Home-based exercise programs delivered by digital health interventions for older adults: A systematic review and meta-analysis

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AUTHORIZATION FOR THE PRESENTATION OF THE TFM

Ms. Mercè Sitjà, full professor at FCS Blanquerna-URL,

I CERTIFY

That the final Master's work presented by Aina Gismero with the title Home-based exercise programs delivered by digital health interventions for older adults:A systematic review and meta-analysis

has been carried out under my tutoring and I AUTHORIZE the student to present their final Master's work to qualify for the title University Master's Degree in Therapeutic Physical Activity for People with Chronic Pathology, Aging or Disability.

And for the record for appropriate purposes, I sign this authorization.

Mrs Mercè Sitjà

Barcelona, September 20,2021

TITLE

Home-based exercise programs delivered by digital health interventions for older adults: A systematic review and meta-analysis

SUMMARY

BACKGROUND: The aged population is growing, and clinical practice guidelines widely report recommendations for therapeutic exercise as a central axis of active and healthy ageing. Digital health interventions (DHI) are defined as the different ways in which digital and mobile technologies are used to support health. The situation of the pandemic has increased the use of digital physiotherapy. However, we do not know what its effects on the elderly population, where the digital divide is still a problem that needs to be studied better.

OBJECTIVES: This systematic review aims to evaluate the effectiveness of combined home-based exercise and digital health interventions on physical function in the elderly. Secondly, we evaluated its effects on autonomy, physical activity levels, quality of life, falls, and adherence.

METHODOLOGY: A search was conducted on digital databases to identify randomised or quasi-randomised studies of people aged 65 or over living at home and participating in any therapeutic exercise program using digital health resources. An analysis of the risk of bias was made and meta-analysis was performed only in a few outcomes due to heterogeneity.

RESULTS: 28 studies met the inclusion criteria for systematic effectiveness evaluation. 20 did a physical exercise programs and 8 did physical activity incentivisation programs. 68% of studies reported physical function, and 32% reported physical performance. 75% of studies looked at our secondary outcomes, and 46% presented results on physical activity level.

DISCUSSION: The most usual DHI are phone calls and apps to deliver physical exercise and phone calls and websites to deliver physical activity incentivisation. There is positive evidence of the good adherence of older people to technology.

KEY WORDS: (Physical Therapy Modalities [Mesh]), (exercise [Mesh]), (telemedicine [Mesh]) and (Aged [Mesh].

Registered at PROSPERO [CRD42021192499].

TÍTOL

Eficàcia de les intervencions de salut digital combinada amb exercici terapèutic domiciliari sobre la funció física en les persones grans: revisió sistemàtica i metaànalisis.

RESUM

ANTECEDENTS: La població envellida és cada cop més nombrosa i les recomanacions d'exercici terapèutic com a eix central d'un envelliment actiu i saludable estan àmpliament reportades en les guies de pràctica clínica. Les intervencions de salut digital (ISD) es defineixen com les diferents formes en què s'utilitzen les tecnologies digitals i mòbils per donar suport a la salut. La situació de pandèmia viscuda ha fet créixer la utilització de la fisioteràpia digital. Tot i així, no sabem quins efectes té en la població de la gent gran, on la bretxa digital encara és un problema que cal estudiar millor.

OBJECTIUS: Avaluar l'eficàcia de les intervencions combinades d'exercici terapèutic domiciliari i de salut digital sobre la funció física en les persones grans. Secundàriament, s'han avaluarat els seus efectes sobre l'autonomia, els nivells d'activitat física, la qualitat de vida, les caigudes i l'adherència.

METODOLOGIA: Es va realitzar una cerca a bases de dades digitals per identificar estudis aleatoris o quasi aleatoris de persones de 65 anys o més que vivien a casa i que participaven en qualsevol programa d'exercicis terapèutics mitjançant recursos digitals de salut. S'ha fet una anàlisi del risc de biaix i la metanàlisi només s'ha realitzat en alguns resultats a causa de la gran heterogeneïtat dels estudis inclosos.

RESULTATS: 28 estudis van complir els criteris d'inclusió per fer l'avaluació sistemàtica de l'eficàcia. 20 estudis feien fer programes d'exercici físic i els altres 8 van feien programes d'incentivació de l'activitat física. El 68% dels estudis van informar sobre la funció física i el 32% van informar sobre el rendiment físic. El 75% dels estudis van examinar els nostres resultats secundaris i el 46% van presentar resultats a nivell d'activitat física.

DISCUSSIÓ: les DHI més habituals en els programes d'exercisi físic són les trucades i les aplicacions i en els programes per incentivar l'activitat física les més habituals son les trucades telefòniques i els llocs web. Hem trobat bona adhesió de la gent gran a la tecnologia per fer programes d'exercisi físic i programes d'incentiu de l'activitat física.

PARAULES CLAU: (Physical Therapy Modalities [Mesh]), (exercise [Mesh]), (telemedicine [Mesh]) and (Aged [Mesh].

Registrat a PROSPERO [CRD42021192499].

INTRODUCTION

The elderly population is growing, and clinical practice guidelines widely report recommendations for therapeutic physical exercise (PE) as a central axis of healthy ageing. This regular PE leads to ageing actively and satisfactorily because it is associated with physical, functional, psychological, and cognitive improvement. Moreover, PE is the basis for treating many diseases such as hypertension, stroke, osteoporosis, metabolic syndrome, obesity, cancer, depression, falls and even pathologies that run with cognitive impairment (1,2,3).

According to the American College of Sports Medicine (ACSM), physical exercise is a "planned, structured, and repetitive bodily movement done to improve and/or maintain one or more components of physical fitness". It is composed of different elements that can be grouped into components related to health and components related to skills (3).

These components can be assessed in older adults with quantitative measures of physical function, which include: muscular strength defined as the maximal amount of force a muscle can produce measured by, for example, grip strength or lower limb strength; gait speed defined as the time it takes to walk a specific distance measured by, for example, 4m speed walk test; balance defined as the ability to maintain a controlled body position during task performance measured by, for example, Berg Balance Scale or tandem stand; mobility defined as the person's ability to move physically measured by, for example, the Timed Up and Go Test or chair rise and stand; and physical performance defined as a multidimensional concept based on the combination of mobility, gait speed and balance skills measured by, for example, the Physical Performance Test (4)

The exercise program is considered home-based if the PE is performed in an informal and flexible place such as the individual's house. It should have clear goals and include monitoring, follow-up visits, calls from the physical therapist or self-monitoring diaries. Studies indicate that elders prefer to do PE at home, especially if it involves a low cost of both time and money (5-9).

According to the World Health Organization (WHO), older people over 65 years old should dedicate 150 minutes a week to do moderate physical activity or 75 minutes of vigorous physical activity. Multimodal PE is the most recommended by clinical practice guidelines, especially one that includes progressive strength training and other components of exercise such as balance, flexibility, and aerobic training (10-12).

For the elderly with a decrease in their physical fitness (with a reduced walking speed) it is recommended that the balance training should be performed three times a week and the strength training should be done at least twice a week, especially with exercises which include strengthening large muscles involved in gait (2,3).

Digital Health Interventions (DHI) combined with PE may be an opportunity to promote more active and healthy ageing. Digital health intervention is the use of digital, mobile and wireless technologies to support the achievement of health objectives. Describes the general use of information and communications technologies (ICT) for health and include mHealth and eHealth (1,5,10,11).

There are still no clear and globally recognised standards for defining these digital practices in physical therapy. However, the World Confederation for Physical Therapy (WCPT) and the International Network of Physiotherapy Regulatory Authorities (INPRA) conclude that "the purpose of digital physical therapy practice is to facilitate effective delivery of physical therapy services by improving access to care and information and managing health care resources". DHI allows you to monitor the person's health and adapt the intervention to the user's known environment. It has also been described as leading to a greater perception of security on the user (8,9,13-15).

Given the complexity of DHI, the WHO classifies them into four categories according to the main target user of the intervention (11,12):

1. Customers
2. Health care providers
3. Resource managers or health systems
4. Data services

In this model, tele-rehabilitation (which is a physical therapy service) would be included in the second group, according to the WHO. The term digital practice replaces and encompasses the term "tele", as it is more representative of the range of technologies and the impact these technologies have on current and future rehabilitation practice, according to WCPT and INTRA (12,13).

Therefore, digital physiotherapy is defined as the performance of distance physiotherapy using telecommunication technologies. Although there are barriers to using digital technology in elders, the current evidence indicates that DHI targeting this population is well accepted, providing more opportunities to perform PE and achieving high adherence to the proposed programs (4,13).

There are currently different studies on the effects of DHI and exercise in this population, although no systematic review focuses on the effects on physical function. For example, a narrative review explores the effectiveness of PE interventions on physical function, in older people living in the community but not exploring the contributions of DHI in these programs. Another review studies DHI, such as m-Health Apps, on physical function and level of physical activity, but does not provide information on the type of exercise, and although the study population is older, it encompasses an adult population of 55 years (4,17).

The use of technology is becoming more and more common in healthcare. The COVID-19 pandemic has shown how important it is to make good use of it and have clear information about its effectiveness, especially in a population where the digital divide is still a reality (18).

To our knowledge, no review encompasses and summarises the effectiveness of digital health and physical exercise interventions at home in the elderly. Therefore, the main objective of this systematic review is to evaluate the effects of digital health interventions combined with home therapeutic exercise on physical function in the older populatioin living in the community, to describe which technologies have been used in physiotherapy in this population, and detail which of all is effective and for which group of older people. In addition, we want to explore its effects on the level of physical activity, quality of life, adherence to the treatment and accidental falls.

HYPOTHESIS

Digital health interventions combined with home therapeutic exercise effectively improve physical function, level of physical activity, quality of life, adherence to programs, and decreasing accidental falls.

OBJECTIVE

General:

- To evaluate the effects of combined home therapeutic exercise and digital health interventions on physical function on older people living in the community.

Specific:

- To examine the effects of home exercise programs with digital health interventions on physical activity levels on older people living in the community.
- To evaluate the effects of home exercise programs with digital health interventions on the quality of life on the older people living in the community.
- To analyze the effects of home exercise programs with digital health interventions on treatment adherence on older people living in the community.
- To determine the effectiveness of home exercise with digital health interventions on accidental falls on the older people living in the community.

METHODS

We performed a systematic review using Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines (20). The review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) CRD42021192499 (Available from https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=192499).

We included randomised clinical trials (RCTs) in older adults over 65 years of age who participate in home-based exercise programs delivered with digital health interventions. The included studies aimed to identify manuscripts that investigate or assess physical function, autonomy in activities of daily living, accidental falls and adherence to home-based exercise programs delivered with digital health in older adults compared to interventions that do not include DHI or PE.

The main outcome was the physical function that will be considered: muscle strength, walking speed, balance, mobility, cardiorespiratory endurance, physical performance, and functional capacity (4). The secondary outcomes were physical activity level, quality of life, accidental falls and adherence to treatment.

We reviewed six databases: Embase, PubMed/MEDLINE, CINAHL, Web of Science, Cochrane Central Register of Controlled Trials (CENTRAL), and Science Direct from their inception to March, 9, 2021 and conducted manual searches using a predefined search strategy (Annex). We imposed no language or publication restrictions.

The terms selected were combined using Boolean logical operators (OR, AND, NOT). Moreover, we did a manual search of the references that were included in the selected articles. Finally, all the references were analysed in Rayyan software, a web-based tool (20).

