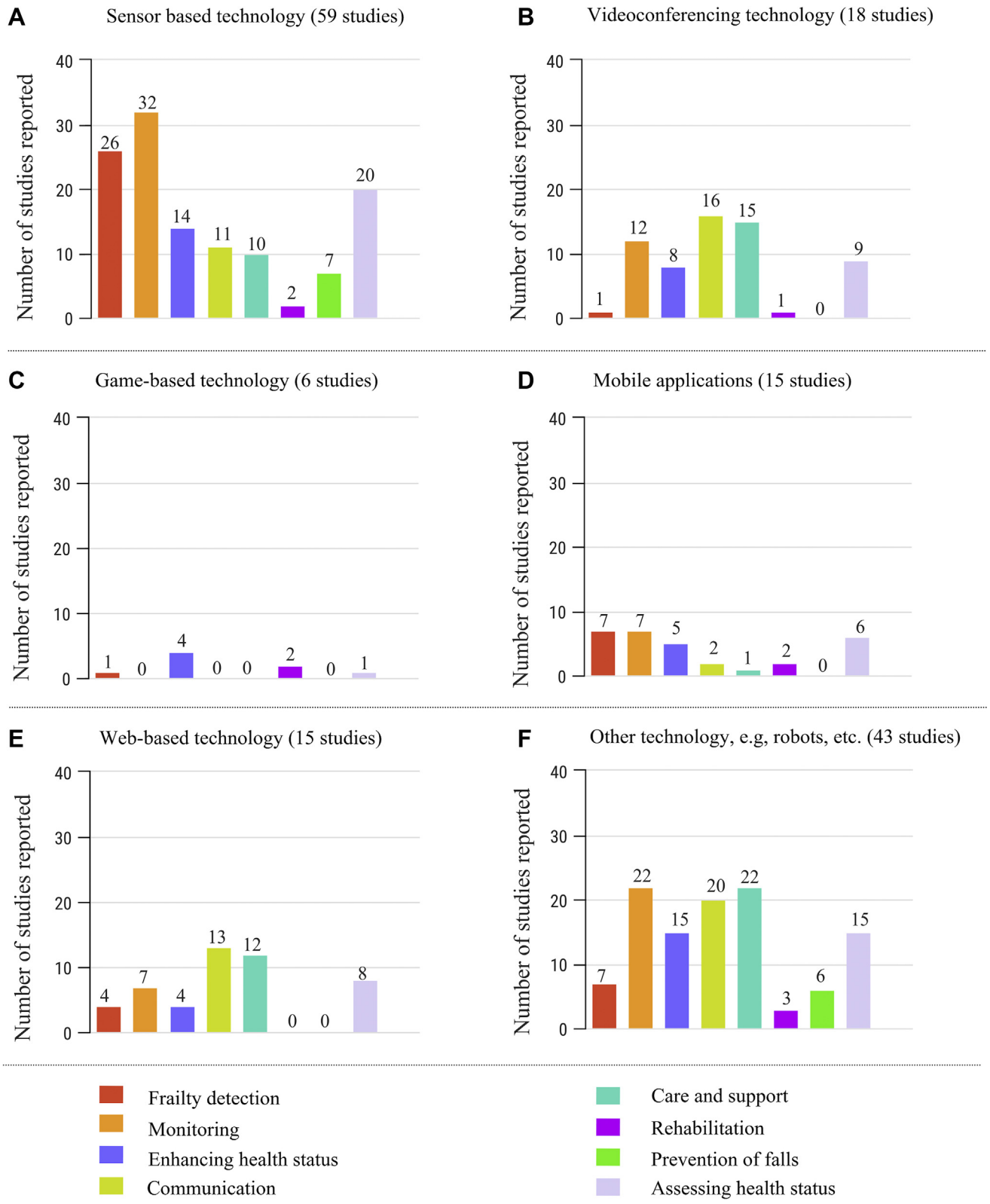

Fig. 2. Distribution of digital health intervention types by purpose of use for people living with frailty. The categories were not mutually exclusive because it is possible that a study reported more than 1 mode of digital technology, or had more than 1 purpose for the digital intervention used, or both. The purposes of frailty detection, enhancing health status, and assessing health status were observed in all forms of digital technologies. The most common delivery of frailty intervention was through sensor-based technologies.

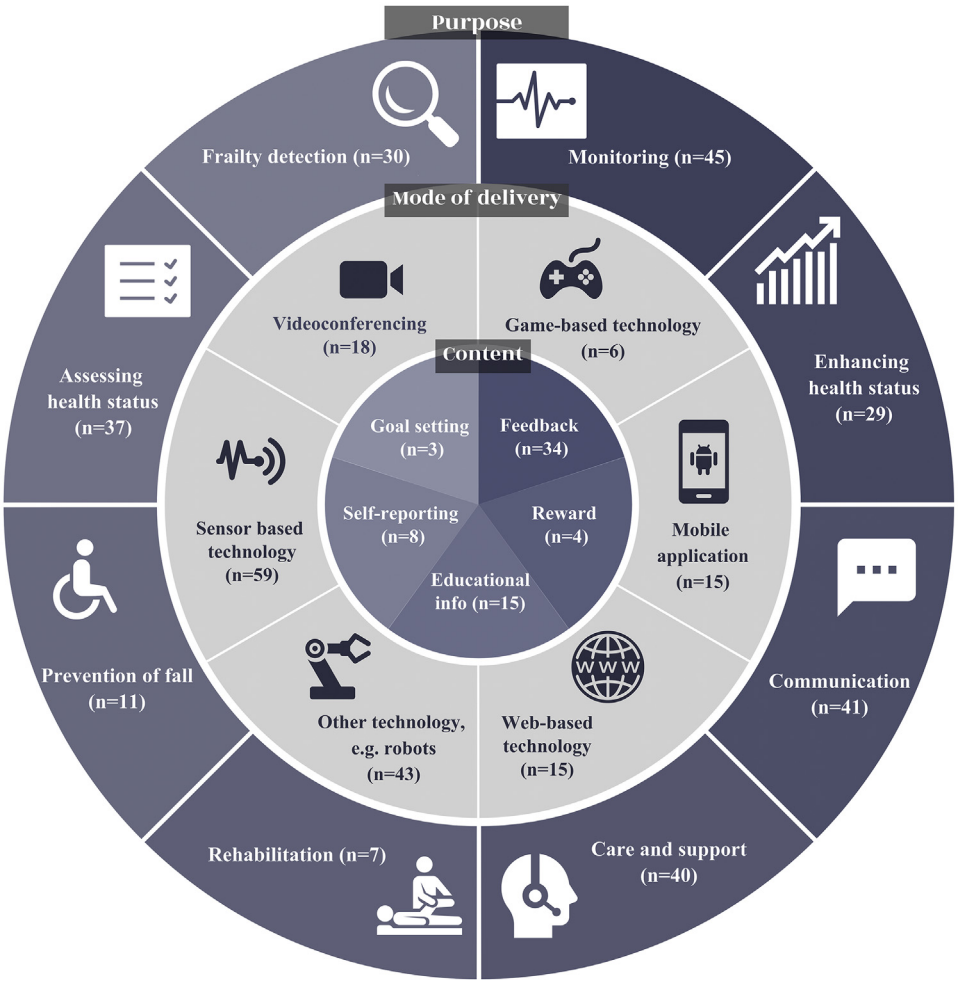

Fig. 3. Purpose, mode of delivery, and content of digital health interventions. Diagram presenting the main data items with the number of studies reported for each. There are 8 purposes for DHI, 6 modes of delivery of DHI, and 5 types of content used in DHI. The categories were not mutually exclusive because it is possible that a study reported more than 1 purpose or mode of delivery or content of DHI used.

diseases. We did not find any review related to video-conferencing technologies. Because it is more widely used nowadays, we highlighted that its efficiency or cost-effectiveness can be further reviewed in future research.

The World Health Organization recommends that DHI should be carefully evaluated.[58] We found high variability of study designs and quality. Many were described as experimental or pilot studies. We found very few RCTs assessing efficacy or usability and even fewer with low risk of bias. In addition, there were very few studies on the cost-effectiveness of DHI. These results suggest that there is room for improvement in the search for DHI for PLF.

Overall, we reported that DHI used in PLF were rather complex and diverse in terms of technologies used, project designs, testing procedures, and outcomes measures. In a review on parameters and measurements in screening, monitoring, and prevention of frailty, Dasenbrock et al argued that a consistent use of frailty scores was required.[50] We strongly support this argument in this review. World Health Organization have already provided recommendations and guidance on DHI on health system strengthening and for researchers[58]

Strengths and Limitations

We think that this study has many strengths. This scoping review strictly followed the PRISMA-ScR guideline (Supplementary Table 7). We included 3 databases, in order to cover a wide scope and provide as comprehensive a review as possible to date. One limitation is that we may not have identified all relevant articles in the published literature, because of heterogeneity in the concepts and definition of frailty as well as complexity of DHI. Another limitation is that we only included studies in English. This was based mainly on a recent publication, which found that excluding non–English language studies from systematic reviews did not have a significant effect on findings and conclusions.[66]

Conclusions and Implications

We have compiled a wide variety of information that can be used for future research on DHI for PLF. In addition, this review provides a deeper and better understanding of this area. In the age of digital technologies, it is undeniable that PLF should benefit from DHI. We believe it is essential to gather stronger evidence that new technologies are delivering the desired results and to balance those benefits with the risks and costs. In addition, user satisfaction should be further explored by involving end users (ie, PLF) in the design of the tools. We believe there is a need for well-designed and methodologically sound clinical trials that collect more evidence among PLF.

