Original Research

DIGITAL HEALTH

Digital Health
Volume 8: 1–11

DOI: 10.1177/20552076221139694
journals.sagepub.com/home/dhj
SAGE

ActiveHip+: A feasible mHealth system for the recovery of older adults after hip surgery during the COVID-19 pandemic

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Abstract

Objective: Half of older adults undergoing hip surgery do not recover their previous functional status. mHealth is a promising tool for rehabilitating older adults after hip surgery. This study aimed to test the feasibility of the ActiveHip+ mHealth system in older adults after hip surgery.

Methods: Sixty-nine older adults who had undergone hip surgery and their family caregivers were recruited from hospitals in Spain and Belgium and used the ActiveHip+ mHealth system for 12 weeks. Assessments were made during hospital stay and 3 months after surgery. Feasibility assessment included: adoption (participation proportion), usage (access to the app), satisfaction with the app (Net Promoter Score) and user perception of the quality of the app (Mobile App Rating Scale). Clinical assessment included: patient-reported outcomes, such as functional status (Functional Independence Measure) and performance-based outcomes, such as physical fitness (Short Physical Performance Battery).

Results: The ActiveHip+ mHealth system obtained satisfactory feasibility results in both countries. In Spain, we observed 85% adoption, 64% usage, 8.86/10 in satisfaction with the app and 4.42/5 in perceived quality of the app. In Belgium, we observed 82% adoption, 84% usage, 5.16/10 in satisfaction with the app and 3.52/5 in app's perceived quality. The intervention had positive effects on levels of functional status, pain and physical fitness.

Conclusions: The ActiveHip+ mHealth system is a feasible tool to conduct the rehabilitation in older adults after hip surgery. Although the intervention seemed beneficial clinically, we do not recommend its implementation in clinical settings until appropriately designed randomised clinical trials confirm these results.

Keywords

eHealth, digital health, tele-rehabilitation, hip fracture, osteoarthritis, osteoporosis, functional status, older people, family caregivers, health providers

Submission date: 8 August 2022; Acceptance date: 1 November 2022

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Introduction

Hip osteoarthritis and hip fractures due to osteoporosis are leading causes of disability in older adults.[1] In general, both conditions are particularly concerning because of their high prevalence, health impact and socio-economic cost.[2] The prevalence of hip osteoarthritis is 40 million people worldwide,[3] a figure that is expected to rise with increasing life expectancy.[4] The consequences of osteoarthritis include loss of function[5,6] and reduced quality of life.[7] The economic cost invested in treating hip osteoarthritis is high due to the high rate of disability[8] and the expensive medical interventions such as hip replacement. The annual cost of each person with hip osteoarthritis during the year prior to the surgery is up to €810.[9] This cost increases exponentially considering the expense associated with hip replacement surgery.[10] Similarly to osteoarthritis, people with osteoporosis face an increased risk for hip fractures; 250 cases out of 100,000 Europeans.[11] The cost associated with osteoporotic hip fractures is €57,000 million in Europe.[11] Importantly, in hip fractures due to osteoporosis, mortality 1 year after the hip fracture episode ranges from 20% and 40%.[12] Additionally, half of those who survive that first year do not fully recover their functional status after surgery.[13] In both hip osteoarthritis and hip fractures due to osteoporosis, hip surgery is considered the most effective treatment[14,15] and post-surgery rehabilitation is crucial. Thus, it is important ensuring the continuity of care in people with hip osteoarthritis or osteoporotic hip fractures, especially from a value-based health care perspective.[16–18]