Two investigators (LSN-AG) performed the review independently, who identified the studies that meet the inclusion criteria. The first step consisted of reviewing the titles and abstracts of all the references retrieved by the database searches (LSN and AG). Next, we ordered all articles that were deemed potentially eligible by at least one of the reviewers. In the second step, the retrieved full texts were evaluated, and a decision on inclusion or exclusion was made according to the predefined selection criteria (LSN and AG). Any disagreement in any step was solved by a third reviewer (MSR). All studies that did not fulfil the predefined criteria were excluded, and their bibliographic details were listed with the specific reason for exclusion. In the third step we searched manually in pairs to identify any other study that could meet the inclusion criteria. We included studies if they fulfilled the following criteria: (1) original research; (2) patients older than 65 years; (3) reported an intervention of therapeutic exercise; (4) used a digital intervention (5) reported a physical function measure and, (6) full text available without language restriction. We excluded trials that used phone calls in less than half of the intervention because it was only used to control the outcomes; therefore, it was not significative for our review.

Two authors (LSN and AG) extracted the data independently and in duplicate using a standardised protocol and reporting forms. The following information was extracted from each included study: author(s), the year of publication, the details of publication, population characteristics (sample size and age), type of therapeutic exercise performed and description of the intervention, typology of digital health intervention and description of the intervention, description of the test, test / scale for each variable and a description of the results. This compilation was done using the COVIDENCE© platform. If some relevant data were not in the article, the author was contacted to request the information.

We used the ProFaNE Taxonomy for falls (21) to classify the type of physical exercise of the studies included and we decided to separate them into two groups: studies which intervention was general physical activity and studies which intervention was the other categories of exercise (gait, balance and functional training, strength/resistance, flexibility, 3D, endurance and multiple categories of exercise). The reason to do this is because the use of digital health interventions and the role of the health professional of an exercise program is very different than a physical activity incentivisation.

The risk of bias of included randomised controlled trials was evaluated using the Cochrane Collaboration Risk of Bias Tool (ref). To minimise bias, the studies were graded independently by two teams of reviewers (CF and XX, LSN and RTC). Any discrepancy in assessment was resolved by a third reviewer (MSR).

We reported summaries of the association between the interventions and the outcomes for each study in terms of the mean differences of absolute values. We obtained combined measurements of effect for each primary outcome through meta-analysis under a random-effect model, due to the expected heterogeneity between the studies (ref). Statistical heterogeneity was measured through the I2 statistic and classified as low (I2 <25%), moderate (I2 25–50%) or high (I2 >50%) (22). A narrative synthesis of the available data was made if the value I2 was greater than 70%. Subgroup analysis was performed (whenever possible) according to sex, pathology, type of exercise and types of digital health intervention.

RESULTS

The results here exposed are the partial results of the project registered at PROSPERO [CRD42021192499].

Study selection

The study selection process flow chart is presented in Figure 1 in Annex; from the 4023 identified references, 28 articles were finally included. We removed 1139 duplicated studies and screened 2885 studies. Finally, we had 154 studies assessed as full text, and we excluded 126. We found seven conference proceedings, so we manually searched those studies to identify if they met the inclusion criteria and 2 of 7 were included.

Characteristics of the included studies

Out of the 28 studies, 14 were unicentric RCTs (23-36), 6 were multicentric RCTs (37-42), 3 were pilot RCTs (43-45), 3 were clustered RCTs (46-48), there was a randomised crossover trial (49) and a phase II preclinical exploratory trial (50). 28,6% of all the studies were conducted in the USA, the other countries are summarised in Table 1 in Annex.

Participants

In total, 5326 participants were enrolled in the included studies. Among the studies, the sample size ranged from 12 to 1256. The mean age of the participants was 76 years (SD=4,8). The population was diverse because of the comorbidities that they had. All the participants were community-dwelling older adults, but 50% of them had different pathologies like musculoskeletal disorders (30,40,41,43) cardiorespiratory problems (31,33,34), balance disorders (24,25,46) mild cognitive impairment (27,49) cancer (37) and others (48). A summary of the patients' characteristics is presented in Table 1 in Annex.

Intervention

Of 28 RTCs included, 20 did programs of physical exercise (23-25,27,28,30-34,37,39-44,46,47,50) and 8 did programs of physical activity incentivisation (26,29,35,36,38,45,48,49).

Of 20 studies of programs of physical exercise, 12 were only physical exercise with a digital health intervention and the other 7 had co-interventions like occupational therapy with consultations on the hospital (30), motivational peer mentor (32), rehabilitation from PT (46), health education (28,34), nutritional education with cognitive training (27), educational, instrumental, appraisal, and emotional support (33) and dual-task by verbal fluency (44).

Following the ProFaNE Taxonomy to classify the type of physical exercise (21), of the 20 studies, 16 did multiple categories of exercise (24,25,27,30,32-34,37,40-44,46,47,50), two did endurance training (31,39), one did strength training (28), and one did gait, balance, and functional training (23). Of the 16 with multiple categories of exercise, all of them did a combination between strength training and other categories of exercise like gait, balance, and functional training (24,25,27,30,32,37,40-42,46,47,50), flexibility training (25,27,30,33,37,43,44,46,47,50), endurance training (27,33,34,37,40,41,43,47) and general physical activity (42). Remarkably, four studies (24,25,32,42) did the Otago program (51) or an adaptation from it, while the others made a program from scratch.

The most usual types of digital health intervention used in the programs of physical exercise were app (23,30-32,46,47,50), and phone calls (24,37,40-43). The device most used was the phone or smartphone (23-25,30,31,37,39-43). 85% of the studies reported some feedback to the participants, and of that 76% was personalised. These results are summarised at Table 2 in Annex.

Of eight studies of programs of physical activity incentivisation, seven had co-interventions like motivational prompts or counseling (26,36), one had changes in PA behavior (35,38), one had financial incentives or peer networks (29), one had peer mentoring with health education (45), and one had only health education (48).

The types of digital health intervention most used of the eight studies of programs of physical activity incentivisation multiple digital health interventions (26,29,45). Only five of eight studies reported the device that was used to give the digital health intervention. The feedback was different for every study, mainly because they used different devices to give feedback to the participants. These results are summarised at Table 3 in Annex.

Outcomes

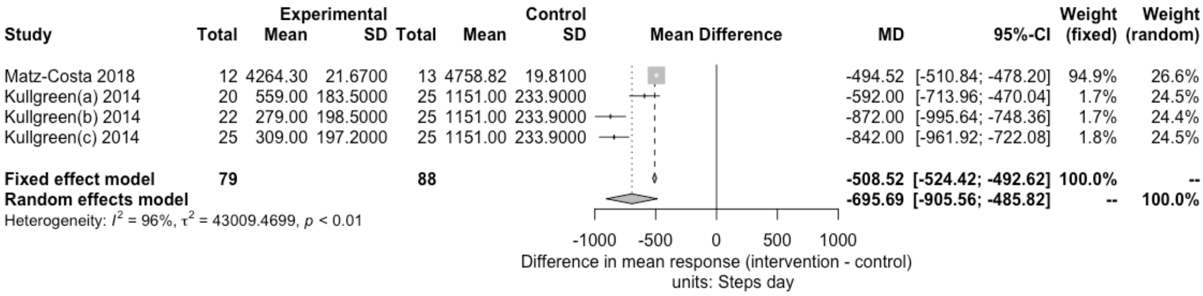
19 of the 28 studies looked at physical function. Physical performance was measured by nine studies (27,28,32,34,37,41,47,49,50), and only four presented small improvements (28,37,41,50), especially in flexibility of the Senior Fitness Test (28) and gait speed of the Short Physical Performance Battery (51). Mobility was measured by nine studies (23-25,30,42-44,46,47), and only two presented a significant decrease on Time-Up and Go points (24,43). Balance was measured by eight studies (23-25,30,32,41,42,46), and only two reported an improvement of balance in the Berg Balance Scale and the mini–Balance Evaluation System Test.

Muscular strength was measured by five studies (23,25,30,44,47), and only one presented a significant decrease of seconds on the 5-Sit to Stand Test (23). Functional assessment was measured by four studies (24, 30,36,46), and three studies presented a positive change in the instrumental activities of daily living (24,30,36). Cardiorespiratory endurance was measured by three studies (31,34,49), and two of them reported an increase of the incremental and endurance shuttle walking test (31,34). Gait speed was measured by three studies (23,27,44), and only one presented an improvement on this outcome (44). It was not possible to pull data to do a metanalysis because of the heterogeneity of the outcomes.

21 of the 28 studies looked at our secondary outcomes. Physical activity level was measured by 13 studies (26,27,29,32,35,37-39,42,45,47-49), and only 5 reported an improvement in self-reported physical activity level (35,37,48) and in daily steps (38,49). The adherence to the program was measured by 12 studies (27,31-33,37,39,40,45,47,49,50), and seven studies presented a good adherence to the programs combined with the DHI (32,33,39,40,44,45,49).

We performed a mean difference metanalysis to see if physical activity incentivisation with DHI was more effective than an intervention without any physical activity incentivisation, just a DHI, in daily steps. Matz-Costa et al. compared a physical activity incentivisation program delivered with a wearable, digital surveys from a tablet and phone calls with self-monitoring of daily physical activity with only a wearable and digital surveys from a tablet. Kullgreen 2014 et al. compared the effects of financial incentives, peer networks and the combination of both in physical activity level with an automatic email or text that tell the participants how often they met their step goal in the past week. The effects of this intervention are in figure 2.

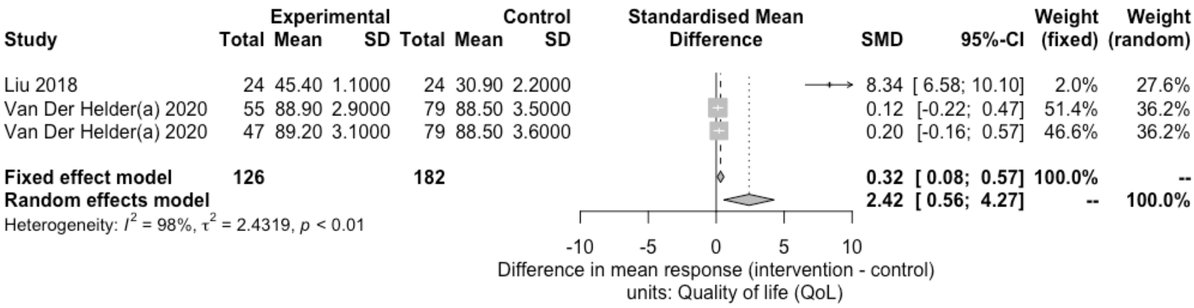
Figure 2: Metanalysis of daily steps (DHI+PA vs only DHI)



The quality of life was measured by ten studies (24,25,27,31,33,34,41,42,46,47,49), and only three reported an increase of que quality of life (24,31,33). The accidental falls was measured by five studies (24,25,37,40,42), and only two of them presented a decrease on falls (24,25).

We performed a standardised mean difference metanalysis to see if physical exercise programs with DHI were more effective than just the physical exercise program alone to increase the quality of life of the participants. Liu 2008 et al. compared an endurance training delivered with an app with the same exercise protocol but without the app. Van Der Helder 2020 et al. compared a personalised exercise program delivered with an app with a group that had the same exercise program without the app and another group that had the exercise program with the app and also had dietary counselling. The effects of this intervention are in figure 3.

Figure 3: Metanalysis of quality of life (DHI+PE vs only PE)



The summary of the outcomes is presented in Table 1 in Annex. We performed other metanalysis that had no significant effect on the outcomes, they are presented in Figures 6 to 22 in Annex.