Table 2
Efficacy of Digital Interventions

Randomized Controlled Trials

First Author, Year	Population	Frailty Score	Risk of Bias*	Intervention Group	Control Group	Outcome	Qualitative Results	Quantitative Results
Daniel, 2012[29]	23 prefrail individuals with certain degree of disability and mean age = 77 y (SD 5.3), 61% women	PHF	High	Two intervention groups: (a) Wii-fit exercise (exercise gaming system) at home and (b) seated exercise (with trainers)	Usual physical activity	Physical functioning tests	Better results for intervention group. Wii-fit exercises were similar to seated exercise and both were superior to the control group for maintaining or improving physical functioning.	Six-minute walk distance increased ES 0.6 (seated); ES 0.4 (Wii) and decreased in control group.
Tchalla, 2013[31]	96 frail individuals with mean age 86.6 ± 6.5 y, 77% women, living with Alzheimer's disease	PHF	High	Nightlight path and tele-assistance service	A fall reduction program	Falls	Better results for the intervention group. The use of a light path significatively reduced the incidence of falls in older participants with Alzheimer's	OR 0.37 (0.15-0.88) of incident falls in intervention group
Upatising, 2013[36]	194 individuals (mean age 80.4 y, SD 8.3) with different frailty status and chronic conditions, 54.1% women	PHF	High	Telemonitoring case management	Usual care	Frailty	No differences between the 2 groups.	OR (having functional decline during first 6 mo = 1.41 (0.65-3.66)
Hagedorn, 2010[37]	27 frail individuals (mean age 81.3 y, SD 6.9), 67% women	FI	High	Visual computer feedback training	Traditional balance training	Physical functioning tests	Most of results did not show differences between groups. Control group was superior in balance measures. Visual computer feedback training showed high efficacy in training-specific performance (not tested in the control group).	Timed and up go ES = 0.0154; 80% increase in balance in control, 400% increase in a training-specific task performance in intervention
Takahashi, 2012[38]	102 frail individuals with multiple comorbidities and mean age 80.3 y, SD 8.9	FI	Some concerns	Telemonitoring	Patient-driven usual care	Hospitalizations and emergency department visits	No differences between the 2 groups. Mortality was higher in the telemonitoring group	ES for main outcome = 0.0991
Dekker-van Weering, 2017[30]	36 prefrail individuals with mean age 70.9 y (SD 3.5) and 69.2 y (SD 3.8) (control and intervention group), 61% women	GFI	Low	Home exercise program using computer/tablet, 3 times a week during 12 wk	Usual care	Use of the intervention, adherence/user experience, and quality of life	Intervention showed excellent adherence and intervention group showed better mental quality of life.	Acceptability: average score SUS 84.2 (±13.3). Adherence: 68%. Quality of life (mental) better in intervention group, other quality of life domains, no difference.

Cross-sectional studies

First author, year	Population	Frailty score	Quality assessment†	Digital intervention	Outcome	Results
Chang, 2013[32]	160 individuals aged >65 y; frailty was evaluated, but not reported	PHF	3	eFurniture (eScale, an eChair, an ePad, an eReach, and electronic questionnaire)	Home-based frailty detection	Good prediction of frailty status. Prediction 79.71% sensitive and 86.25% specific.
Chkeir, 2016[33]	24 frail, 98 prefrail, and 64 nonfrail individuals with mean age of 79.2±5.9 y for females, and 77.8±5.0 for males	PHF	4	Balance Quality Tester, a device based on a commercial bathroom scale	Frailty assessment	Good prediction of gait velocity and grip strength but poor prediction of weight loss, exhaustion and physical activity
Chkeir, 2019[67]	194 individuals (mean age 78.9 y, SD 5.7); frailty was evaluated, but not reported	PHF	5	Balance Quality Tester, a grip ball, a tablet	Frailty assessment	Low sensitivity for frailty classification compared to gold standard PHF: 41.7%, high specificity 99%

Fontecha, 2013[68]	20 individuals, 50% women with mean age 83.6, SD 4.0; frailty was assessed but not reported	FI	3	Centralized mobile system using mobile phone capabilities and integrating other frailty indicators	Frailty assessment	Relative good ability to predict frailty from mobile device data. The system architecture was able to provide frailty diagnosis (most representative similarity degrees: 73.4% and 71.6% considering 61 frailty factors).
Galan-Mercant, 2013[69]	14 frail (mean age 83.7 y, SD 6.4) and 16 nonfrail (mean age 70.3 y, SD 3.3) individuals	PHF	6	A gyroscope, a magnetometer, and an accelerometer in the iPhone 4	Mobility assessment	Able to detect differences in turning transitions (acceleration and gyroscope-based) between frail and nonfrail individuals during the timed up and go test (P values $< .05$)
Galán-Mercant, 2015[70]	14 frail (mean age 83.7, SD 6.4) and 16 nonfrail (mean age 70.3, SD 3.3) individuals	PHF	6	Inertial sensors embedded in the iPhone 4	Mobility assessment and frail classification	High discriminative ability (AUC from 0.888 to 1) to classify frail and nonfrail groups during the timed up and go test
Gonzalez, 2019[71]	81 frail individuals aged $\geq$75 y	PHF	7	Wireless inertial sensors attached to the upper cloth	Gait analysis	Adequate accuracy for quantitative gait analysis in the demarcation of relevant gait events (error margin of $\pm$1 frame (633.3 ms)
Greene, 2014[72]	124 frail and prefrail individuals with mean age 75.9 y, SD 6.6	PHF	7	Inertial and pressure sensors and balance assessments using a touchscreen mobile device	Falls	Very good accuracy when combining methods (timed up and go, 5 times sit to stand and quiet standing balance) 93.94% (95% CI: 91.16%-96.51%) for the male model and 84.14% (95% CI: 82.11%-86.33%) for the female model
Lee, 2018[34]	100 frail individuals with mean age 78.9 y, SD 9.1	TS-FI	6	Single wrist-worn sensor	Frailty detection	Good accuracy of 80.0% (95% CI: 79.7%-80.3%) and area-under-curve of 87.7% (95% CI: 87.4%-87.9%) to identify frailty status.
McCullagh, 2017[73]	32 inpatients with different frailty status (frail, prefrail and nonfrail), mean age 78.1 y, SD 7.8	FI	6	3 motion sensors (an ankle-worn accelerometer, a thigh-worn accelerometer, and a pedometer)	Walking speed and characteristics	The ankle-worn accelerometer overestimated steps (median error 1%, IQR 3%-13%) and was more accurate than a thigh-worn triaxial accelerometer and a pedometer. The other motion sensors underestimated steps (median error 40%, IQR 51%-35%; and 38%, IQR 93%-27%, respectively).
Mulasso, 2019[74]	25 frail and nonfrail individuals with mean age 71 y, SD 6; 56% were frail	TFI	7	Remote monitoring device	Mobility	Good general performance to measure mobility levels. Cluster analysis showed that mobility index measured with the device was associated not only with physical frailty but also with social frailty

(continued on next page)

Longitudinal studies							
First Author, Year	Population	Frailty Score	Quality Assessment‡	Digital Intervention	Follow-up	Outcome	Results
Cabrita, 2017[75]	10 individuals, including 1 prefrail and 9 nonfrail, with mean age 68.7 y, SD 5.5	GFI	2	Hip-worn accelerometer, smartphone application	30 d	Experience of pleasure while doing physical activity	Able to detect physical activity and location. Outdoor activities were associated with higher physical activity than indoor activities ($P < .001$). Performing leisure activities, being outdoors, and not alone significantly predicted pleasure in daily life (all P's $< .05$).
Geraedts, 2017[76]	40 frail individuals with mean age 81 y, SD 4.6	GFI	5	Necklace-worn sensor, tablet-based exercise program	6 mo	Feasibility of wearing the device for physical activity monitoring	Relatively feasible intervention (adherence overall 61% and 69% among completers)
Gray, 2016[77]	39,000 individuals with mean age 80 y; 53% with cognitive impairment, and 75% had disability and a mean FI = 0.44.	FI	3	Telemedicine: web-based clinical decision support system	24 mo	Feasibility of telemedicine calculated as rate of initial consultation	Feasible intervention. The estimated overall rate of initial consultation was 1.83 cases per occupied bed per year and 2.66 review cases per occupied bed per year.
Tchalla, 2012[35]	194 individuals with mean age 84.9 y, SD 6.5; frail and prefrail	PHF	8	Light path coupled with tele-assistance	12 mo	Falls	Reduction in falls at home, OR 0.33, 95% CI 0.17-0.65, P value = .001

AUC, area under the curve; ES, effect size; FI, Frailty Index; GFI, Groningen Frailty Indicator; OR, odds ratio; PHF, Phenotype of Frailty; SD, standard deviation; SUS, System Usability Scale; TFI, Tilburg Frailty Indicator.

*Risk of bias evaluated with ROB 2 Revised Cochrane risk-of-bias tool for randomized trials.

†Quality assessment performed with an adapted version for cross-sectional studies of the Newcastle-Ottawa Scale (a score of ≥6 was considered to be a high-quality study).

‡Quality assessment performed with the Newcastle-Ottawa Scale for longitudinal studies (a score of ≥6 was considered to be a high-quality study).