Currently, continued rehabilitation after hospital discharge is often limited.[19] In fact, acute trauma centres for hip fractures reduced the care of people with osteoarthritis or osteoporosis during the COVID-19 pandemic.[20] These limitations concur with the increasing trend in the use of mobile health, also known as mHealth, the use of mobile and wireless technologies to support the achievement of health objectives.[21] mHealth offers the potential of reducing hospital visits, allowing patients to rehabilitate from home and facilitating follow-up by health professionals.[22] The evidence shows that this type of rehabilitation is effective in many diseases.[22–25] Despite the existence of evidence supporting the use of digital tools after hip surgery,[26–29] to the best of our knowledge, there are just a few mHealth interventions for this population.[30–34] It is important to develop new mHealth interventions to provide a comprehensive tele-rehabilitation program, focussing not only on rehabilitation but also on secondary fracture prevention. Thus, we developed the ActiveHip+ mHealth system as an alternative for those older adults who cannot access to in-person rehabilitation. The ActiveHip+ mHealth system was co-created with older adults with a hip fracture, their family caregivers and health professionals. Co-creation is a step considered essential for uptake, usage and sustainability of this type of intervention.[35] A more detailed information about ActiveHip+ has been published elsewhere.[36] Therefore, the aim of the present study was to evaluate the feasibility of implementing the ActiveHip+ mHealth system in older adults after hip surgery following hip fracture or hip osteoarthritis, in an orthopaedic setting and within two different healthcare systems.

Methods

Design

The present feasibility study was international and multicentre involving participants with osteoporosis and osteoarthritis from (a) three hospitals from southern Spain (Andalusian) Public Healthcare System and (b) three hospitals located in the Belgian north-west region, from the hospital's company Algemeen Ziekenhuis Delta (AZ Delta) hospitals in Belgium. The project followed the guidelines established by the Helsinki Declaration and Law 14/ 2007 on Biomedical Research. This study was approved by the Ethics Committee of Research Ethics Committee Granada (CEI Granada), (21/07/2022), the Ethics Committee of Katholieke Universiteit Leuven (S65606) and AZ Delta (S65606). Informed consent was obtained from older adults and family caregivers.

Participants

The current study included 69 (36 from Spain and 33 from Belgium) older adults admitted to the Orthopaedic services who had undergone hip surgery and their family caregivers. The participants were recruited (a) from September to December 2020 in three different hospitals of the Andalusian Public Healthcare System; namely, the Virgen de las Nieves University Hospital (Granada), Puerto Real University Hospital (Cádiz) and Jerez de la Frontera University Hospital (Cádiz) and (b) from July to October 2021 in three different hospitals of the Belgian company AZ Delta; namely Campus Rumbeke (Rumbeke), Campus Rembert Torhout (Torhout) and Campus Brugsesteenweg Roeselare (Roeselare).

The inclusion criteria were: (a) to have undergone hip surgery to treat a hip fracture or osteoarthritis, (b) to be, at least, 60 years of age, (c) to be authorised weight-bearing on the operated limb 48 h after the surgery, (d) to have been functionally independent before surgery measured with the Functional Independence Measure (FIM), that is, overall FIM score of 90 points or higher a week before surgery, (e) to be discharged to their own home or to a relative's home and (f) to have internet access and the ability of using mobile phone (g) or in cases where the older adults did not have the ability, to have a caregiver with internet access and the ability of using mobile phone. The exclusion criteria were: (a) to have severe cognitive impairment (i.e.

to make, at least, 4 mistakes for literate older adults or 5 mistakes for illiterate in the Short Portable Mental State Questionnaire), (b) to be discharged to an institution or nursery home, (c) to have post-surgery complications precluding the start the rehabilitation and (d) to be diagnosed with a terminal disease.

Recruitment and follow-up

Older adults after hip surgery and family caregivers were offered to participate in the study during their hospital stay. Those who agreed were assessed and trained in the use of the ActiveHip+ mHealth system 1 or 2 days before hospital discharge. During the training, the research team of this study downloaded the app in the participants' mobile phone to check that everything worked. They also explained the different sections of the app and showed how to perform the tele-rehabilitation sessions The exercises of the first tele-rehabilitation sessions were explained to the older adults and their family caregivers. In addition, the most complicated exercises were practiced before hospital discharge. The explanation and follow-up of the subsequent sessions were conducted during the videoconferences. Thus, participants of this study had time to practice, resolve doubts and optimise their digital literacy in order to improve their experience of use before hospital discharge. Additionally, participants receive a leaflet with instructions on how to use the application in case they have any doubts. Moreover, the research team of the study reminded participants that they could ask questions through the messaging section of the application. In some cases where older adults did not have the ability to use a mobile phone and their caregiver was not in the hospital due to the COVID-19 restrictions, the explanation and subsequent training with the caregiver was made via phone call or video call. Participants of this study were contacted regularly, at least once every other week, to solve any issues during their experience using the ActiveHip+ m-Health system. All the assessments were conducted at the hospitals, the first before they started using the ActiveHip+ system, and the last at 12 weeks (end of the program use).