Risk of bias assessment

The quality assessment of the risk of bias for the included studies is summarised in Figures 4 and 5. Due to insufficient information, most trials were scored unclear in the selection bias category (random sequence generation and allocation concealment). Most trials were scored as unclear or high risk for blinding of participants and personnel. Close to half of the authors did not report it, and those who did report it raised the difficulty of blinding due to the interventions nature.

About two-thirds of the trials were unclear or high risk of detection, attrition and reporting bias. However, most of the trials provided insufficient information to assess whether a critical risk of bias existed for other sources of bias.

Figure 4: Risk of bias graphic

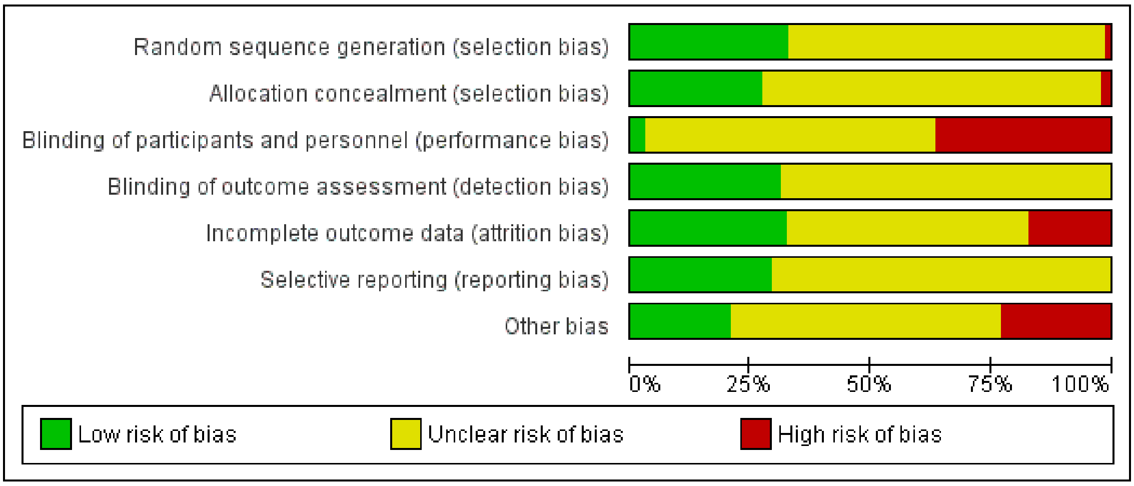


Figure 5: Risk of bias summary

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Arrieta 2019	+	+	−	+	−	+	?
Bao 2018	?	+	+	+	+	?	−
Bernocchi 2019	?	?	?	?	?	?	−
Bickmore 2013	?	?	−	+	−	?	−
Boongird 2017	?	?	?	?	?	?	?
Conn 2003	?	?	?	?	−	?	−
deSoutoBarreto 2020	?	?	?	+	+	?	?
Feng 2019	?	?	?	?	−	?	?
Giangregorio 2018	?	+	−	+	?	+	−
Gibbs 2020	?	?	?	+	+	?	?
Goode 2018	?	+	−	+	−	+	?
Hong 2017	+	?	?	?	?	?	?
Iliffe 2014	?	?	−	?	+	?	−
Kullgren 2014	+	+	−	+	?	?	?
Li 2020	?	?	?	+	?	?	?
Liu 2008	+	?	?	?	?	?	?
Mansson 2020	?	−	−	+	−	+	+
Matz Costa 2018	?	+	?	?	+	?	+
Mzire 2021	?	?	?	?	−	?	?
Tomita 2009	?	?	−	?	?	?	+
Tsai 2017	?	?	?	?	+	+	+
vandenHelder 2020	?	?	−	?	?	+	+
VanDyck 2019	?	?	?	?	?	+	+
vanHetReve 2014	?	?	−	?	?	?	+
Vidoni 2016	+	+	−	?	−	?	?
Volders 2020	+	?	−	?	+	+	+
vonBonsdorff 2008	?	+	?	+	+	?	+
Yamada 2011	+	?	−	+	?	?	+

DISCUSSION

To the best of our knowledge, this is the first systematic review that presents an overview of the literature reporting about the effects on physical function of the combination of home therapeutic exercise and digital health interventions for older people living in the community.

We found a large degree of heterogeneity regarding the characteristics of the participants, the intervention content and delivery, and outcomes reported, making the comparison between interventions difficult.

Four studies targeted older people with musculoskeletal disorders (30,40,41,43), and they were physical exercise programs that had a multi-component program with strength and endurance training in common. Three studies used phone calls as a DHI (40,41,43) and one used an app (30), but all of them used a phone as a device. All studies that targeted people with cardiorespiratory problems (31,33,34) are physical exercise programs and two of them were multi-component programs that had in common a strength and endurance training. The DHI of the studies was different between them but the PC/laptop as a device was in two studies (33,34).

Older people with balance disorders were targeted by three studies (24,25,46) with a multi-component exercise program composed by strength and balance training that had a progression in their program. Two of them (25,46) also had a flexibility training in their program. Two studies had in common the DHI delivered and the device, which were phone calls and a phone respectively (24,25). The older population with mild cognitive impairment were targeted by two studies (27,49), one was a physical exercise program and the other a physical activity incentivization program. The only common factor is that both studies used an accelerometer as a device because their outcome was the step count.

Clinical practice guidelines show that multimodal exercise interventions can currently be recommended for older adults with declining physical capacity (10). Our findings are in accordance with those recommendations because 16 of 20 studies of PE programs had a multi-component exercise program that included a combination between resistance, endurance, flexibility and balance training. By maintaining the functional ability that enables well-being in older age, the elderly can achieve to live with healthy ageing (52).

In our review we founded that the duration of our included studies was 6 or 12 months (24,25,27,33,37,40-42,44,47), between 2 and 4 months (23,28,31,32,34,43,46,51), and 5 or less weeks (30,39). In clinical practice guidelines is remarked that the duration of multimodal exercise intervention of the studies included ranged from 2.7 to 12 months, therefore most of our findings are in accordance with that range (10).

The frequency of 11 of the 20 studies included was three days (23,28,32,34,40-42) or more (25,31,39,50) per week. Four studies had a frequency of two days per week (27,37,44,47) and five studies did not report it (24,30,33,43,46). It is remarked on the guidelines on community-level interventions to manage declines in the intrinsic capacity of the Integrated care for older people (ICOPE) that the frequency of the training is commonly three days per week, which agrees with the most usual frequency of our findings (10).

The ACSM recommends prescribing intensity of the exercise for older adults with a perceived 10-point physical exertion scale, which has shown to be useful to physical exercise prescription (53). We considerate that there was a deficit of information of the studies included because 12 studies (23,24,27,30,32,33,37,42-44,46,50) in our systematic review did not reported the intensity of the exercise and only 8 studies (25,28,31,34,39,40,41,47) reported a specific intensity of training. Not reporting the intensity of the study could constitute a serious bias because physical exercise should comply with the basic principles of training. Despite of that, 17 studies (23-25,27,28,31,32,34,37,39-43,46,47,50) reported that the intensity was progressively increasing throughout the intervention, therefore progressive overload was described.

Geraedts et al. in 2013, did a systematic review that evaluated the effects of remote feedback in home-based physical exercise interventions, and they reported the use of phone calls as the main way to communicate with the participants, and in a limited way, the use of videoconference (1). In our systematic review, phone calls are still prevalent, and we reported an increase in the use of apps (30-32,46,47,50), and websites (23,27,33,39), to deliver the PE intervention. This change probably was explained thanks to recent advances in communication and technology, which allows the use of low-cost internet connections, smartphones and tablets, and the appearance of applications that facilitate video calls that have allowed the rapid adaptation of rehabilitation teams (54).

The included studies on Valenzuela et al. 2018 reported high adherence rates (median 91.25%) to technology-based exercise programs and Geraedts et al. 2013 suggested that adherence to interventions using remote feedback seems mostly acceptable-to-good (1,16). In our review, the adherence of DHI with physical exercise program was reported in 9 studies (27,31-33,37,39,40,47,50) and 8 of them (31-33,37,39,40,47,50) had an adherence above 65%, which is below of the results of Valenzuela but in accordance with Geraedts et al. 2013. Two studies reported an adherence of 100% (31,33), and the only common point was that both had cardiorespiratory patients. De Souto et al. 2020 shows that only 5.2% of their participants did the exercise intervention. This could be because older people with memory complains participated in this RCT maybe with the only goal to improve their memory and therefore the training intervention was not prioritised.

The most common duration of our physical activity incentivization studies was 2 months and it is in accordance with the literature (55). Dorri et al. 2019 reported that the most used technology in their included studies was web-based and mobile-based interventions (56), and that is in accordance with our findings. In the systematic review of Dorri et al. 2019 did not classified wearables as digital health interventions, they classify it as only a device. Either way, Dorri et al. 2019 and our systematic review agree that the most used devices to deliver digital health interventions were the accelerometer and the pedometer (56).

To measure physical function, clinicians and researchers have traditionally relied on instruments focusing on the capacity of the individual to accomplish specific functional tasks such as Activities of Daily Living, but recently assessment of physical performance has been growing because its predictive capacity for negative health-related outcomes (57). In our review, the most reported measure of physical function was physical performance but the component with more improvements was functional assessment. Every study that show an improvement in physical performance, mobility, balance, muscular strength, cardiorespiratory endurance and gait speed was a physical exercise program with a digital health intervention.

In our review, physical activity level was the most usual reported secondary outcome, but only 39% of the studies show an improvement of this outcome, and just one study was a physical exercise program (37). Muellmann et al. 2017 reported that the number of studies employing subjective vs. objective PA assessment in their systematic review was not balanced because studies employing subjective assessment prevailed over objective assessment (5). In out review, eight studies reported an objective physical activity assessment with the step count of the accelerometers or the pedometers, and eight studies measured self-reported physical activity with diverse questionnaires, only the International Physical Activity Questionnaire (IPAQ) was used in two studies (37,39). Our findings disagree with the conclusions of Muellmann et al. 2017 because they did not consider accelerometers and pedometers as an eHealth intervention.

The ten studies that reported good results on quality of life are physical exercise programs and they use different measurements and questionnaires to report it. Moreover, accidental falls was an outcome only reported by studies with an exercise program.

The strengths of this review include the comprehensiveness of the search strategy, the currency of the studies, and the importance of the topic due to the pandemic of COVID-19.

The major limitation of this review was the heterogeneity of RCTs in the included systematic reviews due to the lack of consistency of the definition of digital health interventions and the width classification of the WHO of DHI. Because of that, it was difficult to identify if the studies were using a DHI and to investigate the effects of different types of DHI. Studies that used other types of digital health interventions like exergames might be missing, since they are not explicit on our search strategy.

Another limitation was the diverse definitions of what an older adult is. The MeSH term involving older adults it is defined as “a person 65 through 79 years of age”.

Some of the studies lowered the age to 50 or 55 years old and for that reason it has limited our included studies. As Nuñez 2021 point out, as life expectancy increases, the traditional age cut-off points become obsolete, in such way that the selection people below 65 years as a homogeneous age group is not justified, for example, in relation to the skills to use new technologies (58).

Half of our studies had healthy older people and the other half was older people with pathologies. This could affect the conclusions about the effectiveness of digital health interventions in exercise programs.

For clinical practice with community-dwelling older adults, we recommend doing a multi-component exercise program that includes a combination on resistance, endurance, flexibility and balance training three times per week. The intensity should be moderate-to-vigorous (5-8 in the perceived 10-point physical exertion scale), following the recommendations of the ACSM (3).