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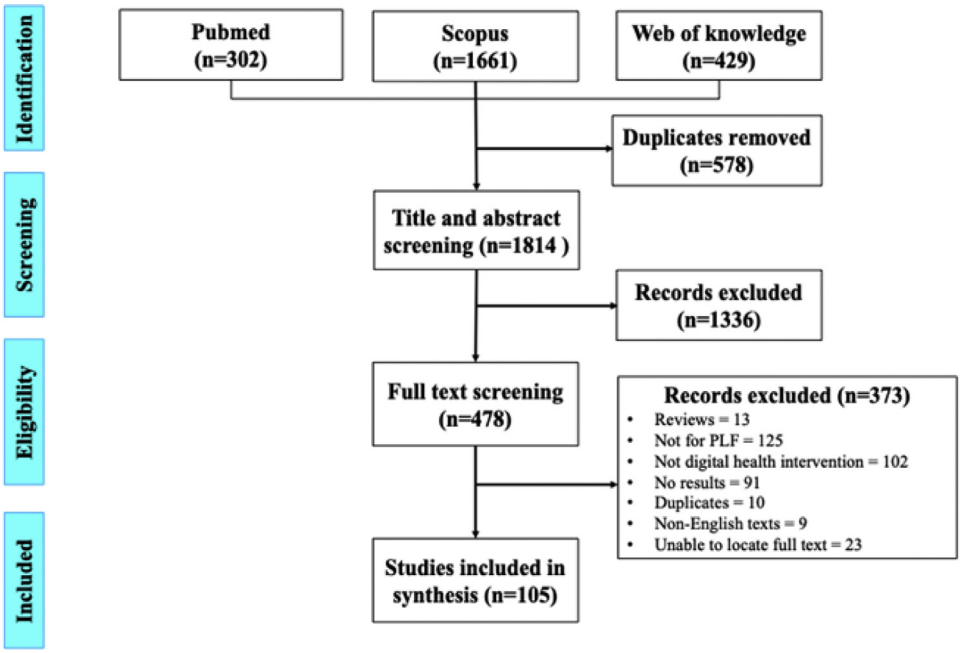
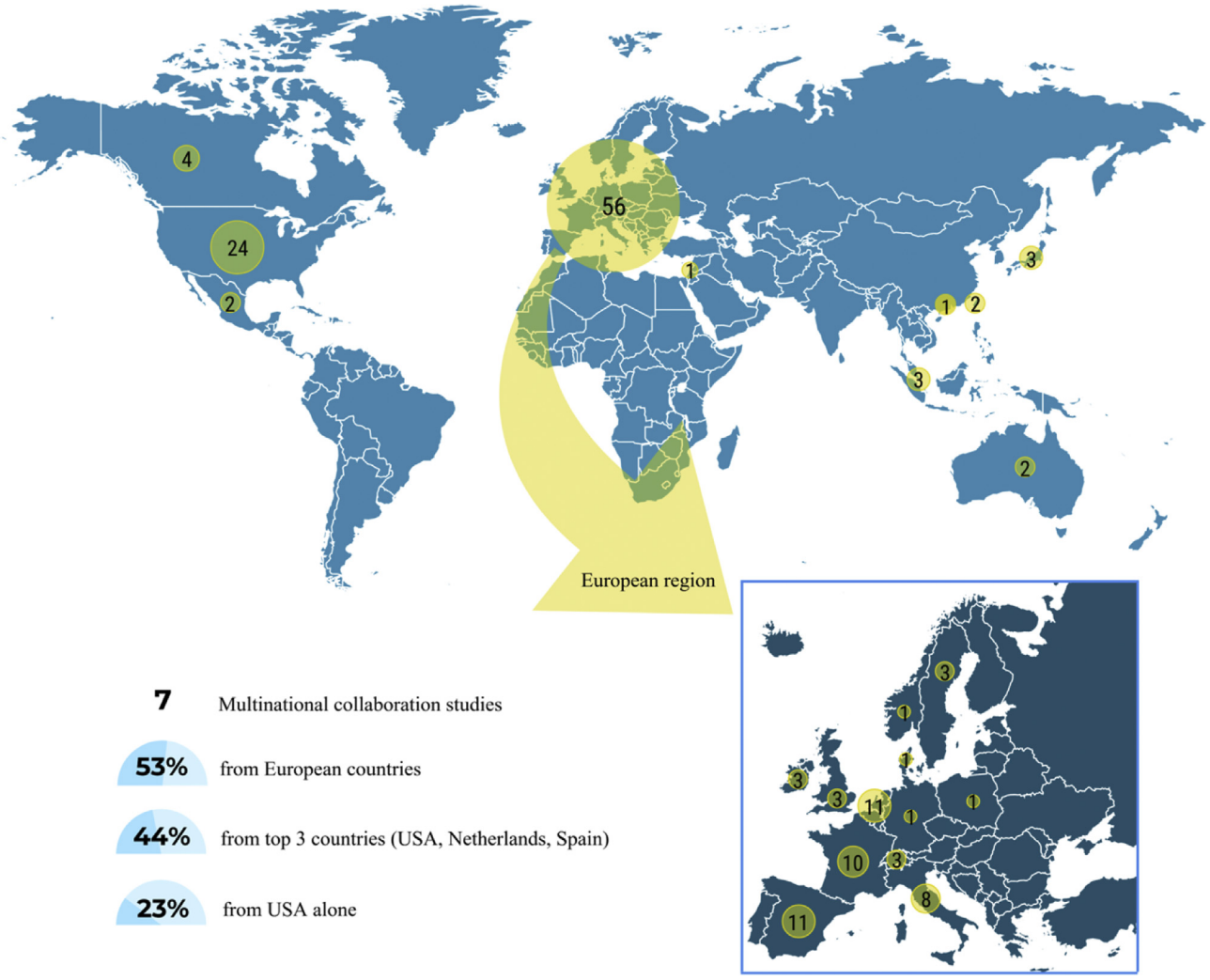
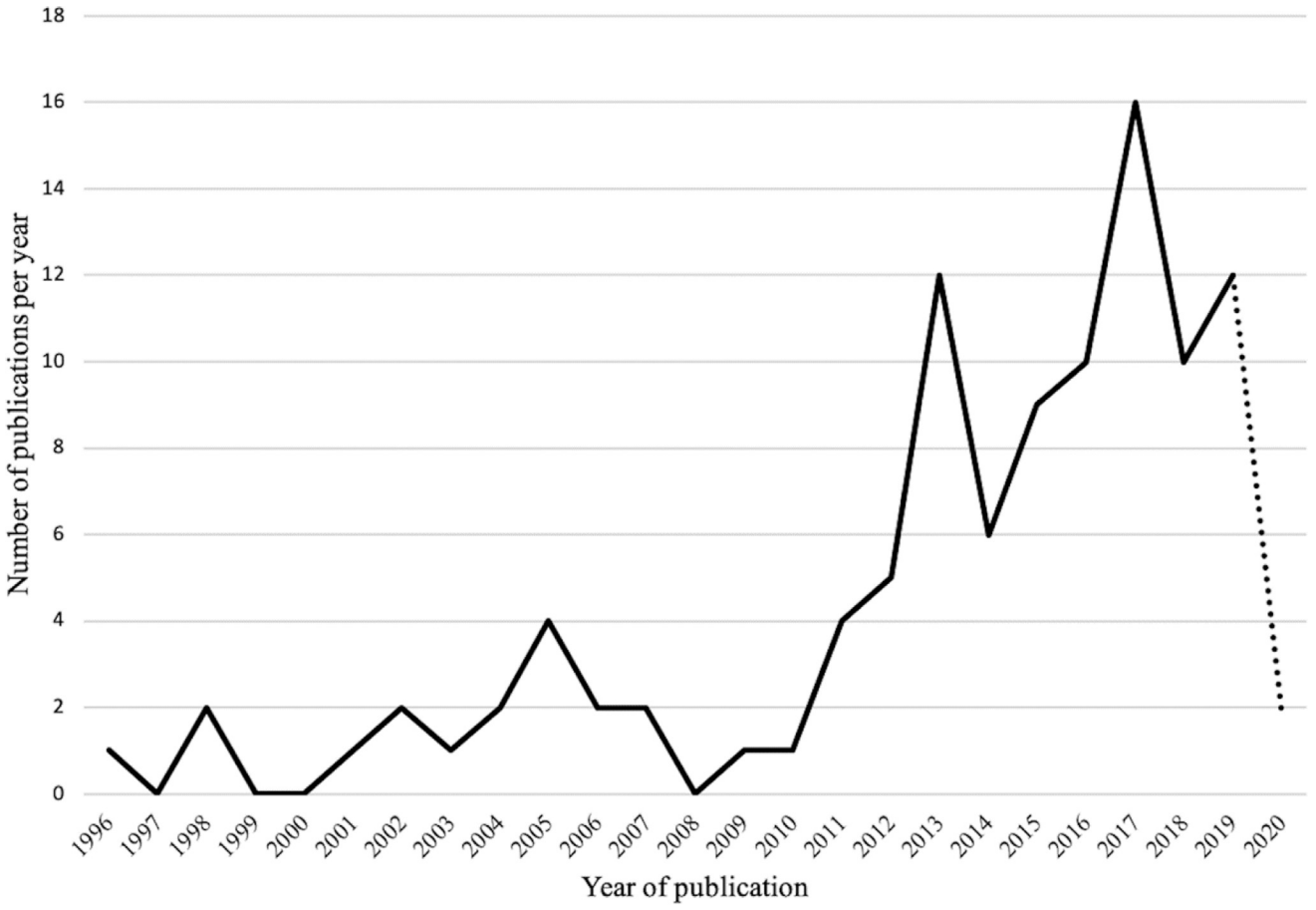


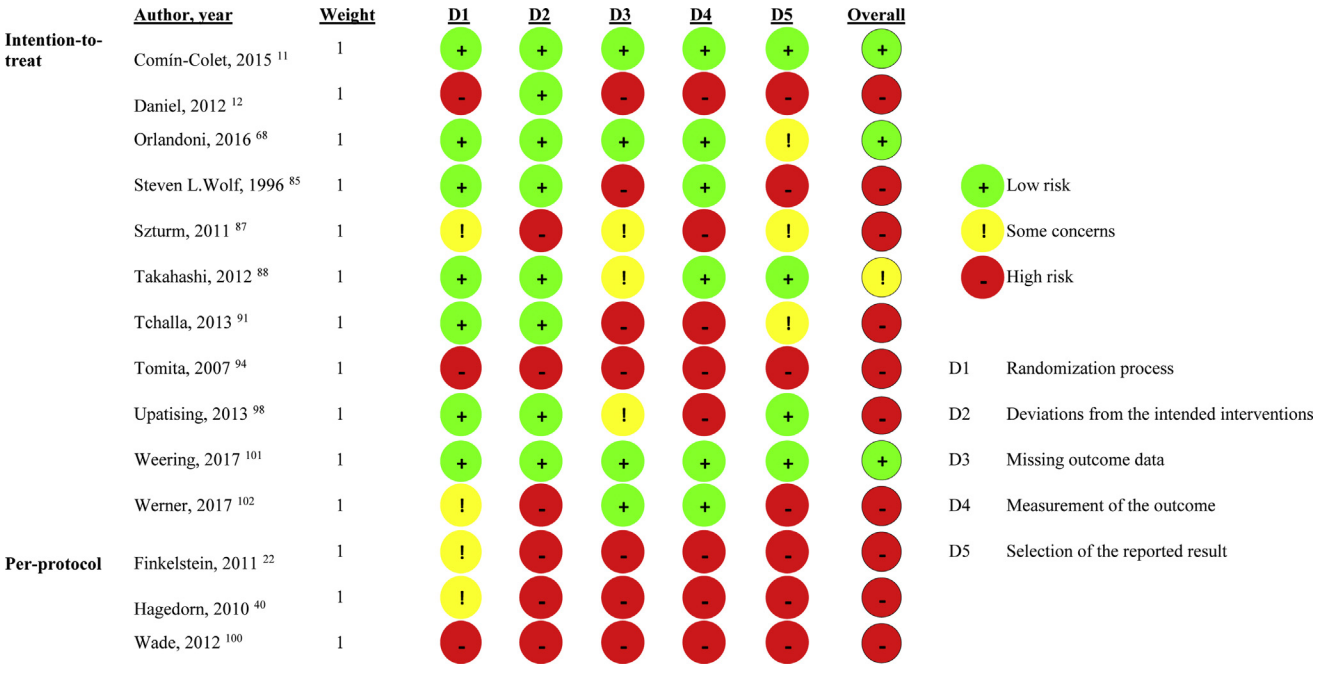
Supplementary Fig. 1. Study selection flowchart.