ActiveHip+ mHealth system

A detailed description of the ActiveHip+ program is available elsewhere.[36] The ActiveHip+ mHealth system[36] is comprised of: (a) a mobile application for older adults after hip surgery and family caregivers, who play an essential role to help older adults to use mHealth and (b) a webpage for health professionals, where they can monitor and adjust the evolution of the older adults in their recovery process.

The contents of the educational health and tele-rehabilitation program delivered through the ActiveHip+ mHealth system for older adults after hip surgery and family caregivers are grouped into two main sections. Firstly, the health educational section was composed of five modules for older adults and family caregivers, and two additional specific modules for family caregivers. The modules offered relevant information about the hip recovery process (e.g. type of surgery, medication, overview of the recovery process during hospital stay and at hospital discharge, supporting devices for the development of the activities of daily living since the first day after surgery, keys to the physical and mental well-being) and keys for prevention of secondary fractures. This section was provided through videos, one for each module, which were translated and cross-culturally adapted for older adults and family caregivers from both Spain and Belgium. Between each module, there is a brief summary of the content they have just watched and an introduction to the next module. These summaries were created to facilitate the participants' learning and to allow them to stop at some points if they needed to continue the educational section at a different time. The total duration of the 5 and 7 modules was one hour and one and a half hours, respectively. Secondly, the rehabilitation section, where older adults can perform two sessions of physical exercise and one session of occupational therapy per week for 12 weeks. The rehabilitation sessions were delivered through pre-recorded videos with a voice-over to describe each exercise. The physical exercise sessions consist of a warm-up, the main training and a cool-down. These sessions have 18–20 exercises depending on the level of difficulty and include balance, resistance, upper body, step and other exercises. The duration of the physical exercise sessions ranges from 25 min to an hour. The occupational therapy sessions are composed of the body of the session (ranging from 5 to 7 activities and a cool down with a choreography to improve the mobility. Activities such as mobility in bed, transfer with and without supporting devices or walking among others. The duration of the sessions ranges from 25 to 50 min. The tele-rehabilitation intervention was asynchronous due to requests of older adults and family caregivers during the co-creation process. The asynchronous delivery allows them both to adapt the sessions to their daily routine and set their own pace. At the end of each session, older adults respond to three questions regarding pain, effort and satisfaction with the session. This information is accessible through the health professional's webpage to individualise the rehabilitation program of the participant adapting the difficulty level of the sessions to the condition of the older adults. Moreover, there is an alert system on the website for health professionals to notify them if any value of these three questions is inadequate, that is, pain > 5, so that they can contact the participants quickly. Although asynchronous delivery does not allow for real-time follow up, we set the aforementioned alert system and a video call system. Through these video calls, health professionals could check in real-time the how older adults were progression, how they were performing the most complicated exercises and answer questions doubts about the recovery. Additionally, the app contains videos showing how to perform the activities of daily living (ADL) safely (i.e. dressing, bathing, up and down stairs). These videos are available anytime to the participants. The follow-up is based on messages and videoconferences between health professionals, older adults and caregivers, using a two-way communication system. The two-way communication system is composed of a messaging system in which older adults and caregivers can send messages to health professionals and vice versa. It also allows the possibility of making video calls in order to improve communication for older adults, family caregivers and health professionals.

Feasibility outcomes

To measure the feasibility of the ActiveHip+ mHealth system for older adults after hip surgery, the following measures were collected and analysed.

Adoption: Proportion of older adults agreeing to use ActiveHip+ out of the total number of older adults eligible to participate in the project. This information has been extracted from the register of the eligible and finally included participants.