The COVID-19 pandemic has shown that professional health caregivers have the capacity to rapidly adapt a traditional way to deliver an exercise program to an asynchronous and online way. Since the most used digital health intervention was phone calls, we encourage to incorporate it to the exercise program prescribed because the adherence is acceptable-to-good. Nevertheless, we also want to animate health caregivers to be up to date with the recent advances in communication and technology, especially with the use of low-cost internet connections, smartphones, tablets, and applications that facilitate video calls, to incorporate them with the older people exercise interventions.

Future research should adopt a consistent definition of DHI to clearly identify when it is delivered a digital health intervention and investigate the effects of the combination of this intervention with exercise. Together with this, there is a need to taxonomize DHI into different groups to identify which type of DHI is using every study, and not only identify the main target user of the intervention.

We also recommend to future investigators to use the consort CERT about how to report exercise programs (59). It is needed to report what frequency, intensity, time and type of exercise the researchers are going to deliver the exercise program so that it can be replicated if needed and therefore reduce the risk of bias of the study. Additionally, if the exercise program is combined with a DHI it should have some objective assessments to measure the quality and the execution of the exercise training.

In our systematic review we have noticed that sometimes studies about older people report an outcome with an assessment based on their pathology and not based on their age. We recommend using questionnaires and scales that are more reported and studied on older people with the goal to being able to unify and compare results of different studies. Consequently, we could study the effect of an intervention in a more practical way.

We did not target any pathology, but we think that could be interesting to investigate if there is link between the effectiveness of certain type of DHI and the chronic illness that could target. Therefore, this could allow us to use a specific type of DHI to deliver a physical exercise program or a physical activity incentivisation.

CONCLUSIONS

In this paper, we aimed to systematically review the effects on physical function of the combination of home therapeutic exercise and digital health interventions for older people living in the community. We founded a large degree of heterogeneity because of different reasons. The characteristics of the participants was very diverse, there was a lot of types of intervention and a lot of ways to deliver them and we did not find a homogeneity of the outcomes reported and their assessments. Therefore, the findings of this systematic review must be interpreted with caution and the study quality ranged from unclear to high risk of bias.

We founded that exercise programs should have a multi-component program with resistance, balance, endurance and flexibility and that it should be delivered three times per week. The duration of the intervention should be between 6 and 12 months and the intensity should be between moderate to vigorous. These types of interventions could promote physical activity and physical exercise to improve the quality of life of older adults in order to prevent the progression of chronic diseases in later stages of life.

Digital health interventions are a good way to help improve older adults' health when it is combined with exercise programs. There is positive evidence of the good adherence of older people to technology. Nevertheless, further research is needed to elucidate which type of DHI is the most effective, and to compare DHIs with traditional interventions to promote PA and PE in older adults.

Acknowledgments

I would like to thank Carles Fernández Jané (Facultat de Ciències de la Salut Blanquerna and Global Research on Wellbeing (GRoW) Research Group, Ramon Llull University, Barcelona, Spain), Clara Bergé Ortínez (Global Fisio SL, Lleida, Spain), Joan Ars Ricart (REFiT Research Group, Parc Sanitari Pere Virgili – Institut de Recerca Vall d'Hebron, Barcelona, Spain), Mireia Sola (Facultat de Ciències de la Salut Blanquerna, Universitat Ramon Llull; Associació de Dones No Estàndards and Centre Ocupacional Asproseat, Barcelona, Spain) Laura Mónica Perez Bazán (REFiT Research Group, Parc Sanitari Pere Virgili – Institut de Recerca Vall d'Hebron, Barcelona, Spain) and Rodrigo Torres Castro (Hospital Clínic de Barcelona, Spain) for helping me when needed as a great research team.

I would also like to thank my co-worker Lilian Solis Navarro (Departamento de Kinesiología, Facultad de Medicina, Universidad de Chile. Santiago, Chile) for helping me to keeping me motivated with the project and for the combined effort of both of us. Lastly, I would like to thank my tuthor Mercè Sitjà Rabert (Facultat de Ciències de la Salut Blanquerna and Global Research on Wellbeing (GRoW) Research Group, Ramon Llull University, Barcelona, Spain) for being that one person that pulled me to keep moving forward.

During the systematic review process, this project got a scholarship from the "Col·legi de Fisioterapeutes de Catalunya" (Resolució 005/2020, de 22 de desembre de 2020, per la qual es regula la concessió d'ajuts a la recerca del Col·legi de Fisioterapeutes de Catalunya, registrat amb el núm. d'ajut R02/20).

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Tables

Figures

Abbreviations

DHI: Digital Health Intervention

PE: Physical exercise

ICT: Information and communications technologies

PT: Physiotherapist

PA: Physical activity

ANNEX

Search strategy

1: Aged[MeSH Terms] OR Adult*[tiab] OR Frail elderly [tiab] OR Old*[tiab] OR Senior adult*[tiab]

2: Exercise[MeSH Terms] OR Physical activity*[tiab] OR Active*[tiab]

3: mhealth[tw] OR mobile health[tw] OR telehealth[tw] OR eHealth[tw] electronic health[tw] OR digital health[tw] OR mobile app*[tw] OR mobile phone*[tw] OR cell phone*[tw] cellular phone*[tw] OR smartphone*[tw] OR tablet*[tw] OR smart phone*[tw] OR iPhone* OR iPad* OR android OR handheld*[tw] OR phone call*[tw] OR short messag*[tw] OR sms[tw] OR multimedia message*[tw] OR mms[tw] OR text messag*[tw] OR Telemedicine[MeSH Terms] OR Mobile applications[MeSH Terms] OR Reminder Systems[MeSH Terms] OR telerehab*[tw] OR homebound[tw]

4: "physical fitness"[MeSH Terms] OR fit*[All Fields] OR strength*[All fields] OR "activities of daily living"[MeSH Terms] OR (activities[All Fields] AND “daily living"[All Fields]) OR "frailty"[MeSH Terms] OR "frail*"[All Fields] OR "quality of life"[MeSH Terms] OR "quality of life"[All Fields] OR "accidental falls"[MeSH Terms] OR "fall*"[All Fields] OR Adher*[All Fields]

5: Clinical Trial[ptyp] OR Randomized Controlled Trial[ptyp] OR trial[tiab] OR ransomized[tiab] OR randomised[tiab]

1 AND 2 AND 3 AND 4 AND 5

Figure 1: PRISMA flowchart chart of study selection and inclusion process

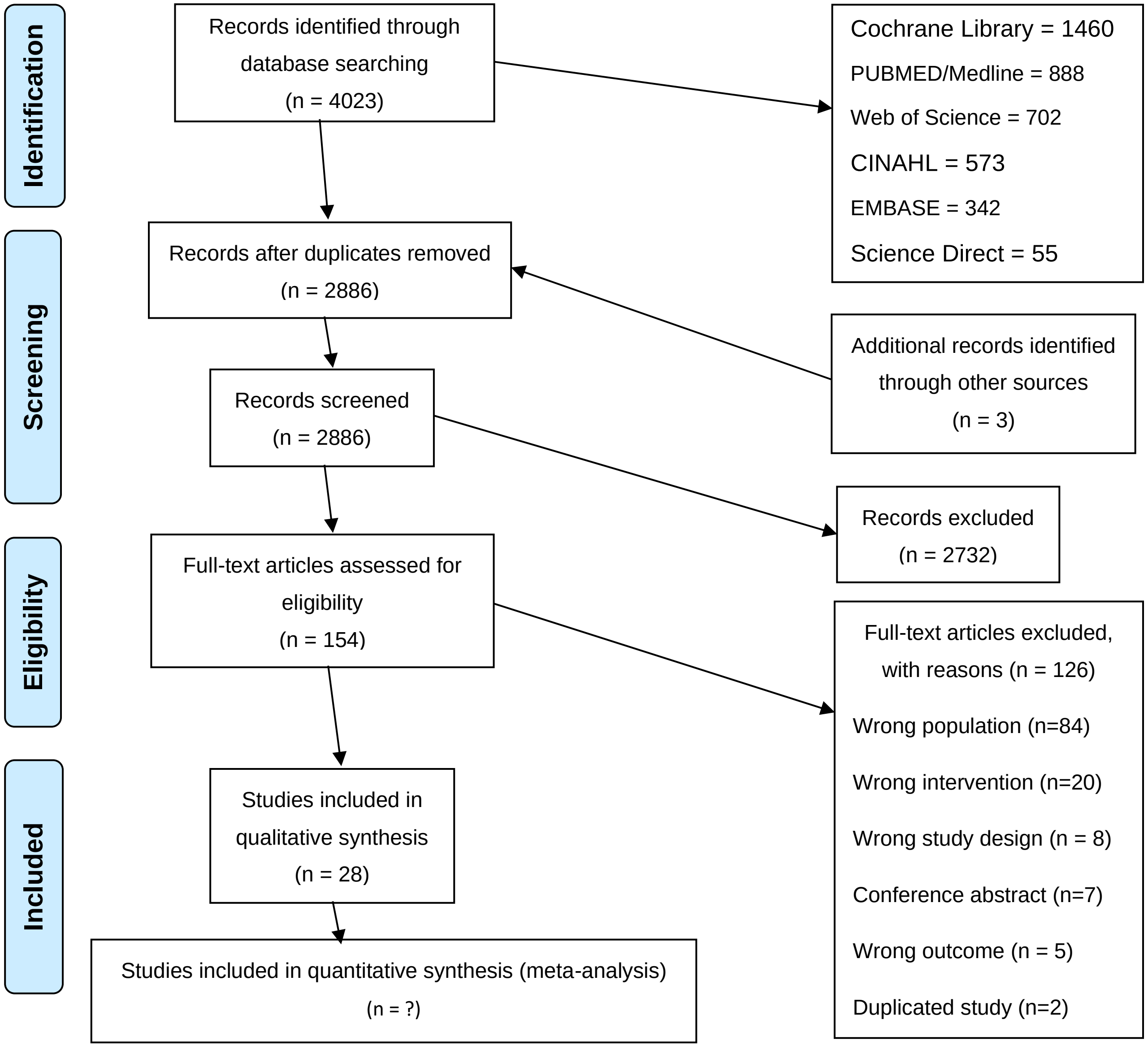

Figure 6: Metanalysis of Time Up and Go (Only DHI+PE vs other treatments)

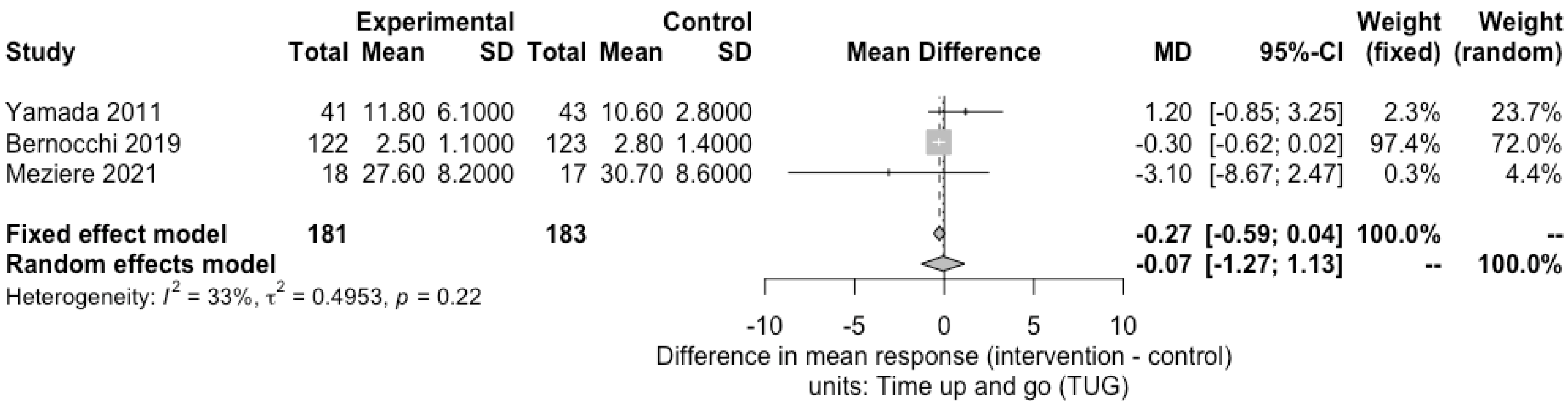

Figure 7: Metanalysis of Barthel Index (Only DHI+PE vs other treatments)