Supplementary Fig. 2. Distribution of publications by geographical regions.



Supplementary Fig. 3. Trend of publications by year.



Supplementary Fig. 4. Quality assessment of randomized controlled trials with intention to treat design evaluating efficacy of digital interventions in PLF (ROB 2 Revised Cochrane risk-of-bias tool for randomized trials).

Supplementary Table 1
Summary of Criteria Based on Population, Concept and Context

	Eligibility Criteria	Exclusion Criteria
Population	Studies with participants identified as frail or prefrail or studies aimed at frail populations	Studies with participants identifying sarcopenia only and not frailty.
Concept	Digital health intervention: - used by frail person, at risk of frailty - for any purpose related to frailty	Digital health interventions that do not involve direct interaction with patients, such as database management. Digital imagining interventions that are primarily used for diagnosis of other diseases such as X rays, computerized tomography, magnetic resonance imaging, echocardiograms, etc. Nondigital intervention for frailty (telephone-based), biomarkers, and serological testing
Context	Community or clinical setting, inclusive of any publication date, geographic region, gender, age and study design	Studies published in non-English language

Supplementary Table 2
PubMed Search Strategy Accessed to all Databases

Final Query in PubMed (Last Accessed on April 19, 2020)	Items Found
((Frailty[MH]) OR (Frail[TW] OR Frailties[TW] OR Frailness[TW]) OR ("Frailty Syndrome"[TW]) OR (Debility[TW] OR Debilities[TW])) AND ((telemedicine[MH] OR telecommunications[MH]) OR ("digital health"[TW] OR "mobile app"[TW] OR "mobile apps"[TW] OR "mobile application"[TW] OR "mobile applications"[TW] OR ehealth[TW] OR "e-health"[TW] OR "m-health"[TW] OR mhealth[TW] OR "mobile health"[TW]) OR (Computers, Handheld[MH]) OR (Reminder Systems[MH]) OR (smartphone[TW] OR smartphones[TW] OR internet[TW] OR "web-based"[TW] OR "electronic monitoring"[TW] OR "reminder device"[TW] OR "reminder devices"[TW] OR "reminder system"[TW] OR "reminder systems"[TW]) OR "helping hand"[TW]) OR (internet[TW] OR "mobile phone"[TW] OR "mobile phones"[TW] OR "cd-rom software"[TW] OR "cd-rom softwares"[TW] OR "internet website"[TW] OR "internet websites"[TW] OR "computer based clinical protocol"[TW] OR "computer based clinical protocols"[TW] OR "e-mail contact"[TW] OR "e-mail contacts"[TW] OR "sms based system"[TW] OR "mms based system"[TW] OR "sms based systems"[TW] OR "mms based systems"[TW] OR "telemedicine platform"[TW] OR "telemedicine platforms"[TW] OR "new technologies"[TW] OR "advanced telehealth approaches"[TW] OR "eHealth intervention"[TW] OR "eHealth interventions"[TW] OR "text message"[TW] OR "text messages"[TW] OR "monitoring device"[TW] OR "monitoring devices"[TW] OR "mobile application"[TW] OR "mobile applications"[TW] OR "computer program"[TW] OR "computer programs"[TW] OR "computer program"[TW] OR "computer programmes"[TW] OR "digital assistant"[TW] OR "digital assistants"[TW]) OR ("health website"[TW] OR "health websites"[TW]))	302

Supplementary Table 3
Purpose, Content, and Evaluation of Digital Interventions: Categories and Their Definitions

Category	Definition
Purpose	
Frailty detection	Aimed to detect or assess frailty
Monitoring	Regular recording of vital signs or physical activity of participants
Enhancing health status	Intervention playing a role in the treatment, management, improvement of performance or outcomes
Communication	Intervention with any type of communication tools allowing participants to connect with others
Care and support	Intervention aimed to help participants at home or at work
Rehabilitation	Intervention aimed to rehabilitate the participants in any way
Prevention of falls	Intervention aimed to measure body posture or balance to estimate and prevent the risk of falls.
Assessing health status	Intervention used to measure physical functioning or health status to detect evolution of medical conditions
Content	
Goal setting	Feature to set a personal goal or improvement.
Feedback	Intervention providing some feedback to the users
Rewards	Intervention where the user can acquire some rewarding experience
Educational information	Intervention that provided the users with any information related to health education
Self-reporting	User was invited to fill in or report their health or progress through the digital interventions by themselves
Assessment	
Efficacy	Mentioning any kind of evaluation measure for the digital intervention
Safety and accuracy	Study testing the accuracy, precision, sensitivity, and specificity of the digital intervention
Usability and feasibility	Testing for usability, feasibility, barriers, or facilitators of the technologies or devices
User experiences	Study of user perspectives on digital interventions that affect user knowledge, attitude and behavior
Cost-effectiveness	Study describing the analysis of the costs of the intervention

Supplementary Table 4
Population, Concept, and Context of Included Articles (n=105)

First Author, Year	Objective	Study Design	Country	Frailty			Population	Concept	Context		
				FA	VFS	FS			Context	LTH	CHR
Participants With Cognitive Impairment and Disability and Other Conditions (1 Study)											
Magnusson,[1] 2005	Cost analysis of multimedia caring program for frail older people	CR	Sweden	No	No	—	Frail individuals in 5 families	A range of multimedia caring programs via TV sets and subsequently via personal computers	Community (with home care)	Yes	Stroke, Parkinson's disease, neurologic disorder
Participants with cognitive impairment and disability without other conditions (1 study)											
Gray,[2] 2016	Inspect the practical use and long-term continuity of teleconsultation service model for older patients in small rural hospitals	LS	Australia	Yes	Yes	FI	39,000 individuals, mean age 80 y, 53% with cognitive impairment, 75% had disability and a mean FI = 0.44.	Web-based clinical decision support system (CeGA Online platform)	Clinical	Yes	—
Magnusson,[3] 2002	Assessment of an information and communication technology for supporting family and people living with frailty	QR	Sweden, England, Ireland, and Portugal	No	No	—	1838 individuals including family carers and frail older members, age groups range from <20 y to >80 y	A small set-top box (equivalent to a small multimedia personal computer, with CD-ROM and a videoconferencing card)	Community (with home care)	Yes	—
Participants With Cognitive Impairment and Other Conditions (3 Studies)											
Glascock,[4] 2006	Examine the home-based monitoring technology used by caregivers to provide timely response to emergency and better care to older clients	VAL	USA	No	No	—	7 individuals (age range 43-73 y) with unclear frailty status	An automated behavioral monitoring system (ABMS), including Base Station and wireless motion detectors	Community (home)	Yes	Multiple illnesses
Makai,[5] 2014	Assess the effect on disability of using an online community service compared to people who did not use the service.	MM	NL	Yes	Yes	FI	179 frail individuals with mean age 81.69 y, SD 5.38	A personal online health community network for multidisciplinary communication	Community (home)	Yes	Multiple illnesses
Reeder,[6] 2013	Evaluate patient satisfaction with a care program consisting of an automated telehealth device and a nurse coordinator.	VAL	USA	YOD	No	—	96 frail individuals with mean age 80 y, SD 7.93	Medication dispenser (pillbox)	Community (home)	Yes	Diabetes, depression, COPD, and heart disease
Participants With Cognitive Impairment Without Other Conditions (12 Studies)											
Delmastro,[7] 2019	Evaluate the acceptability of care solutions for the older population living in retirement homes, consisting of e-health and m-health services	QR	Italy	YOD	No	—	10 frail individuals with mean age 80.4	A mobile application for nutrition, a portable electroencephalogram headset, a Nintendo Wii Balance Board, a chest strap for cardiorespiratory monitoring, and, an indoor localization system.	Community (with home care)	Yes	—
Ellis,[8] 2009	Enhance the well-being of old population by creating a therapeutic environment of visuals, sound, and vibrations	CR	UK	No	No	—	1 frail individual, age 95 y	Vibro-acoustic sound therapy, using sound beam sensor (ultrasonic distance sensor), sound chair set with 2 loudspeakers, projection screen	Community (nursing home)	Yes	—
Farris,[9] 1995	Observe whether playing computer games improve the recollection ability in the old population	DES	USA	No	No	—	5 frail individuals with age range 70-80 y	The computer game "Memory of Goblins"	Community (nursing home)	Yes	—
Fujiwara,[10] 2017	Trace the cognitive attributes in old population by comparing results from writing tests on tablets	DES	Japan	YOD	No	—	6 frail individuals with age range 77-92 y	Six kinds of spiral tracing tasks (using an active type of stylus pen with a fine nib, the tablet device with a 7-inch touch panel and a 213-dpi resolution)	Not reported	No	—