Usage: The rate of older adults who access the mobile application at least half of the days of the health educational and tele-rehabilitation program delivered through the ActiveHip+ mHealth system. We measured the number of times older adults and their caregivers access the application through: (a) the number of interactions through the logging data and (b) the number of tele-rehabilitation sessions performed through the activity register, where health professionals could check the date and the time spent for each session.

Satisfaction with the app: The Mobile App Rating Scale (MARS) is an easy-to-use and reliable tool to measure the quality of several aspects of healthcare mobile applications.[37]

Perceived quality of the app: The Net promoter Scale (NPS) is a tool used to measure the satisfaction of the users of a mobile application through the question 'how likely would you recommend this mHealth tool to other older adults like you?' It scores from 0 to 10 points, scores are interpreted as indicating dissatisfaction (≤5 points) and satisfaction (>5 points).[38]

Clinical outcomes

Functional status: The functional level was assessed using the Functional Independence Measure (FIM). In the first assessment conducted during the first week after surgery, older adults were asked to report their functional status at two different times: (a) a week before surgery (i.e. to evaluate an inclusion criterion) and (b) at the moment of the assessment, which was during the week after surgery (i.e. pre-intervention measure). The FIM consists of 18 items, of which 13 concern physical activities divided into four categories: self-care, sphincter control, transfers and locomotion.[39] The remaining five items relate to cognitive and social functioning aspects divided into two categories: communication and social cognition. The total FIM score range is between 18 and 126 points. Higher scores indicate a higher level of independence. The psychometric properties of the FIM are adequate.[40] The FIM has been used previously during the follow-up of older adults after hip surgery, both during their hospital stay[41] and after hospital discharge.[42]

Physical performance: The Short Physical Performance Battery (SPPB) assessment has previously been used to evaluate older adults and older adults with hip fracture.[43–45] This tool consists of three tasks: balance, walking and chair stands.[43] The SPPB evaluates the ability to maintain balance for 10 s in certain positions, time to walk 4 m and time required to sit and stand up from a chair five times. We considered the individual scores to enhance understanding of patient physical performance. The total score ranges from 0 to 12 points, where higher scores indicate better mobility. The psychometric properties of the SPPB are adequate.[24,46]

Pain: The numeric rating scale for Pain (NRS) test is a fast and convenient way to evaluate the intensity of pain perceived by the patient. The patient indicates the perceived pain by pointing out on a physical scale a value from 0 (without pain) to 10 (maximum pain).[47] Psychometric properties of the NRS-pain are adequate.[47]

Statistical analysis

The normal distribution of the data was checked with the Kolmogorov–Smirnov test. When variables did not show a normal distribution, the Blom formula was performed.[48] Descriptive characteristics of the sample are presented as mean and standard deviation (SD) or frequency and percentage when appropriate.

The Acceptability of both the MARS and the NPS has been calculated. In both of them, the overall mean score of the scale and the standard deviation have been calculated and provided, as well as the mean score of each of the categories which compose the MARS scale.

To examine the effects of the ActiveHip+ mHealth system, we conducted a repeated measures ANCOVA, where the hospital stays assessment and the assessment 3 months after the surgery were the repeated measures to estimate the intra-subject effect. A previous stepwise regression was performed to decide the inclusion of the cofounders (i.e. age, gender, level of studies, body mass index (BMI), falls during last year, hospital stay, number of sessions and number of interactions) in the model which are the best predictors (i.e. explain the largest proportion of the variance) of functional status (subjective through the FIM scale and objective through the SPPB).[49] All analyses were performed using Statistical Package for Social Sciences (SPSS, IBM Corporation version 25.0; Armonk, NY) and the level of significance was set at $p < 0.05$.

Results

In Spain, from 125 older adults admitted to the orthopaedics settings, 55 were identified as eligible participants who met the inclusion criteria. Of them, 47 accepted to participate in the ActiveHip+ study and were recruited and trained in the use of the app. Out of these 47 participants who accepted, 36 were included in the final analysis. In Belgium, from 105 older adults admitted to the traumatology department in the AZ Delta hospitals, 48 met the inclusion criteria. Of them, 34 accepted to participate in the ActiveHip+ study. Out of these 34 participants who accepted, 33 were included in the final analysis. The exclusion and dropouts of older adults in both countries are detailed in the CONSORT 2021 flowchart (Figure 1).