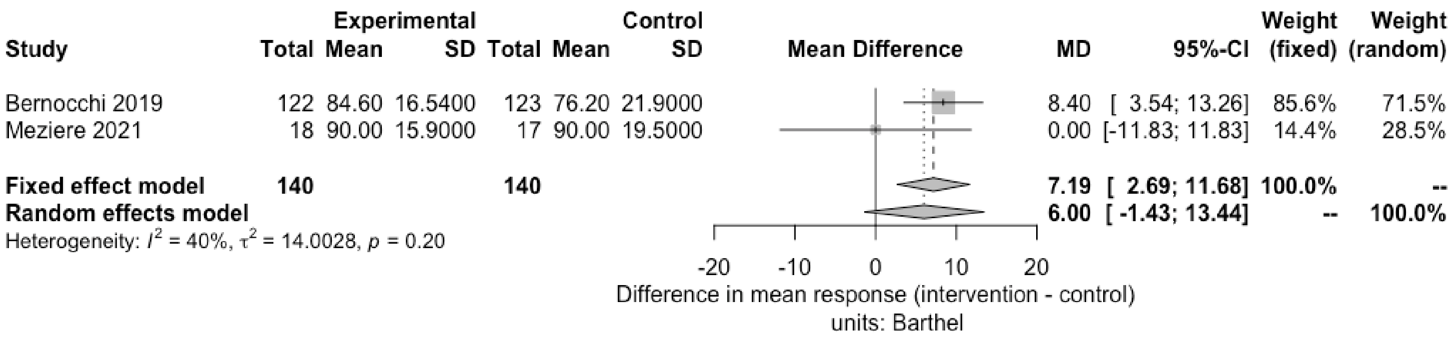

Figure 8: Metanalysis of number of falls (Only DHI+PE vs other treatments)

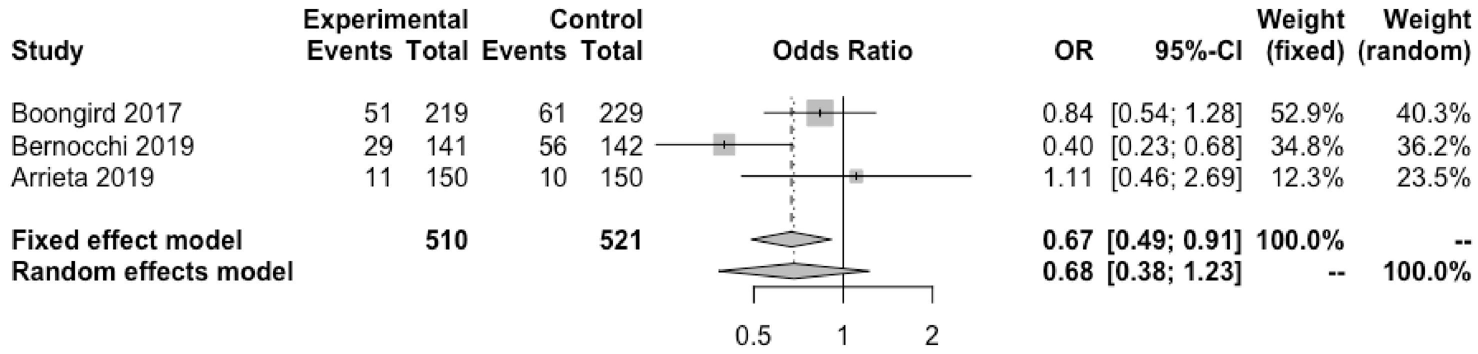

Figure 9: Metanalysis of Functional Reach Test (Only DHI+PE vs only PE)

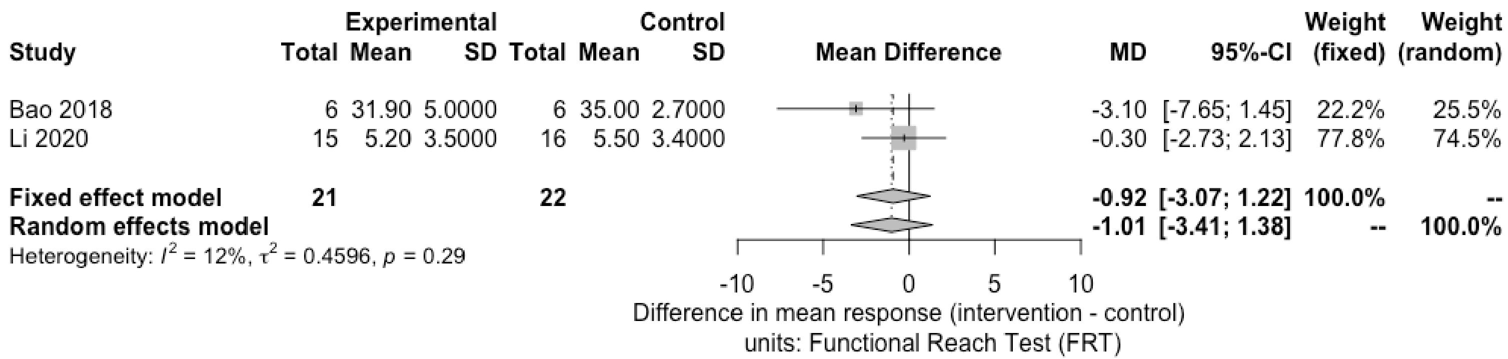

Figure 10: Metanalysis of Time Up and Go (Only DHI+PE vs only PE)

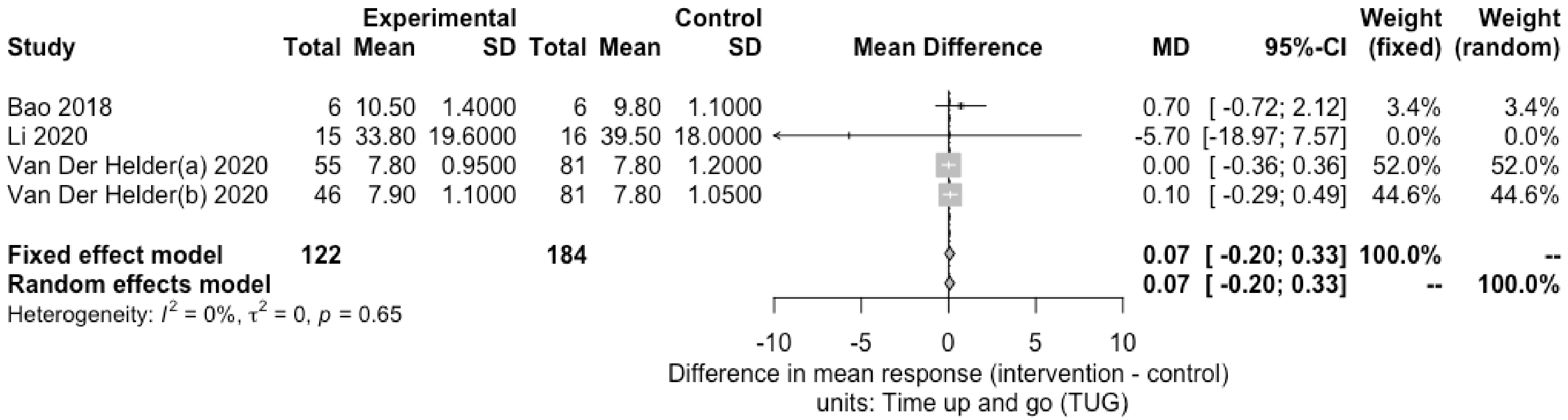

Figure 11: Metanalysis of quality of life (DHI+PE+cointerventions vs other treatments)

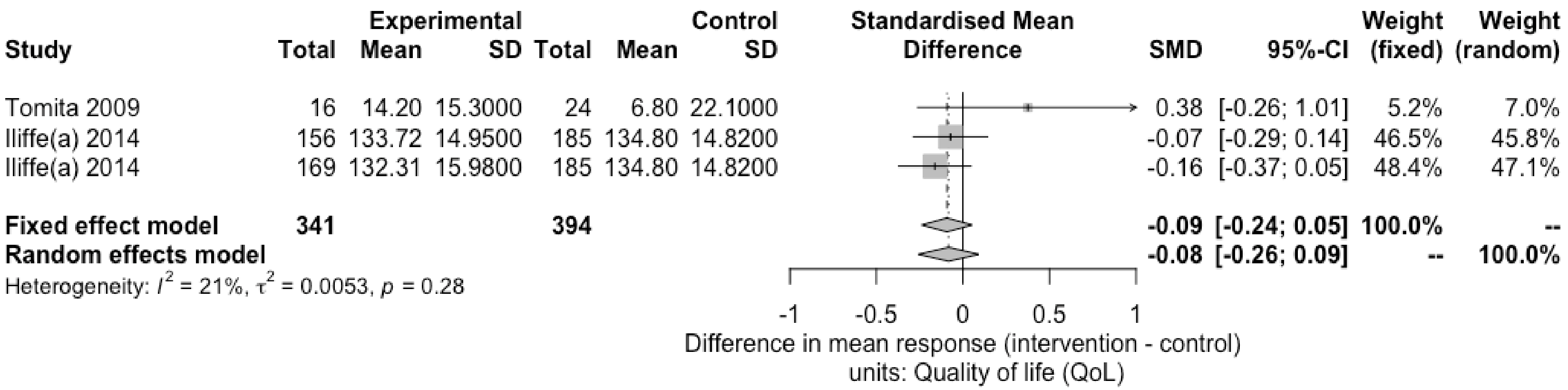

Figure 12: Metanalysis of Time Up and Go (Only DHI+PE+cointerventions vs other treatments)

Study	Experimental Total	Experimental Mean	Experimental SD	Control Total	Control Mean	Control SD	MD	95%-CI	Weight (fixed)	Weight (random)
Yamada 2011	41	11.80	6.1000	43	10.60	2.8000	1.20	[-0.85; 3.25]	0.1%	5.4%
Bernocchi 2019	122	2.50	1.1000	123	2.80	1.4000	-0.30	[-0.62; 0.02]	2.4%	40.7%
Meziere 2021	18	27.60	2.7000	17	30.70	3.2000	-3.10	[-5.07; -1.13]	0.1%	5.8%
Iliffe(a) 2014	203	2.27	0.2700	273	2.28	0.2700	-0.01	[-0.06; 0.04]	97.5%	48.1%
Fixed effect model	**384**			**456**			**-0.02**	**[-0.07; 0.03]**	**100.0%**	**--**
Random effects model							**-0.24**	**[-0.75; 0.26]**	**--**	**100.0%**