Petcu,[11] 2017	Examine the acceptance of teleconsultation using intraoral cameras in dental patients	VAL	France	No	No	—	135 individuals with unclear frailty status	An asynchronous teleconsultation, using electric toothbrush, and intraoral camera	Community (nursing home)	Yes	—
Sävenstedt,[12] 2005	Describe experiences of teleconferencing in a nursing home	QR	Sweden	No	No	—	11 individuals with unclear frailty status	Teleconsultations (using a broadband Internet protocol desktop videoconferencing unit with high-resolution image)	Community (nursing home)	Yes	—
Tchalla,[13] 2012	Evaluate the effectiveness of a light path combined with a remote assistance service on falls among frail older people at home	LS	France	Yes	Yes	PHF	94 individuals (mean age 84.9 y, SD 6.5) frail and prefrail	Light path coupled with tele-assistance. The tele-assistance service included a remote intercom, and an electronic bracelet.	Community (home)	Yes	—
Tchalla,[14] 2013	Evaluate the effectiveness of a light path combined with a remote assistance service on falls among people with Alzheimer's disease living at home	RCT	France	Yes	Yes	PHF	96 frail individuals with mean age 86.6 ± 6.5 y, 77% women, living with Alzheimer's disease	A nightlight path and a wire sensor installed on the floor, coupled with tele-assistance service	Community (home)	Yes	—
Werner,[15] 2018	Observe the betterment of navigation among users including frail older people, who were assisted by robotic rollators	RCT	Germany	YOD	No	—	22 frail individuals with mean age 84.1 y, SD 7.7	"Robotic walkers," or "robotic rollators"	Clinical	Yes	—
Zhou,[16] 2017	Analyze the practical use of sensor-based instrumental trial-making task among older population with 3 different cognitive conditions to inspect functional decline	DES	USA	Yes	Yes	PHF	10 individuals with mild cognitive impairment (mean age 85.2, 80% prefrail or frail), 9 individuals with Alzheimer's disease (mean age 80.8 y, 90% prefrail or frail) and 11 healthy individuals (mean age 80.5 y, 55% prefrail or frail)	Instrumented trail-making task platform, using wearable sensor and human-machine interface technology	Clinical	Yes	—
Zhou,[17] 2018	Assess the accuracy of motor planning error by measuring tests of ankle involvement to identify cognitive frailty	VAL	USA	YOD	No	—	32 frail individuals with mean age 77.3 y, SD 9.1	Instrumented trail-making task, low-cost wearable sensor attached to patient's lower shin and interactive interface technology	Clinical	Yes	—
Participants With Cognitive Impairment and Other Conditions (2 Studies)											
Lacey,[18] 1998	Videoconferencing, tele monitoring—2-way audio video	DES	Ireland	No	No	—	8 frail individuals with age range 76-90 y	PAM-AID—walking aid robot	Community (not precise)	Yes	Blind
Upatising,[19] 2013	Perform a randomized controlled trial to assess how home telemonitoring contributes to slowing down the adverse outcomes of frailty process in older community	RCT	USA	Yes	Yes	PHF	194 individuals (mean age 80.4 y, SD 8.3) with different frailty status and chronic conditions, 54.1% women	Telemonitoring	Community (home)	No	Diabetes, heart disease, stroke, chronic obstructive pulmonary disease, cancer, and dementia
Participants With Cognitive Impairment Without Other Conditions (3 Studies)											
Daniel,[20] 2012	Improve the mobility and physical function of older adults by exercise intervention using home-based video game	RCT	USA	Yes	Yes	PHF	23 prefrail individuals with a certain degree of disability and mean age 77 y (SD 5.3), 61% women	A Nintendo Wii, utilizing basic games such as bowling, tennis, and boxing	Community (retirement home)	Yes	—
Hanton,[21] 2017	Observe the smartphone-based measurements of physical activities and compare with standard survey-based tools and clinical performance measures for frailty	VAL	USA	Yes	Yes	PHF	22 robust (age range 50-90 y) and 18 frail (age range 61-100 y) individuals	An intrinsic 3-dimensional (3D) accelerometer, a tablet computer (iPad), Nokia N79 mobile phones	Clinical	Yes	—

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Supplementary Table 4 (*continued*)

First Author, Year	Objective	Study Design	Country	Frailty			Population	Concept	Context		
				FA	VFS	FS			Context	LTH	CHR
Szturm,[22] 2011	Randomized controlled study to show how interactive game-based exercise program improve balance and mobility in the older frail population	RCT	Canada	No	No	—	13 individuals (median age 80.5 y, IQR 65-85) with unclear frailty status	Dynamic balance exercise coupled with computer games.	Community (home)	Yes	—
Participants With Other Conditions (31 Studies)											
Bruns,[23] 2019	Assess the feasibility of a cancer patient rehabilitation program consisting of computer support for physical training and nutritional support	VAL	NL	Yes	Yes	PHF, CFS, SPPB	14 frail individuals with median age 79 y, range 74-86 y	Fit4SurgeryTV program (a daily elderly-adapted computer-supported strength training workout)	Community (home)	Yes	Colorectal cancer
Chumbler,[24] 2004	Compare the differences in disability and motor function between a group of older men who receive a telehealth intervention and a group of older men without intervention	CC	USA	No	No	—	111 frail individuals with mean age 72.7 y, SD 9.3	Telemonitor from American Telecare with 2-way audio-video connectivity, a videophone with 2-way audio-video connectivity without biometric monitoring	Clinical	Yes	Hypertension, diabetes, respiratory, and heart disease
Comín-Colet,[25] 2015	Assess the impact of adding telemedicine to a multidisciplinary heart failure care program	RCT	Spain	YOD	No	—	81 frail and nonfrail individuals (mean age 74 y, SD 11) including 24% of frail people	Telemedicine platform (telemonitoring and teleintervention using videoconference, audio-conference, or telephone)	Clinical	Yes	Heart failure
Delmastro,[26] 2018	Enhance the well-being of older frail population through mobile phone, wearable sensors, and tablets to provide customized monitoring and rehabilitation care	QR	Italy	YOD	No	—	10 frail individuals (mean age 80.4 y) with unclear frailty status	A mobile application for nutrition, a portable electroencephalogram headset, a Nintendo Wii Balance Board, a chest strap for cardiorespiratory monitoring, a smartphone/tablet collecting sensor data, and an indoor localization system	Community (with home care)	Yes	Mild cognitive impairment
Donesky,[27] 2017	Examine the results of home-based tele-yoga program via videoconferencing for patients with chronic lung and heart conditions	QE	USA	No	No	—	7 individuals (mean age 73 y, SD 14.3) with unclear frailty status	Multipoint videoconferencing via DocBox technology (a hard drive box connected to the participant's television and remotely controlled by a technician)	Community (home)	Yes	Chronic obstructive pulmonary disease and heart failure
Duke,[28] 2005	Investigate the effects of a community medical and educational program, including telehealth, in reducing or preventing the frailty of older people in the community	CRS	USA	No	No	—	107 frail individuals older than 65 y of age	A tele-health unit that is the size of a breadbox and allows regular physical assessments in the convenience of one's home by providing 2-way audio and visual interface	Community (with home care)	Yes	Chronic illnesses
Finkelstein,[29] 2006	Assess the acceptability of a home telecare program among frail individuals	QR	USA	No	No	—	25 frail individuals with mean age 80.3 y, SD 6.6	PC platform with a broadband connection, videoconferencing software, and a web camera, videoconferencing unit, blood pressure cuffs, pulse oximeters, spirometers, glucometers, and scales	Community (home)	Yes	One or more chronic conditions

Finkelstein,[30] 2011	Assess a home telecare service in frail older participants compared with usual care	RCT	USA	YOD	No	—	40 frail individuals with average age of those completing the study, 79 y (range 60-99 y)	Web portal that facilitated subjects' access to health education resources, a telehealth nurse, and electronic ordering of various health and community services	Community (home)	Yes	One or more chronic conditions, had functional limitations
Ganea,[31] 2011	Appraise the different parameters in postural changes of older population by a portable sensor-based monitoring system	VAL	Switzerland	Yes	Yes	PHF	79 frail individuals with mean age 80 y, SD 7.1	A monitoring system composed of a small inertial sensor and a light portable data-logger carried on the waist	Clinical	Yes	Post-acute rehabilitation
Gokalp,[32] 2018	Assess the feasibility of an integrated health care system using sensors in frail older people at home	DES	UK	Yes	Yes	EFS	36 frail individuals with mean age 82 y, SD 10	A home gateway, a remote server to store patient data, and a clinician portal to view and manage patient data and records. Gateway and sensors: pulse oximeter, motion sensor, bed sensor, glucose meter, weight scale, medication dispenser, blood pressure meter	Community (home)	Yes	Respiratory disease and cardiac failure
Jaatun,[33] 2015	Establish the user insights from computerized pain body map which is developed to assess pain in frail cancer patients	DES	Norway	No	No	—	Four groups of frail individuals, 9 with mean age 60 y, 9 with mean age 77 y, 10 with mean age 59 y, 8 with mean age 63 y	Computerized pain body map (CPBM) on laptop and iPad	Clinical	Yes	Advanced cancer patients
Lee,[34] 2018	Assess a frailty diagnostic algorithm using a device worn on the wrist	CRS	USA	Yes	Yes	TS-FI	100 frail individuals with mean age 78.9 y, SD 9.1	A single wrist wearable sensor (gyroscope device)	Clinical	No	Geriatric inpatients
Makai,[35] 2014	Evaluate the differences in use and facilitators of use in using an online health and wellness portal for frail people	QE	NL	Yes	Yes	FI	290 frail individuals with mean age 82.13 y, SD 5.77	Online health community (secure messaging system supplemented by a shared electronic health record)	Community (home)	Yes	Multiple illnesses
Moreau-Gaudry,[36] 2005	Introduce an easy-to-use bedside instrument to inspect swallowing in the older population in the hospitals	VAL	France	No	No	—	14 individuals (age range 75-100 y) with unclear frailty status	Computer-assisted respiratory inductance plethysmography (RIP) system (which includes sensor in elasticized jacket that could easily be worn by the patients over their usual clothing)	Clinical	No	Geriatric inpatients
Mulasso,[37] 2019	Compare the accuracy of a mobility index measured with a remote monitoring device with the gold standard measure (traditional physical functioning measures)	CRS	Italy	Yes	Yes	TFI	25 frail and nonfrail individuals with mean age 71 y, SD 6; 56% were frail	ADAMO system (includes a base station, and a care watch with sensors, ie, triaxial accelerometer)	Community (home)	No	One or more chronic diseases
Najafi,[38] 2013	Demonstrate the wearable technology by using sensors for monitoring mobility and estimating risk of falls in the older community, especially with diabetes	VAL	USA	YOD	No	—	8 individuals (mean age 77 y, SD 7) with unclear frailty status	A physical activity monitoring system that includes a lightweight, small sensor unit and an embedded battery, which allows recording of data on a memory unit	Not reported	No	Diabetes with peripheral neuropathy
Nathwani,[39] 2020	Assess the feasibility, usability, and acceptability of a tablet for evaluating frailty	QE	USA	Yes	Yes	FI	165 frail and nonfrail individuals with mean age 72 y, SD 6.5	A platform (collects both ePRO and clinical data, which are processed by a rules engine that enables display of results back to clinicians in a dynamic summary)	Clinical	Yes	Multiple Myeloma