Table 1 shows the descriptive characteristics of the ActiveHip+ sample by country. In Spain, most of the sample had hip fracture (86%). In Belgium, most of the sample had osteoarthritis (85%).

Feasibility outcomes

Adoption: The ActiveHip+ adoption rate was 85% in Spain, meaning that 47 out of 55 older adults who were offered to participate accepted to use the ActiveHip+. The adoption in Belgium was 82%, with 34 out of 48 participants accepting to participate in the study.

Dropout: The rate of dropout in Spain was 15% (7/47). In addition to the 7 dropouts, 4 patients died during the first week after accepting to participate in this study. In Belgium, the dropout rate was 3% (1/34).

Usage: The usage of the ActiveHip+ mHealth system has been measured in two ways, the number of interactions with the app to watch any of the resources available in the different sections and the number of sessions of tele-rehabilitation performed.

Regarding the number of interactions with the app, the usage rate in Spain was 64%. It means that 23/36 older adults included in the analysis had at least 42 interactions with the app, which is half of the 84 days that the health educational and tele-rehabilitation program delivered through the ActiveHip+ mHealth system lasts. The usage rate in the Belgian sample was 84%, with 28/33 performing the minimum interactions with the app.

Regarding the number of tele-rehabilitation sessions performed the usage rate in Spain was 25%. It means that 9/36 older adults included in the analysis have performed at least 10 tele-rehabilitation sessions. Concerning the Belgian sample, the rate of video-recorded sessions performed is 9%. It means that 3/33 older adults performed at least 10 sessions during the ActiveHip+ intervention.

MARS and NPS score. Figure 2 presents the user's perception of the quality of the app for each country. In Spain, the mean of the overall MARS scale was 4.42/5 (SD 0.42), whereas in Belgium, the overall mean score was 3.51/5 (SD 0.39). Regarding the score of the different categories, in the Spanish sample, all of the scores are similar, ranging from the lowest, 4.40/5 (*Information*) to 4.44/5 (*Functionality*). Nevertheless, in the Belgian sample, there are differences, the most valued category is