Heterogeneity: $I^2 = 79\%$, $\tau^2 = 0.1384$, $p < 0.01$

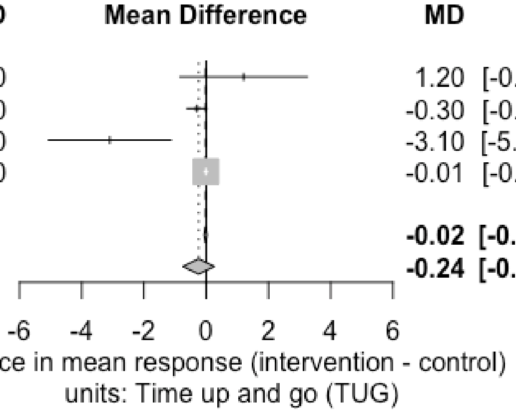

Figure 13: Metanalysis of quality of life (Only DHI+PE+cointerventions vs other treatments)

Study	Experimental Total	Experimental Mean	Experimental SD	Control Total	Control Mean	Control SD	SMD	95%-CI	Weight (fixed)	Weight (random)
Bernocchi 2019	122	0.42	0.5300	123	0.18	0.7000	0.39	[0.13; 0.64]	24.8%	27.8%
Tomita 2009	16	14.20	15.3000	24	6.80	22.1000	0.38	[-0.26; 1.01]	3.9%	12.8%
Iliffe(a) 2014	156	133.72	14.9500	185	134.80	14.8200	-0.07	[-0.29; 0.14]	34.9%	29.6%
Iliffe(b) 2014	169	132.31	15.9800	185	134.80	14.8200	-0.16	[-0.37; 0.05]	36.4%	29.8%
Fixed effect model	**463**			**517**			**0.03**	**[-0.10; 0.15]**	**100.0%**	**--**
Random effects model							**0.09**	**[-0.20; 0.37]**	**--**	**100.0%**

Heterogeneity: $I^2 = 77\%$, $\tau^2 = 0.0598$, $p < 0.01$

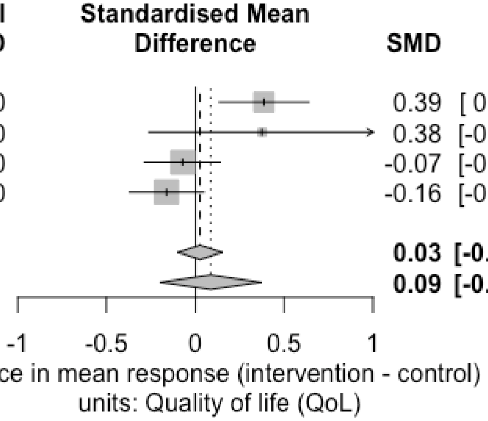

Figure 14: Metanalysis of household related PA (Only DHI+PA vs other treatments)

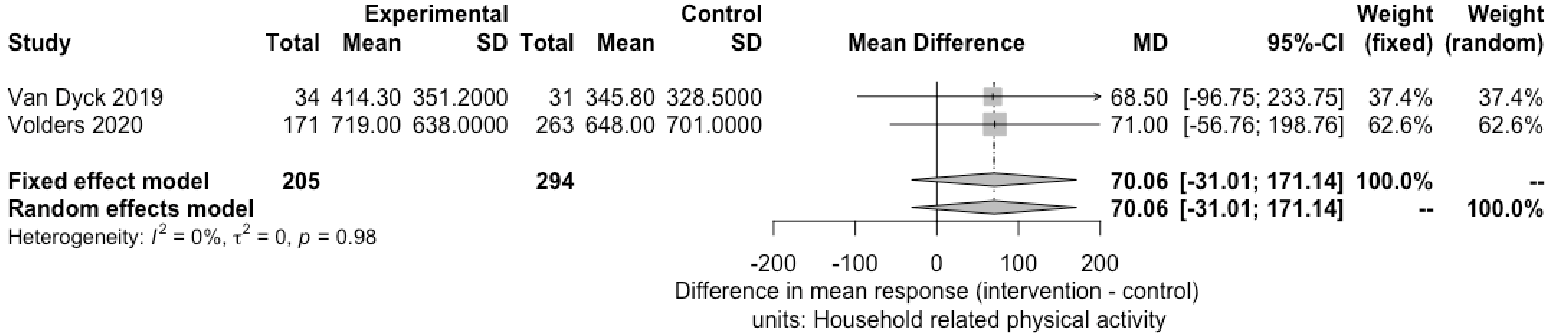

Figure 15: Metanalysis of moderate-to-vigorous PA (Only DHI+PA vs other treatments)

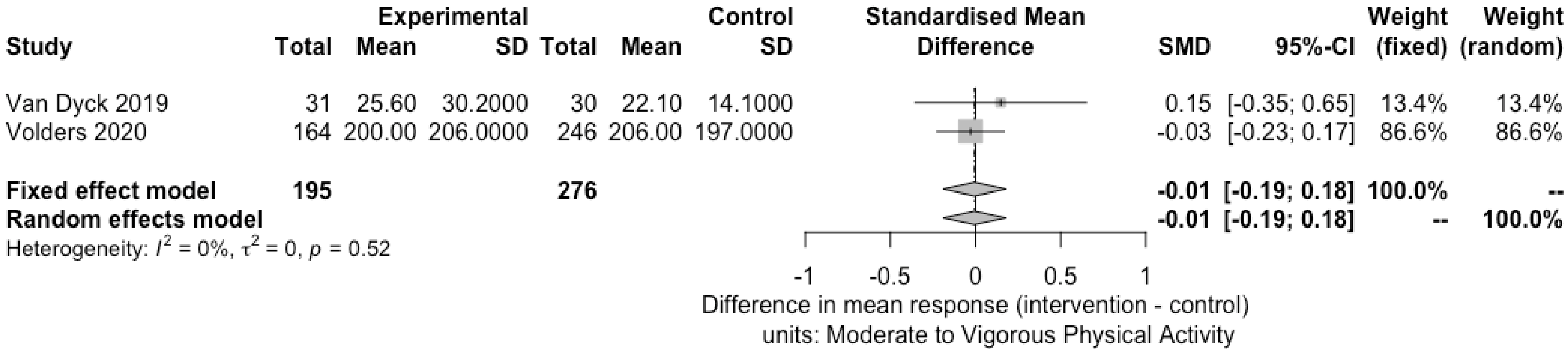

Figure 16: Metanalysis of walking for transport in PA (Only DHI+PA vs other treatments)

Study	Experimental Total	Experimental Mean	Experimental SD	Control Total	Control Mean	Control SD	MD	95%-CI	Weight (fixed)	Weight (random)
Van Dyck 2019	34	92.90	122.6000	31	161.60	178.6000	-68.70	[-143.87; 6.47]	31.7%	46.0%
Volders 2020	171	216.00	257.0000	263	185.00	279.0000	31.00	[-20.19; 82.19]	68.3%	54.0%
Fixed effect model	**205**			**294**			**-0.59**	**[-42.90; 41.73]**	**100.0%**	**--**
Random effects model							**-14.89**	**[-112.29; 82.50]**	**--**	**100.0%**

Heterogeneity: $I^2 = 78\%$, $\tau^2 = 3893.4088$, $p = 0.03$

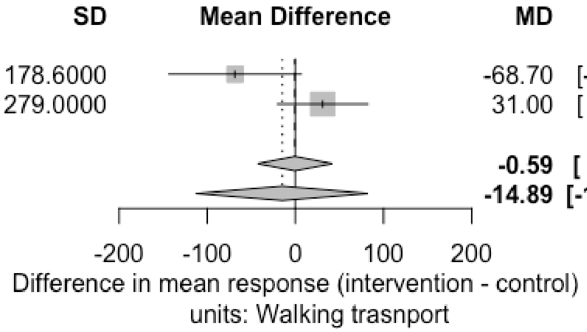

Table 1: Data extraction

U: Unicentric; M: Multicentric; IG: intervention group, CG: control group; NR: not reported; HVis: Home Visit; PO: principal outcome, SO: secondary outcome; interv: intervention; PT: Physical therapist; OT: occupational therapists. N: sample; FITT (F: frequency (times/week); intensity (nºrep/sets, watts, %MHR: and progression (tp describe individualizated progression or not); time (duration); type)); PA: physical activity; 6MWT: six-min walk test; ISWT: incremental shuttle walk test; ESWT: endurance shuttle walk test; CRDQ: Chronic Respiratory Disease Questionnaire

ABC: Activity-specific Balance Confidence; CDP: Computerized Dynamic Posturography; SOT: Sensory Organization Test: Mini-BESTest: Mini Balance Evaluation Systems Test; 5-STS: five times sit to stand; FSST: Four Square Step Test; FRT: Functional Reach Test; 10-MWT; TUG: Timed up and go; TUG-COG: and Go with Cognitive Task; EQ-VAS: Euro Quality of life-visual analog scale; GDS: Geriatric Depression Scale; HADS: Hospital Anxiety and Depression Scale; VAS: Hospital Anxiety and Depression Scale; MBI: Modified Barthel Index; ISWT, FVC, FEV1, FEV1/FVC, IC; Digit Symbol Substitution Test of Wechsler Adult Intelligence Scale-Revised (DSST, WAIS-R), Free and Cued Selective Reminding test (FCSRT), Category Naming test (CNT); Controlled Oral Word Association Test (COWAT); Falls Efficacy Scale International (FES-I); Balance Outcome Measure for Elder Rehabilitation (BOOMER), Time Loaded Standing (TLS), Health Assessment Questionnaire (HAQ); Roland-Morris Disability Questionnaire(RMDQ), Community Healthy Activities Model Program For Seniors (CHAMPS) scale; Physical Activity Scale for the Elderly (PASE). Saltin-Grimby Physical Activity Level Scale (SGPALS); Attitudes to Falls Related Interventions (AFRIS); Functional Performance Inventory – Short Form (FPI-SF); Barthel Index: BI

COPD Assessment Test (CAT); Modified Medical Research Council (MMRC). Falls Management Exercise Programme (FaME).

Author year; country	Participants, age, N	General description of intervention group			General description of comparation group	Outcome of interests	Principal results
		Duration of intervention	FITT (Frequency; Intensity; Time; Type of exercise)	Digital Health Intervention			
Arrieta 2019; France	Onco-geriatric patients 76.7±5 yr. N= 301	12 m	F: 2 s/wk;I:low to high , with progression; Ti:NR T: Strength, balance, proprioception, flexibility and aerobic training	T:Phone calls DT: physical activity and sport sciences instructor	N=150 half an hour a day of any type of physical activity	SPPB; IPAQ, self-reported falls	A decline of ≥1 point SPPB in 14.0% in UCG and 18.7% in IG
Bao 2018; USA	Community-dwelling healthy older adults.	8 wk	F: 3 s/wk; I:NR, with progression; Ti:45 min.	T: Application and Vibrotactil SA To: Smartphone,	N= 6 The same treatment (Balance training exercises) without the	ABC, CDP, SOT, Mini-BESTest, 5-STS, FSST, FRT, 10-MWT, TUG,	IG improvements in SOT and Mini-BESTest scores than CG. Significant improvement 5-STS within the IG, but not in CG.