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Supplementary Table 4 (*continued*)

First Author, Year	Objective	Study Design	Country	Frailty			Population	Concept	Context		
				FA	VFS	FS			Context	LTH	CHR
Barbosa Neves,[40] 2019	Explore the practical issues, user experience, and outcomes of a communication application among the older population	QR	Canada	Yes	Yes	PHF	13 frail individuals with mean age 82.5 y, range 74-95 y	An accessible iPad-based communication app that supports older adults' asynchronous communication with family and friends	Community (retirement home)	No	Multiple conditions (vision, auditory problems, etc)
Orlandoni,[41] 2016	Examine the improvement among older frail population on home enteral nutrition, guided by hospital nutritionists via tablet-based videoconference	RCT	Italy	No	No	—	100 frail individuals with mean age 86.5 y, SD 7.0	Video consultation by the Clinical Nutrition physician (with a Samsung Galaxy tablet)	Community (with home care)	Yes	Receiving home enteral nutrition
Orsini,[42] 2017	Enhance the well-being and health knowledge of older population living with HIV through web-based and smartphone application	QE	Italy, Spain, Australia, Hong Kong	Yes	Yes	FI	115 HIV-positive patients older than 50 y of age. FI was performed but frailty status was not reported.	Wearable device including steps, energy expenditure and sleep, electronic patient-reported outcomes (ePRO) collected with smartphones.	Clinical	Yes	People living with HIV
Porath,[43] 2017	Assess the effects of a telecare service on frail population compared with frail individuals who did not use the service	QE	Israel	YOD	No	—	389 frail individuals with mean age 79.6 y, SD 7.4	Unified Communication System (to conduct audio and video calls with patients), tele-medical sensors, such as tablets and transmitting glucometers, electronic pill organizers	Clinical	Yes	Three or more active chronic diseases
Queyroux,[44] 2017	Evaluate the accuracy of a telehealth diagnostic tool in dentistry vs direct examination as a gold standard	CRS	France and Germany	No	No	—	235 individuals (mean age 84.4 y, SD 8.3) with unclear frailty status	Tele-dentistry intervention (using a Tele Pack X endoscope with a cold light source, integrated camera, and digital video recorder)	Community (nursing home)	Yes	Oral or dental complaints
Ramezani,[45] 2019	Analyze the association of a combination of physical activity measurement and indoor location characteristics with readmission to hospital	CRS	USA	No	No	—	154 individuals in the community (mean age 82.16 y, SD 9.55) and in the hospital (mean age 84.22 y, SD 13.87), with unclear frailty status	A 3-axial accelerometer, indoor localization using Bluetooth low-energy sensors known as BLE beacons in smartwatch	Community and Clinical	No	Admitted to a subacute rehabilitation center for 21 d
Seiffert,[46] 2018	Analyze the frailty assessment of frail older patients by using tablet-based manual dexterity test	QE	Poland	Yes	Yes	PHF	14 frail individuals with mean age 83 y, SD 7, range 62-93	Physical obstacle, superimposed over a tablet screen and a software application, displaying 2 fields on the tablet screen and acquiring the measurements	Clinical	No	Geriatric inpatients
Singer,[47] 2018	Assess the feasibility of treating frailty in lung transplant candidates with an m-health home technology program	QE	USA	Yes	Yes	PHF and SPPB	15 frail individuals with mean age 62.9 y, SD 5.7	An application platform installed in tablets or smartphones	Clinical	Yes	Lung transplant candidates
Soangra,[48] 2018	Analyze the association of walking speed and postural variables using sensors integrated in a smartphone with adverse postoperative outcomes	CRS	USA	YOD	No	—	16 individuals including both frail (mean age 76.38 y, SD 4.03) and robust (mean age 76, SD 3.55)	Inertial sensors embedded inside smartphones (Apple iPhone 5); "Lockhart Monitor" application to collect data	Clinical	No	CVD
Takahashi,[49] 2012	Analyze the effect on hospitalizations of a telemonitoring intervention in frail elderly people compared to usual care	RCT	USA	Yes	Yes	FI	102 frail individuals with mean age 80.3 y, SD 8.9	Intel Health Guide, a device that had real-time videoconference capability. Peripheral devices (scales, blood pressure cuff, glucometer, pulse oximeter, and peak flow). A health website.	Community and clinical	Yes	Multiple comorbidities (respiratory, diabetes, heart failure and renal)

Toh,[50] 2015	Observe whether teleconsultation using videoconferencing technology can bring down hospital admission in older population in nursing home	QE	Singapore	No	No	—	245 individuals (mean age 75 y) with unclear frailty status	Telemedicine consultation by 2-way videoconferencing (included a high-resolution camera and high-definition video monitor)	Community (nursing home)	Yes	Multiple conditions
Tomita,[51] 2007	Randomized controlled study on usability and benefits of the smart home technology for older population with chronic illnesses	RCT	USA	No	No	—	34 individuals (mean age 72 y, SD 6), with unclear frailty status	Stand-alone products, including door and window sensors, a motion sensor, a power flash, and a wall switch for manual control for lighting connected to a motion detector	Community (home)	Yes	Chronic health conditions without cognitive impairment
Tong,[52] 2016	Observe the practicality of frailty assessment by tablet-based software for older population in emergency care	VAL	Canada	Yes	Yes	CGA-FI and CFS	325 individuals (mean age 75.8 y, SD 7.6) with unclear frailty status	Software suite that includes digital versions of existing frailty and functional assessments, installed in 10.1-inch screen tablets manufactured by Samsung	Clinical	No	Needed emergency assistance
Wade,[53] 2012	Examine the reasons for the failures of a telehealth program for an older and frail population	RCT	Australia	No	No	—	43 individuals including clients and carers (mean age 81 y), with unclear frailty status	A telehealth equipment, a Tunstall monitor, programed with questions for the participants, 4 peripherals accompanied the telehealth equipment; these measured weight, blood pressure, heart rate and oxygen.	Community (home)	Yes	Chronic disease and at risk of being admitted into residential care
Participants Without Other Conditions, Cognitive Impairment or Disability (52 Studies)											
Almeida,[54] 2018	Appraise the performance of a monitoring system and data management system for older population	DES	Greece, UK, Italy, France, Singapore, Spain	No	No	—	24 individuals with unclear frailty status	Personal Data Capturing System (using a Samsung A5 2017 smartphone, and application "Android City4Age App" that collects data related to body motility and indoor/ outdoor localization)	Community (home)	No	—
Berner,[55] 2016	Describe the user experience with a tablet and Skype for frail and older participants	QR	Sweden	No	No	—	15 frail individuals with age range 69-87	Skype on the tablet PC(iPad), which is a free communication application with video	Community (home)	No	—
Beukema,[56] 2017	Examine the preferences of older people for online messages regarding health screening	QR	NL	Yes	Yes	GFI	10 nonfrail, 10 prefrail, and 10 frail individuals with mean age 69.5 y (SD 2.9), 71 y (SD 2.5), and 69.9 y (SD 3.5), respectively	Online messages with the results of a health screening	Community (home)	No	—
Cabrita,[57] 2017	Discover the link between daily mobility and pleasure among everyday life of the older population by using sensors and smartphones during 30 consecutive days	LS	NL	Yes	Yes	GFI	10 individuals, including 1 prefrail and 9 nonfrail, with mean age 68.7 y, SD 5.5	The Activity Coach, a system composed of a hip-worn 3-axial accelerometer and a smartphone application	Community (home)	No	—
Castro,[58] 2015	Introduce mobile phone sensing to collect data for behaviors among older population	VAL	Mexico	Yes	Yes	PHF	15 individuals, including 4 frail and 11 nonfrail, with mean age 75.3 y, SD 1.8	The InCense mobile phone sensing toolkit (include a graphical user interface sensors)	Community (home)	No	—
Chang,[59] 2013	Develop a wireless system with automatic analysis based on artificial intelligence to measure the frailty of older population	CRS	Taiwan	Yes	Yes	PHF	160 individuals (>65 y of age). Frailty was evaluated but not reported.	eFurniture (eScale, an eChair, an ePad, an eReach, and electronic questionnaire)	Clinical	No	—

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Supplementary Table 4 (*continued*)