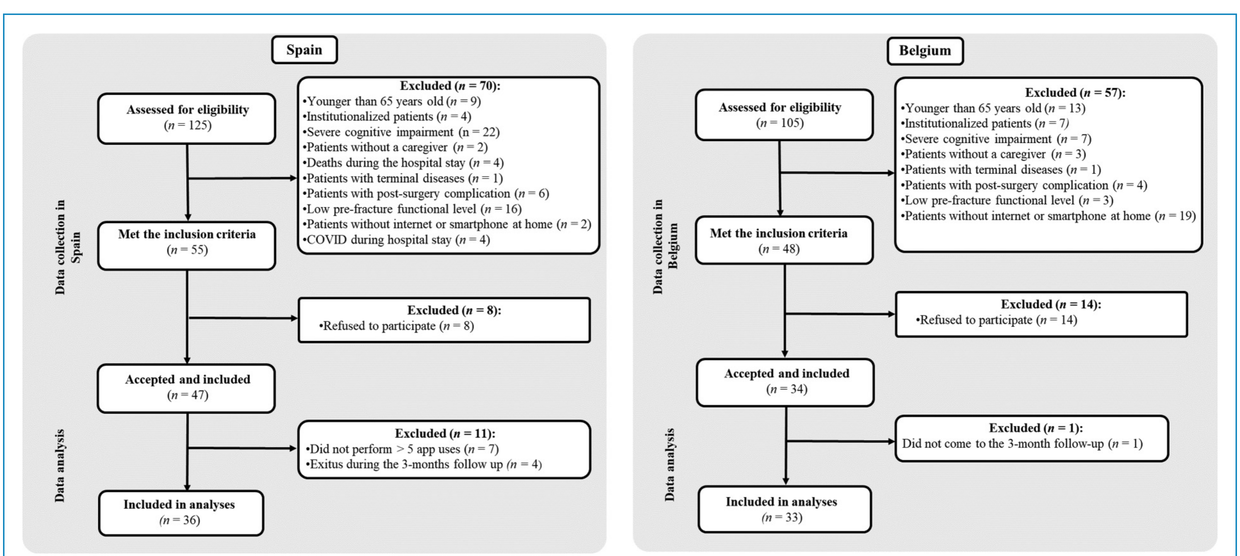

Figure 1. Flowchart of the sample in Spain (left panel) and Belgium (right panel).

Table 1. Baseline characteristics of the older adults who used ActiveHip+ mHealth system.

Variable	Spain $n=36$	Belgium $n=33$
Age (years), Mean (standard deviation)	80.3 (8.9)	71.1 (5.6)
Gender, *n* (%)		
Women	29 (80)	16 (49)
Men	7 (20)	17 (51)
Body mass index (kg/m^2) categories, *n* (%)		
Underweight (<18.5)	2 (6)	4 (12)
Normal (18.5–24.9)	7 (19)	17 (52)
Overweight (≥25)	27 (75)	12 (36)
Educational level, *n* (%)		
Without formal education	17 (47)	2 (6)
Primary school	15 (42)	17 (52)
Secondary school	3 (8)	12 (36)
University	1 (3)	2 (6)
Type of injury, *n* (%)		
Fracture cervical femoral (intracapsular)	5 (14)	1 (3)
Fracture trochanteric (extracapsular)	26 (72)	24 (12)
No fracture, but degeneration	5 (14)	28 (85)
Type of surgery, *n* (%)		
Prosthesis	10 (28)	30 (91)
Screw plate	7 (19)	0 (0)
PFN-A nail	18 (50)	3 (9)
Others	1 (3)	0 (0)
Falls in the previous year, *n* (%)		
Yes	17 (42)	11 (33)
No	19 (53)	22 (67)
Pre-fracture residence, *n* (%)		
Own home	34 (94)	33 (100)
Nursing or relative's home	2 (6)	0 (0)
Change of residence at hospital discharge, *n* (%)		
Yes	12 (33)	3 (9)
No	24 (67)	30 (91)
Support at hospital discharge, *n* (%)		
Formal caregiver	8 (22)	2 (6)
Informal caregiver (relative or friend)	28 (78)	31 (94)

PFN-A: Proximal femoral nail.

Engagement (3.70/5), whereas the worst-rated category is *Information* (2.54/5).

Concerning the NPS, the Spanish sample overall score was positive 8.86/10 (SD 1.00), whereas the Belgian overall score was less positive 5.16/10 (SD 1.97).

Clinical outcomes

Functional status: The ANCOVA model including the variables age, body mass index (BMI), level of studies and existence of previous falls during last year as covariate, performed on the functional status showed statistical differences in the pre-post intervention analysis of the FIM scale in both countries after using the ActiveHip+ mHealth system. In Spain, the pretest score (assessed in the first week after surgery) was 68.30 (95%CI: 62.16–74.46) and the posttest score was 109.20 (95%CI: 106.04–112.34). In the Belgian sample, the pretest score (assessed in the first week after surgery) was 105.73 (95%CI: 102.609 −108.85) and the posttest score was 121.21 (95%CI: 119.65–122.77). The results of the pre-post intervention analyses of the FIM older adults are provided in Figure 3.