	IG=76.2±5.5 yr. CG=75.0±4.7 yr N= 12		T: Gait, balance, and functional training	Vibrotactil SA (sensory augmentation) Fe:NR DT:NR	Vibrotactil SA (sensory augmentation).	TUG-COG	
Bernocchi 2018; Italy	Patients who had a medium/high fall risk 79±6.6 yr N= 283	6 m	F:NR I:NR individualized, with progression Ti:NR T: strength, gait, balance, and functional training	T: Phone calls DT: Nurse and PT	N= 142 Usual care by their general practitioner. exercise and walking recommendations, written information on fall risk factors	Incidence of falls, Barthel index, Katz index, Lawton-Brody IADL, BBS, TUG, FES, EQ-VAS,EQ-5D	Reduction in the risk of fall in IG with respect to CG. Functional status improved much more in IG. BBS improved and TUG decreased only in IG. FES significantly increased in CG and was unchanged in IG. EQ-5D and EQ-VAS improved only in IG.
Bickmore 2013; US	Inactive community-dwelling adults 71.3 ± 5.4 yr N= 263	2 m until 12 m	F:daily steps I:NR, no progression Ti:NR T:walking	T: embodied conversational agent (ECA) To: tablet and d pedometer Fe: the ECA discuss daily with the subject DT: ECA	N= 131 CG received pedometers,	Steps/day and adherence	Adherence: 95% and 86% in 2- and 12-m respectively IG walked more steps than CG at 2-m but this effect waned by 12-m.
Boongird 2017; Thailand	Older adult with mild-to-moderate balance dysfunction. CG=73.9±7.5 yr IG=74.1±5.9 yr N= 439	12 m;	F:6 s/wk; I: Mild-Moderate, with progression; Ti:NR T: Multiple categories of exercise (strength, flexibility and gait, balance, and functional training)	T: Phone calls and DVD-based To: Phone, video disck recorded (VDR) Fe: Phone calls DT: Nurse	Fall prevention education and home safety information.	Self reported falls, TUG, BBS, 5- STS, Fall efficacy scale, EQ-5D, EQ-VAS, exercise adherence	The IG showed the incidence of falls was 0.30 person/year, compared with 0.40 in CG. No significant difference in physical functioning.
Conn 2003; USA	Community-dwelling older women;	3 m;	F: NR	T: phone calls and email	N=NR	PA; Baecke PA Scale; rating of perceived exertion	The prompting intervention consistently increased exercise and PA scores. The motivational

	independent; sedentary 75,0±6,72 N= 190		I: NR, progression NR Ti: NR T: General physical activity	To: NR Fe: weekly; personalised with model answers to typical questions DT: trained staff	CG with educational information about exercise benefits and appropriate exercise; CG1 with prompts and CG2 without prompts		intervention did not affect outcome scores.
De Souto 2020; France	Community-dwelling older adults with subjective memory complaints, without dementia 74.2 ±5.6 years N= 120	6 m	F: 2s/wk I: individualized, with progression Ti: NR T: Multiple categories of exercise (strength, endurance, flexibility and gait, balance, and functional training)	T: web multidomain platform (videos, chat, agenda) To: Tablet; accelerometer Fe: frequency NR; chat personalized DT: research team	N= 60 Received only an accelerometer	Adherence MMSE, DSST, WAIS-R, FCSRT, CNT, COWAT, SPPB and gait speed; 15 ítem - GDS; MNA; EQ-5D-5L and VAS; self-reported PA, METS/week and step count	No statistically significant effects were found, except for the two variables: index value and VAS. HRQOL, showing MIG had an improved HRQOL compared to CG.
Feng 2019; US and Sweden	Older adults 73.2 Adaptive: 73.0 (5.7) Control: 73.8 (6.5) Mindfulness: 72.3 (5.6) Physical: 73.6 (6.8) N =156	5 weeks;	F: 5 sesions/wk I: self-regulating (somewhat hard extertion with Borg RPE), with progression Ti: 35-40 min/session T: Endurance	T: interactive web-based software (exercise videos with real-time registration and regulation of exertion); phone calls. To: laptop computer and phone Fe: weekly; automatic in website DT: research assistant	G2: mindfulness meditation (N=39) G3: Cogmed Adaptive Computerized Working Memory-Training Programs (N=41) G4: Cogmed Non-Adaptive Computerized Working Memory-Training Programs(N=40)	Completion and adherence rate. % time spent at each intensity and physical activity; IPAQ	The PACE-Yourself group's adherence rate was 93%.

Giangregorio 2018; Canada and Australia	Community-dwelling women with vertebral compression fractures IG= 76 (6.4) CG= 77 (7.3) N= 141	12 m. N=71	F: min. 3 s/wk I: 5-8 Borg (Progression in time, repetitions and difficulty) Ti: minimum of 30 min. aerobics + other components. T: Strength, endurance and gait, balance, and functional training. Better Bones with Exercise (B3E) program.	T: Calls Phone To: Phone Fe: Monthly; personalized DT: Physiotherapist	N= 70 6 home visits and 12 call phone focused on health or social discussion	Adherence, incidence of falls	92% of participants completed the study; adherence was 66%. The IG did not differ in the number of falls (IRR 0.97, 95% CI 0.58 to 1.63) or fragility fractures (OR 1.11, 95% CI 0.60 to 2.05) compared to the CG.
Gibbs 2020; Canada and Australia	Community-dwelling women with vertebral compression fractures IG= 76 (6.4) CG= 77 (7.3) N= 141	12 m. N=7 Better Bones with Exercise (B3E) program.	F: min. 3 s/wk I: 5-8 Borg (Progression in time, repetitions and difficulty) Ti: minimum of 30 min. aerobics + other components. T: Strength, endurance and gait, balance, and functional training.	T: Calls Phone To: Phone Fe: Monthly; personalized DT: Physiotherapist	N= 70 6 home visits and 12 call phone focused on health or social discussion	SPPB, BOOMER, TLS, Occiput-to-wall distance and standing height; EQ5D-3L and mini-Osteoporosis Quality of Life Questionnaire (mini-OQLQ); VAS; FES-I	There was a small effect of exercise on 5-STS versus CG. There were no other major or statistically significant MDs for any other measured outcomes after follow-up. Adherence declined over time.
Goode 2018; US	Sedentary older adults with chronic low back pain (CLBP) 70.3 (4.9) yr.	12 wks; N= 20 PA group and PA + CBT-P group received written	F: NR I: NR, with progression Ti: NR T: Multiple categories of exercise (strength,	T: Calls Phone based To: Phone Fe: every 4 weeks by PT, (3 telephone calls). 1 time/week by exercise	Wait- list group N=20 Continue with their current lifestyle. PA + CBT-P group	TUG and PROMIS, HAQ; RMDQ, satisfaction with physical function scale, Patient-Specific Functional Scale (PSFS)	Small to medium treatment effects were found for the IG in the Timed “Up & Go” Test (PA group: −2.94 [95% CI = −6.24 to 0.35], effect size = −0.28;

	N= 60	instructions and video .	flexibility, and endurance).	counselor, (10 telephone calls) DT: PT and exercise counselor	N= 20 Physical activity plus cognitive-behavioral therapy for pain (delivered in the weekly phone call)		
Hong 2017; South Korea	Community-dwelling senior citizens (69-93) yr. N=23	12 wks. N= 11 Supervised home-based tele-exercise resistance training program	F: 3s/wks I: somewhat hard (RPE 13-14) and hard (RPE 15-16) starting at RPE 11, with progression Ti: 20-40 min T: strength. Nutrition and exercise education was provided	T:Videoconference To: PC. F: face to face during exercise DT: exercise instructor	N=12 Maintained their lifestyles without any special intervention.	upper limbs muscle mass, lower limbs muscle mass, appendicular lean soft tissue (ALST) and total-body skeletal muscle mass (TSM); SFT	Significant improvements in lower limb muscle mass (p=.017), appendicular lean soft tissue (p=.032), total muscle mass (p=.033), and chair sit-and-reach length (p=.019) for the tele-exercise group compared to the control group
Iliffe 2014; UK	Older adults who were independently mobile 73 (65–94) yr. N=1256	24 wks. N=411 ProAct65+ study	F: 3 s/wk I: NR, with progression Ti: 30 min. T: multiple categories of exercise (leg strength, general physical activity and gait, balance, and functional training). Home-based exercise based on the Otago Exercise Program (OEP)	T:phone calls To:phone Fe: fortnightly (12calls/24wks) personalized DT: trained peer mentors	CG: Usual care N= 458 Comparador: Community-based group, class-based exercise programme Falls Management Exercise (FaME). N= 387	CHAMPS scale, PASE. Telephone questionnaire (Phone-FITT), nº of falls; risk falls (FRAT score); FES-I; SF-12, EQ-5D and OPQoL; balance confidence; Nutrition and exercise education was provided FRT and Long-TUG; costs and resources	No statistically significant increase in MVPA in the OEP arm compared with the usual-care arm PASE showed a small, benefit for FaME Improvements in balance confidence for both intervention arms

Kullgren 2014; US	Older adults 71.9 yrs. IG1: 72.4 (5.8) IG2: 71.9 (5.6) IG3: 71.9 (5.8) CG: 71.5 (5.1) N =92	16 wks. N= G1=20 Financial incentives IG2= 22 Peer Networks IG3= 25 both.	Daily steps F: Min. 5 days/wk I: NR, progression of 50% from baseline level of walking Ti: NR T: general physical activity	T: website and email or text feedback To: Computer and Fitbit pedometer Fe: weekly; automatic e-mail, text message. DT: NR	N= 25 Each week participants received automated e-mail or text feedback about how often they met their walking goal in the past week	daily steps	No differences in the proportion of days walking goals were met in the Financial Incentive (39.7%; p = .78), Peer Network (24.9%; p = .08), and Combined (36.0%; p = .77) arms compared with the Comparison arm (36.0%)
Li 2020; Hong Kong	Older adults, post hip-fracture surgery. CG= 82.1 (9.7) IG= 76.5 (8.6) N= 31	3 wks. N=15;	F: NR, personalized I: NR personalized, progression NR Ti: NR personalized T: multiple categories of exercise (strength, flexibility and gait, balance, and functional training). + conventional therapy in day hospital	T: app To: smartphone (videos, pictures, written and verbal instructions) Fe: in each session, automatic. DT: in app by therapist	N= 16 Home program through written sheets + conventional therapy in day hospital	TUG, FRT, force gauge and pain perception VAS; MBI, IADL, the Morse Fall Scale (MFS) and FES	No significant differences in TUG, FR, pain VAS, MBI and FES between the two groups at pretest, post test and follow-up (p > 0.05). IG showed greater improvement in the mean scores of the MFS and IADL scale.