First Author, Year	Objective	Study Design	Country	Frailty			Population	Concept	Context		
				FA	VFS	FS			Context	LTH	CHR
Chkeir,[60] 2016	Observe the balance quality assessment as a potential indicator of frailty in older population	CRS	France	Yes	Yes	PHF	24 frail, 98 prefrail, and 64 nonfrail individuals with mean age of 79.2 ± 5.9 y for females, and 77.8 ± 5.0 y for males	Balance Quality Tester, a device based on a commercial bathroom scale	Community (not precise)	No	—
Chkeir,[61] 2019	Compare the measures of frailty obtained by a technological set with the traditional measures used for the calculation of the Fried frailty score	CRS	France	Yes	Yes	PHF	194 individuals (mean age 78.9 y, SD 5.7). Frailty was evaluated but not reported	Balance Quality Tester, a "Grip-ball" sensor, questionnaires included in the tablet	Clinical	No	—
De Cola,[62] 2020	Assess the feasibility of a telemedicine service and its association with demographics and type of service	DES	Italy	No	No	—	131 individuals (mean age 79.8 y, SD 5.3) with unclear frailty status	PHOEBO tool (web-based platform with various application modules: eVoMed to monitor biometric data, eVoCall for audio-videoconference sessions)	Community (home)	No	—
Ezumi,[63] 2003	Compare peer support via videophone in frail older people living at home with frail older people who do not make video calls	QE	Japan	No	No	—	14 frail individuals with mean age 80.8, SD 1.04	Videophones (Phoenix mini, made by Nippon Telegraph and Telephone) connected by a single ISDN line	Community (with home care)	Yes	—
Fontecha,[64] 2013	Build a smartphone technology for frailty assessment of older population	CRS	Spain	Yes	Yes	FI	20 individuals, 50% women with mean age 83.6 y, SD 4.0. Frailty was assessed but not reported.	Centralized mobile system using mobile phone capabilities	Community (retirement home)	No	—
Fontecha,[65] 2013	Introduce a smartphone-based technology for physicians for frailty assessment in the older population	CRS	Spain	Yes	Yes	FI	20 individuals, 50% women, age range 75-90 y. Frailty was assessed but not reported.	Accelerometer-enabled mobile devices, mobile application	Community (retirement home)	No	—
Galan-Mercant,[66] 2013	Assess variability of an instrumented smartphone application to measure physical movements during the timed get up and go test in frail and nonfrail participants	CRS	Spain	Yes	Yes	PHF	14 frail (mean age 83.7 y, SD 6.4) and 16 nonfrail (mean age 70.3 y, SD 3.3) individuals	A gyroscope, a magnetometer, and an accelerometer	Community (nursing home)	No	—
Galán-Mercant,[67] 2015	Identify the most discriminating kinetic variables for frailty classification from accelerometers	CRS	Spain	Yes	Yes	PHF	14 frail (mean age 83.7 y, SD 6.4) and 16 nonfrail (mean age 70.3 y, SD 3.3) individuals	Inertial sensors embedded in an iPhone 4, xSensor Pro application	Community (not precise)	No	—
Ganea,[68] 2007	Introduce a new way of measuring postural changes in old population by portable motion sensors	DES	Switzerland	No	No	—	30 frail individuals with mean age 80.7 y, SD 6.6	Inertial sensor fixed on the trunk (chest) and a light portable data-logger carried on the waist	Clinical	No	—
Ganea,[69] 2012	Propose a single wearable sensor-based method to monitor postural changes in frail older community	VAL	Switzerland	Yes	Yes	PHF	10 frail individuals with mean age 81.3 y, SD 4.76	ASUR, Autonomous Sensing Unit Recorder (includes a 2D accelerometer, a 1D gyroscope, and electronics (memory, batteries), allowing 8 h of continuous data logging)	Clinical	No	—
Geraedts,[70] 2017	Assess the feasibility of a home exercise program including a tablet and a sensor for community-dwelling older adults	LS	NL	Yes	Yes	GFI	40 frail individuals with mean age 81 y, SD 4.6	Necklace-worn sensor, accelerometer, a barometric pressure sensor and an exercise program in a tablet	Community (home)	No	—

Gianaria,[71] 2016	Develop sensor-based technology, which precisely measures gait and posture indexes to assess the onset of frailty syndrome in an older population	DES	Italy	Yes	Yes	TFI	30 individuals (mean age 75.6 y, SD, 7.5); 43% were nonfrail and 57% frail	Microsoft Kinect RGBD sensor	Community (home)	No	—
Goh,[72] 2019	Introduce the Bluetooth-interface monitoring system, which can be widely implemented with low-budget, for community-dwelling older population who are frail and lives alone	VAL	Singapore	No	No	—	81 individuals (older than 50 y of age) with unclear frailty status	Bluetooth low-energy (BLE) beacons, Android mobile application, the MQ Telemetry Transport, web monitoring dashboard, system monitoring framework	Community (home)	No	—
Gonzalez,[73] 2016	Assess walking parameters with a device worn at the waist in 2 groups of people: frail and healthy	DES	Spain	No	No	—	5 prefrail and 5 nonfrail individuals with mean ages 85 y (SD 2.7) and 29 y (SD 2.8) respectively	Internet of Things infrastructure for gait characterization (includes a set of wearable inertial sensors (nodes) connected to the same wireless local area network [WLAN])	Not reported	No	—
Gonzalez,[74] 2019	Investigate gait characteristics measured with a sensor associated with frailty and cognition	CRS	Spain	Yes	Yes	PHF	81 frail individuals over 75 y of age	The mobile phone, equipped with a LSM330 digital triaxial accelerometer and digital triaxial gyroscope	Community (nursing home)	Yes	—
Greene,[75] 2014	Assess a body-worn device for physical functioning diagnosis	CRS	Ireland	Yes	Yes	PHF	124 frail and prefrail individuals with mean age 75.9 y, SD 6.6	A touchscreen mobile assessment platform using wireless inertial and pressure sensors	Community (home)	No	—
Hagedorn,[76] 2010	Analyze the results between balance trainings, with or without a computer feedback system using computer games and infrared sensors	RCT	Denmark	Yes	Yes	FI	27 frail individuals (mean age 81.3 y, SD 6.9), 67% women	A computer game with feedback system (included computer connected to 3 infrared sensors)	Clinical	No	—
Hassani,[77] 2017	Analyze signals from sensors by interpreting the results of the Timed Up and Go test to detect frailty symptoms	DES	France	YOD	No	—	12 frail and robust individuals with age range 26-50 y	Kinect sensor	Clinical	No	—
Hernandez,[78] 2015	Introduce a mobile application that can predict the physical tiredness felt by older people during walking	DES	Mexico	No	No	—	3 individuals (mean age 68 y, SD 6.1) with unclear frailty status	An electrical pulse reader to monitor heart rate and 2 cell phones with a 3-axes accelerometer. A mobile application that allows the user to report their perception of physical fatigue.	Not reported	No	—
Hui,[79] 2001	Assess the satisfaction of residents and nursing home staff with a telemedicine service	VAL	Hong Kong	No	No	—	Frail patients	Teleconferencing system with real-time, 2-way audio-video link. A high-resolution portable camera for better visualization of skin lesions	Community (nursing home)	Yes	—
Lin,[80] 2016	Introduce a set of devices with wireless sensor network to investigate frailty in old population at home	DES	Taiwan	Yes	No	—	309 individuals, <65 y of age, with unclear frailty status	Home-based wireless frailty detection system (eScale, ePad, eChair, and eReach wireless devices, and the integrated measurement system: includes wireless routers and the Home-Gateway)	Not reported	No	—

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Supplementary Table 4 (*continued*)

First Author, Year	Objective	Study Design	Country	Frailty			Population	Concept	Context		
				FA	VFS	FS			Context	LTH	CHR
Man,[81] 2015	Develop an interactive computerized software that contains a variety of functions to provide older frail populations with information and communication support	DES	NL	No	No	—	33 individuals (age range 65-88 y) with unclear frailty status	A telecommunication platform (an interactive software on a standard PC)	Community (home)	No	—
Martinikorena,[82] 2016	Observe how muscle condition and functionality relate to the changes, frequency, and balance in gait performance of frail older population	DES	Spain	Yes	Yes	PHF	24 frail individuals with mean age 93.1 y, SD 3.6	An inertial Orientation Tracker MTx (combination of 9 individual Micro-Electro-Mechanical System [MEMS] sensors)	Community (nursing home)	Yes	—
McCullagh,[83] 2017	Evaluate the accuracy of a step counter in frail patients	CRS	Ireland	Yes	Yes	FI	32 inpatients with different frailty status (frail, prefrail and, nonfrail), mean age 78.1 y, SD 7.8	3 motion sensors (an ankle-worn accelerometer, a thigh-worn accelerometer, and a pedometer)	Clinical	No	—
Mengoni,[84] 2015	Create a supportive workplace for older workers who use computerized machines with an adaptive user interface (AUI)	CS	Italy	YOD	No	—	5 individuals (age range 60-65 y) with unclear frailty status	An augmented reality application, an augmented adaptability intelligence on the server, a Java virtual machine	Community (home)	No	—
Millor,[85] 2013	Evaluate and enhance the measurement of parameters by 30-s Chair Stand Test in older community by using motion sensors	DES	Spain	Yes	Yes	PHF	13 frail (mean age 85 y, SD 5), 16 prefrail (mean age 78 y, SD 3) and 18 nonfrail individuals (mean age 54 y, SD 6)	An inertial orientation tracker MTx (3 degree-of-freedom [DOF] human orientation tracker)	Community (home)	No	—
Millor,[86] 2013	Perform automatic appraisal of the results from 30-s Chair Stand Test by body-fixed motion sensors	DES	Spain	Yes	Yes	PHF	26 prefrail individuals with mean age 83.16 y, SD 4.32	An inertial MTx Orientation Tracker	Not reported	No	—
Mokhtari,[87] 2014	Examine the user behavior regarding assistive low-cost nonintrusive sensors available in the market	DES	France, Singapore	No	No	—	246 survey participants including 123 frail older people	Low-cost and nonintrusive sensors (motion sensors, contact sensors) with an Internet-connected gateway	Community (home)	No	—
Nakajima,[88] 2011	Use of sensor-featured shoe device to measure mobility among subjects of different age groups and frailty status	DES	Japan	No	No	—	270 frail and 228 robust individuals with mean age 74 y, SD 4.7	The shoe device consists of insoles for shoes with 7-point pressure-sensitive conductive rubber sensors and wireless communication units	Community (not precise)	No	—
Neves,[89] 2018	Introduce the communication application for older population for social interaction	MM	Canada	No	No	—	5 frail individuals with mean age 87.2 y, SD 4.8, range 81-93	An accessible Android tablet-based communication app (supports asynchronous communication, enabling users to send a "wave," audio, video, and images captured with the tablet)	Community (nursing home)	Yes	—
Noury,[90] 2004	Monitor the daily motor activities of older population by sensor-based system	DES	France	No	No	—	5 individuals with unclear frailty status	The Kinemeter (includes 3 accelerometers and 3 magnetometers)	Clinical	No	—
Pedroli,[91] 2018	Evaluate the feasibility of a virtual reality system combining physical and cognitive therapy for frail people	VAL	Italy	No	No	—	5 individuals (mean age 70 y, SD 11.7) with unclear frailty status	A cycle-ergometer, a board connecting the button to the computer and an Xbox controller. A Cave Automatic Virtual Environment, a room-sized cube with 3D visualization, and a tracking system.	Not reported	No	—

Portet,[92] 2013	Evaluate the user acceptance and discover their concerns over assisted smart home technology using voice command	DES	France	No	No	—	8 older individuals (mean age 79 y, SD 6), 7 relatives and 3 caregivers with unclear frailty status	DOMUS smart-home voice command/audio processing, videoconferencing, alert system, shared electronic calendar	Community (home)	No	—
Quintana,[93] 2019	Describe the models for using an online platform for older people and their families	CS	USA	No	No	—	162 individuals including older people (mean age 75.5 y) and caregivers (mean age 56.6 y) with unclear frailty status	The InfoSAGE website, a free-to-use Internet platform	Community (home)	No	—
Ramdani,[94] 2013	Use of recurrence quantification analysis in investigating postural changes among both fallers and nonfallers in older community	DES	France	No	No	—	14 individuals (mean age 81.1 y, SD 9.1) with unclear frailty status	A force platform where the signals are converted to digital form	Community (nursing home)	Yes	—
Robben,[95] 2012	Describe the outcomes, barriers, and enablers of a health and wellness information portal for frail older individuals	MM	NL	Yes	Yes	ETOS	290 frail older individuals (mean age 81.2 y, SD 5.7) and 158 health care professionals	Health and Welfare Information Portal (ZWIP), a shared Electronic Health Record combined with a communication tool for community-dwelling frail older people and primary care professionals	Community (home)	No	—
Soaz,[96] 2015	Enhance the monitoring of gait parameters in older population by an acceleration sensor, placed inside a belt buckle	VAL	Spain	YOD	No	—	31 individuals including 10 adults (mean age 37.3 y, SD 18.5, age range 22-64 y) and 21 seniors (mean age 82.2 y, SD 6.3, age range 67-90 y)	Acceleration sensor, placed inside a belt buckle and high-speed video camera	Community (nursing home)	Yes	—
Wolf,[97] 2003	Compare the outcomes (physical, mobility, mental and social markers as well as frequency of fall accidents) from 2 different exercises participated by old population	RCT	USA	YOD	No	—	72 individuals (mean age 76.9 y, SD 4.8) and 64 individuals (mean age 76.3 y, SD 5.1)	A computerized balance system	Community (retirement home)	No	—
Subbe,[98] 2014	Introduce an electronic triage system in acute medical unit to facilitate the categorization of low risk patients	QE	UK	Yes	Yes	CFS	3680 individuals (mean age 65.25 y, SD 20.37) with different frailty status	An Electronic Point of Care (EPOC), which is a computer-assisted triage system	Clinical	No	—
Tan,[99] 2019	Evaluate homes with sensors to detect seniors at risk	DES	Singapore	No	No	—	2 individuals (reported age 70 and 80 y) with unclear frailty status	Sigfox-powered sensor-enabled homes (includes UnaMotion sensor and a UnaProtect sensor)	Community (home)	No	—
Tegou,[100] 2019	Evaluate an indoor locating system for accuracy in room estimation and for ability to assess frailty	VAL	Greece, Cyprus, France	Yes	Yes	PHF	117 nonfrail, 131 prefrail, and 23 frail individuals with mean ages of 76.8 ± 5.2 y (males) and 76.7 ± 5.4 y (females)	Indoor localization system including a small passive Bluetooth low-energy devices, an application for setting up the localization installation and collecting RSS fingerprints, an application for real time, and a cloud service	Community (home)	No	—
Tsai,[101] 2013	Examine the user acceptance and perception toward fitness testing platform in an assisted living community	VAL	USA	No	No	—	101 individuals (mean age 79.6 y, SD 7.5) with unclear frailty status	A fitness testing platform (integrates wireless remote sensors in a virtual reality games)	Community (retirement home)	No	—
Tsipouras,[102] 2018	Use of Bluetooth localization technology to measure mobility of older frail population at home	VAL	Greece, Cyprus, France	Yes	Yes	PHF	26 nonfrail, 27 prefrail and 20 frail individuals with mean age of 77.5±5.3 y (males) and 78.8±5.7 y (females)	Bluetooth localization with a smartphone as the tracking device	Community (home)	No	—

(continued on next page)

Supplementary Table 4 (*continued*)

First Author, Year	Objective	Study Design	Country	Frailty			Population	Concept	Context		
				FA	VFS	FS			Context	LTH	CHR
Versleijen,[103] 2015	Compare the costs of a tele −geriatric service model with the costs of the usual service	CR	NL	No	No	—	35 individuals with unclear frailty status	Mobile videoconference system (fixed videoconferencing device at studio end, mobile device at remote end)	Clinical	No	—
Dekker-van Weering,[104] 2017	Compare the use, user experience, and quality of life of prefrail older adults who received an intervention from an online exercise program vs a similar group of participants who did not receive the intervention	RCT	NL	Yes	Yes	GFI	36 prefrail individuals with mean age 70.9 y (SD 3.5) and 69.2 y (SD 3.8) (control and intervention group)	Technology-supported self-management exercise program using computer/ tablet	Community (home)	No	—
Zhang,[105] 2015	Examine the clinical applicability of sensor-based chair rise performance test in frail older population	VAL	NL	Yes	Yes	GFI	25 frail individuals with mean age 79.7 y, SD 5.7	The pendant sensor (consists of a 3D accelerometer and an air pressure sensor), a micro-SD card inside the device	Community (retirement home)	No	—

CC, case-control study; CFS, Clinical Frailty Scale; CGA-FI, Comprehensive Geriatric Assessment (Frailty Index); CHR, chronic condition; CR, case-report study; CRS, cross-sectional study; CS, case-series study; CTX, context; DES, descriptive exploratory study for new methodology or technology; EFS, Edmonton Frail Scale; ETOS, Easycare-TOS; FA, frailty assessment; FI, Frailty Index; FS, frailty score name; GFI, Groningen Frailty Indicator; LS, observational longitudinal study; LTH, long-term health care; NL, the Netherlands; MM, mixed methods; PAM-AID, personal adaptive mobility aid; PHF, Phenotype of Frailty; QE, quasi-experimental; QR, qualitative research; RCT, randomized controlled trial; RSS, received signal strength; SPPB, Short Physical Performance Battery; TFI, Tilburg Frailty Indicator; TS-FI, Trauma-Specific Frailty Index; VAL, validation study; VFS, validated frailty score; YOD, Yes, but using their own definition (not validated frailty score).

Supplementary Table 5
Newcastle-Ottawa Scale Assessment of Cross-Sectional Studies

Author, Year	Selection (Maximum 5 Stars)				Comparability (Maximum 2 Stars)	Outcome (Maximum 3 Stars)		Total Stars
	Representativeness of the Sample	Sample Size	Nonrespondents	Ascertainment of the Exposure (Risk Factor)		Assessment of the Outcome	Statistical Test	
Chang,[59] 2013				§		§§		3
Chkeir,[60] 2016				§§		§§		4
Chkeir,[61] 2019	§			§§		§§		5
Duke,[28] 2005	§							1
Fontecha,[64] 2013				§		§§		3
Fontecha,[65] 2013				§		§§		3
Galan-Mercant,[66] 2013	§			§§		§§	§	6
Galán-Mercant,[67] 2015	§			§§		§§	§	6
Gonzalez,[74] 2019	§			§§	§	§§	§	7
Greene,[75] 2014	§			§§	§	§§	§	7
Lee,[34] 2018	§			§§		§§	§	6
McCullagh,[83] 2017	§			§§		§§	§	6
Mulasso,[37] 2019	§			§§	§	§§	§	7
Queyroux,[44] 2017		§		§		§§	§	5
Ramezani,[45] 2019				§		§§	§	4
Soangra,[48] 2018				§		§§	§	4

Supplementary Table 6
Newcastle-Ottawa Scale Assessment of Longitudinal Studies

Author, year	Selection (Maximum 4 Stars)				Comparability (Maximum 2 Stars)	Outcome (Maximum 3 Stars)			Total Stars
	Representativeness of the Intervention	Selection of the Nonintervention	Ascertainment of Intervention	Outcome of Interest Was Not Present at Start of Study		Assessment of the Outcome	Length of Follow-Up	Adequacy of Follow-Up	
Geraedts,[31] 2017	§		§	§		§	§	§	6
Gray,[38] 2016			§			§	§		3
Tchalla,[90] 2012	§	§	§	§	§§		§	§	8
Cabrita,[5] 2017			§		§				2

Supplementary Table 7
PRISMA-ScR Checklist

Section	Item	PRISMA-ScR Checklist Item	Reported on Page No.
title			
Title	1	Identify the report as a scoping review.	Front page
Abstract			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	1
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (eg, population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	3
Methods			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (eg, a Web address); and if available, provide registration information, including the registration number.	4
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (eg, years considered, language, and publication status), and provide a rationale.	4, Supplementary Table 1
Information sources*	7	Describe all information sources in the search (eg, databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	4
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Supplementary Table 2
Selection of sources of evidence†	9	State the process for selecting sources of evidence (ie, screening and eligibility) included in the scoping review.	4
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (eg, calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	4-6
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	5-7, Supplementary Table 3
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	7
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	8-10, Figures 2 and 3; Tables 1 and 2; Supplementary Figures 1 and 2
Results			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	7, Supplementary Figure 1
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	07.sept
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	9-10, Supplementary Figure 3, Supplementary Tables 4 and 5
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	8-10 and Supplementary Table 3
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	8-10, Figure 2, 3, 4; Table 1 and 2, Supplementary Figures 1 and 2 Supplementary Table 4
Discussion			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	11-13
Limitations	20	Discuss the limitations of the scoping review process.	14
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	14
Funding			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	Title page

JBI, Joanna Briggs Institute; PRISMA-ScR, Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.
Source: Tricco AC, Lillie E, Zarin W, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med 2018;169:467–473.

*Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and websites.

†A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (eg, quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡The frameworks by Arksey and O'Malley[6] and Levac and colleagues[7] and the JBI guidance[4,5] refer to the process of data extraction in a scoping review as data charting.

§The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (eg, quantitative and/or qualitative research, expert opinion, and policy document).

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