Liu 2008; Taiwan	Patients with moderate-to-severe COPD IG=71.4±1.7 CG=72.8±1.3 N= 4	3 m N=24 Endurance walking exercise with constant intensity.	F: daily I: walking speed at 80% of maximal capacity, with progression Ti: until they could not keep up the tempo walking speed T: endurance.	T: app (linked with website) To: phone Fe: telephone reinforcement when patients missed 1 day of walking training. DT: in website.	N=24 Received the same protocol and telephone reinforcement every 2 weeks during the first 3 month.	SF-12; frequency of performance and the duration of the endurance walking programme every week;	ISWT distance improved and duration of endurance walking after 8 weeks. Improvements in ISWT distance, inspiratory capacity and SF-12 scoring at 12 weeks persisted until the end of the study.
Mansson 2020; Sweden	Older adults, living independently 77 ± 4 yr. N= 67	4 m N=29 Otago exercises plus FaME	F: 3s/wks I: self-management by feeling of difficulty, with progression Ti: 30min at least T: multiple categories of exercise (strength and gait, balance, and functional training)	T: app (video clips and self-reported digital exercise diary) To: laptop, tablet or smartphone Fe: weekly; pre-written messages from virtual physiotherapist (automatic) DT: researchers (digital diary)	N= 38 Program based Otago exercises plus paper booklet.	SGPALS; SPPB; ABC; AFRIS; questionnaire of experience of using the programme and perceived effects; completion, attendance, duration, and intensity	Attrition rate was 17% in the digital programme group and 37% in the paper booklet group. At 12 months follow-up 67% of digital programme continued to exercise regularly compared with 35% for the paper booklet (*p* = .036).
Matz-Costa 2018; US	Older adult inactive community-dwelling, 72.9 (SD 6.6) N= 30	8 wks. N= 15 The Engaged4Life program.	F: NR I: NR TI: NR, progression NR T: walking psychoeducation + goal-setting, and one-on-one peer mentoring	T: wearable, digital surveys and phone calls, To:pedometer, tablet and phone Fe: 5 calls/2.5wk, personalized. DT: Peer mentors	N= 15 Self monitoring of daily activity via pedometers and daily tablet based surveys	Adherence, steps per day; number of cognitively stimulating activities participants had engaged in that day.	Retention rate was 83%. Daily steps increased by 431 (11% increase) from baseline to Week 4 for the intervention ($p < .05$), but decreased by 458 for the control, for a net difference of 889 steps ($p < .05$).

Mèzierè 2021; France	Older adults with risk of falls or loss of personal independence with a home helper. N=36 IG=90 [86.9-93.4] CG=88.6 [84.1-92.0]	3 m N=18; TH4 intervention: home-helper-led exercise program.	F: NR personalized I: 3 levels of intensity, with progression Ti: NR personalized T: multiple categories of exercise (strength, flexibility and gait, balance, and functional training) + home helper-led program and usual rehabilitation	T: app (videos, text, and voice instructions) To:tablet Fe: by the helper at the PT, 2-3/wk personalized DT: PT	N=17 Standard home help and usual rehabilitation	32 closed-ended questions; 16 closed-ended questions; TUG and the single-leg balance test; BI; Duke Health Profile	Satisfaction: 70% with IT devices, and 92% with their home helper's level of involvement. falls were higher in the T4H group (92.3%) than in the CG (81.8%). No differences in TUG or BI (
Tomita 2009; US	Older adults with heart failure 76.2 yr.	12 m N=16	F: NR I: NR, progression NR Ti: NR T: multiple categories of exercise (strength, endurance, flexibility) + support (informational, instrumental, appraisal, and emotional) and recorded daily vital signs	T: website, streaming video to do exercises. To: PC Fe: monthly vía email, personalized DT: health care professionals	N=24 Usual care (a three-month regular check up with their physicians)	20 questions; nominal scale; Congestive Heart Failure Questionnaire (CHFQ); 50-item age relevant questionnaire; times/month entering the website	The treatment group had a high (85%) adherence to the intervention. Only the treatment group showed a significant improvement in the knowledge level (p 0.001), amount of exercise (p = 0.001), and HRQOL (p = 0.001), and reduction in HF related symptoms, blood pressure (systolic, p = 0.002; diastolic, p 0.001), frequency of emergency room visit, and length of hospital stay (both p = 0.001)
Tsai 2017, Australia	Patients with COPD	8 wks. N= 20	F: 3 s/wk. I: moderate to somewhat severe (3-4 RPE) of	T: videoconferencing	N= 17 Usual medical management including optimal	6MWT, ISWT, ESWT; Chronic Respiratory Disease Questionnaire	IG showed an increase in ESWT time, self-efficacy, no difference in CRDQ and physical activity.

	74 yr. 8 SD N= 37	+ cycle ergometer, booket and education session.	endurance and 3x10 of strength, with progression Ti: 41 to 55 min, then strength training (more than an hour) T: multiple categories of exercise (strength and endurance)	To: laptop computer with a camera Fe: each session, using real-time video conferencing in group (4 patient) DT: PT	pharmacological intervention and an action plan was provided. This group did not participate in any exercise training and had no education session	(CRDQ); PA FPI-SF; CAT; MMRC; HADS; Pulmonary Rehabilitation Adapted Index of SelfEfficacy (PRAISE)	
Van Der Helder 2020; Nederland	Community-dwelling older adults; 72.0 ± (6.5) N=245	12 m G1=HBex N= 65 App that made a personalized exercise program with progressive functional training exercises	F: at least 2 days/wk I: moderate to vigorous (5-6 to 7-8 on the 10 point scale RPE) Ti: 10min to 45min, with progression T: multiple categories of exercise (strength, flexibility, endurance and gait, balance and functional training)	T: app-based To: tablet PC Fe: face-to-face visits or tablet-supported video calls, weekly in the first 2 months, fortnightly in the next 2 months, and once a month in the final 2 months; personalized DT: junior exercise coach	N=91 CG The same exercise programme without tablet PC N=68 G2=HBex-Pro The same exercise program and personalized dietary counselling to optimize their protein intake	Modified Physical Performance Test (m-PPT) SPPB, TUG, 6MWT, physical activity level (PAL), handgrip muscle strength (HGS), health status, and adherence	For the primary outcome m-PPT, no significant intervention effects (HBex, +0.03, P = 0.933; HBex-Pro, 0.13, P = 0.730) were found. Gait speed (+0.20 m/s, P = 0.001), PAL (+0.06, P = 0.008), muscle strength (+2.32 kg, P = 0.001), and muscle mass (+0.33 kg, P = 0.017) improved significantly in the HBex-Pro group compared with CG
Van Dyck 2019; Belgium	Older adults; 70.9 yr. 4.1 SD N=72	5 weeks; N=38 Both groups used accelerometer for 3 weeks	F: NR self-elected I: NR self-elected, with progression Ti: NR self-elected T: General physical activity	T: web-based To: PC and accelerometer Fe: 5 website visits reminded by email DT: in website	N=34 Use of accelerometer for 3 weeks	PO: Self-reported PA and objective PA	Effective in increasing self-reported PA, mainly in the intermediate term. A positive intermediate-term effect was found for leisure-time vigorous PA (P=.02), moderate household-related PA (P=.01), and moderate PA in the garden (P=.04).

Van Het Reve 2014; Switzerland	Autonomously living older adults. 75 yr. 6 SD N=44	3 m. Social Group N=13; Individual Group N=14; HVis: NR; Participants from all groups performed the same exercises. Both groups used the tablet with the app	F: 2/week resistance and stretching training, and 5/week balance training I: NR with progression Ti: NR T: Multiple categories of exercise (strength, flexibility and gait, balance, and functional training)	T: app-based To: tablet Fe: for each time they performed an exercise, automatic DT: NR	Brochure group N=17 The same exercises using a training plan on paper sheets	Adherence; GAITRite walkway and SPPB; Falls Efficacy Scale International (FES-I)	The tablet groups showed significant improvements in single and dual task walking, no significant Changes in the brochure group. Between-groups comparisons revealed significant differences for gait velocity (U=138.5; P=.03, r=.33) in favour of the tablet groups. Significant between-groups differences were seen between the tablet groups and the brochure group, in favor of the tablet groups.
Vidoni 2016; US	Older adults with and without cognitive impairment; 69'6 (5'8) N=30	8 weeks N=14 IS started immediately the PACER intervention and DS after 8 weeks. Exercise prescription booklet to set daily goals and to record their step counts	F: NR I: NR, increase goal step count 20% every week Ti: NR T: general physical activity	T: tool-based To: accelerometer Fe: if study coaches saw no activity recorded, they made phone-calls DT: study coaches	DS group N=16 The first 8 weeks wearing a masked accelerometer and then the same as IS	% of enrolees who were able to use the accelerometer, completion for 8 weeks and number of adverse events; change in weekly step count; 6MWT; mini-Physical Performance Test (mPPT); Quality of Life – AD (QoL-AD) scale; General Self-Efficacy Scale (GSES)	Set-up and use of the device was not a barrier to participation. All participants in the cohort with normal cognition were able increase their weekly step count above Week 1. There were no differences between Week 1 and Week 8 for any secondary measures in either cohort
Volders 2020; Netherlands	Older adults with chronic illness;	4 months; follow up at 6 and 12 months; N=260 Tailored information on	F: NR I: NR, progression NR Ti: NR	T: computer-tailored To: computer and accelerometer for one week	Waiting List CG N=325 Usual care. After 12 months follow up of IG, CG received	Objective light PA (LPA) and moderate-to-vigorous PA (MVPA) and self-reported moderate-to-vigorous PA	No effects on objectively measured PA. Active Plus increased the likelihood to perform self-reported cycling and gardening at six months and

	74'5 (±6'4) N=585	PA and presented tools on how to implement PA in daily life	T: general physical activity	Fe: 3 online personal advices DT: NR	personalised PA advice		participants who cycled increased their MVPA min/week of cycling.
Von Bonsdorff 2008; Finland	Older people; 77.6 (±1,9) N=632	24 months; N=318 Received initial 1h individual motivational face-to-face PA counseling and personal PA plan by the PT	F: NR personalized I: NR personalized, progression NR Ti: NR personalized T: general physical activity	T: phone calls To: NR Fe: every 4 months, personalized DT: NR	N=324 No intervention	IADL	IADL disability had increased in both groups (P.001) and was lower in the IG
Yamada 2011; Japan	Older people; IG 83 (±6,7); CG 82,9 (±5,5) N=93	6 m N=48	F: 2/week I: NR, progression NR Ti: 20min T: Multiple categories of exercise (flexibility + strength)	T: DVD-based To: DVD Fe: NR DT: NR	N=45 No exercise program was prescribed	10-m walking under the single-task condition, 10-m walking under dual-task condition, TUG, and 5-chair stand test	The adherence was 87.5% (25th–75th, 83.3%–95.8%) in the DVD group. The DT walking time and DT time lag among participants in the DVD group were improved. However, other outcome measurements were not significantly different between the two groups (p > 0.05).

Table 2: Type of digital health interventions and devices of the exercise programs

Autor year	Type DHI in PE	Device in PE
Arrieta 2019	Phone call	Phone
Giangregorio 2018		
Gibbs 2020		
Goode 2018		
Iliffe 2014		
Bernocchi 2018		
Li 2020	App	Phone
Liu 2008		
Bao 2018		Vibrotactile SA in the smartphone
Van Der Helder 2020		Tablet PC
Van Het Reve 2014		
Mèzierè 2021		
Mansson 2020		Laptop, tablet or smartphone
Hong 2017	Videoconference	PC/Laptop
Tsai 2017		
De Souto 2020	Web site	Tablet and accelerometer
Tomita 2009		PC
Yamada 2011	DVD	DVD
Feng 2019	Multiple DHI (website+phone calls)	Laptop and phone
Boongird 2017	Multiple DHI (DVD+phone calls)	Video disk recorded and phone

Table 3: Type of digital health interventions and devices of the physical activity incentivisation programs

Autor, year	Type DHI in PA incentivisation	Device in PA incentivisation
Van Dyck 2019	Website	NR
Volders 2020		Computer and accelerometer
Vidoni 2016	Wearable	Accelerometer
Von Bonsdorff 2008	Phone calls	NR
Bickmore 2013	Embodied conversational agent (ECA)	Tablet computer and pedometer
Conn 2003	Multiple DHI (phone call+email)	NR
Kullgreen 2014	Multiple DHI (Website+email or text)	Computer and pedometer
Matz-Costa 2018	Multiple DHI (Wearable (FITBIT) + phone calls)	Tablet, iPad, phone