Physical performance: The ANCOVA model including the variable number of tele-rehabilitation sessions performed as covariate, performed on the physical performance showed statistical differences in the pre-post intervention analysis of the SPPB results in both countries after the health educational and tele-rehabilitation program delivered through the ActiveHip+ mHealth system. The results of the analyses pre-post intervention of the SPPB older adults are provided in Figure 4. The pretest score of the Spanish

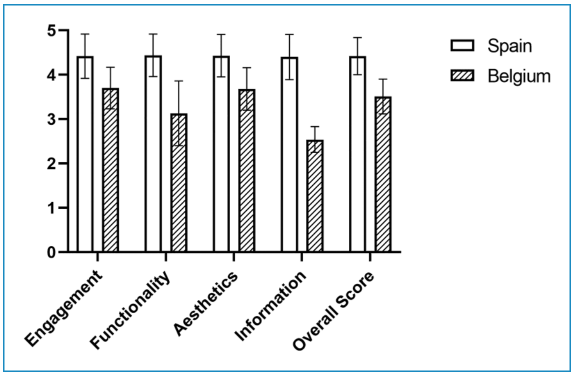

Figure 2. Quality assessment of the ActiveHip+ app by older adults and caregivers, divided by country. The evaluation was conducted using the Mobile App Rating Scale (MARS).

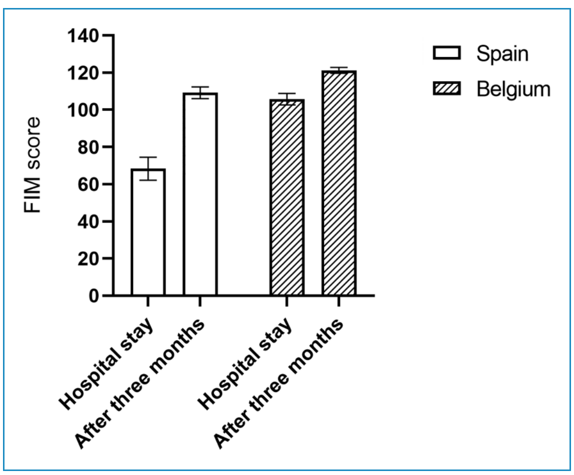

Figure 3. Evolution of older adults functional status after using the ActiveHip+ app, divided by country. Functional status was measured using the Functional Independence Measure (FIM).

sample was 3.14 (95%CI: 2.40–3.89) and the posttest score was 7.22 (95%CI: 6.40–8.05). In Belgium, the pretest score of the SPPB scale was 3.36 (95%CI: 2.72–4.01) and the posttest score was 6.85 (95%CI: 5.94–7.76). The results of the analyses pre-post intervention analyses for SPPB are provided in Figure 4.

Pain: The ANCOVA model including the variable number of interactions with the app performed as covariate, performed on the pain showed statistical differences in the pre-post intervention analysis of the NRS results in both countries after the health educational and tele-rehabilitation program delivered through the ActiveHip+ mHealth system. In Spain, the pretest score was 5.28 (95%CI: 4.36–6.20) and the posttest score was 2.14 (95%CI: 1.36–2.91). In the Belgian sample, the pretest score was 5.21 (95%CI: 4.34–6.08) and the posttest score was 3.06 (95% CI: 2.43–3.67). The results of the analyses pre-post intervention of the NRS older adults are provided in Figure 5.

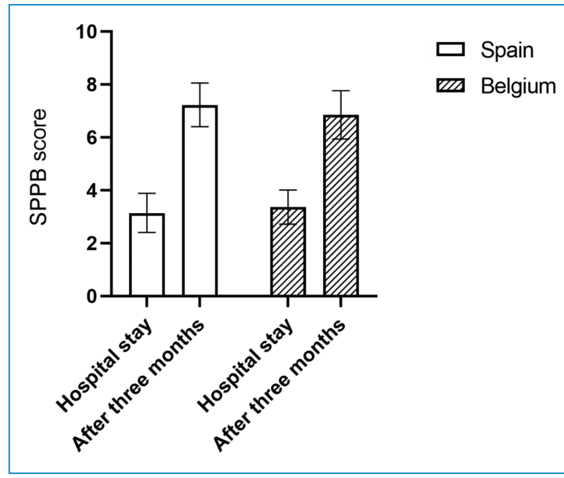

Figure 4. Evolution of older adults' physical performance after using the ActiveHip+ app, divided by country. Physical performance was measured using the Short Physical Performance Battery (SPPB).

Discussion

The aim of the present study was to evaluate the feasibility of implementing the ActiveHip+ mHealth system for older adults after hip surgery in an orthopaedic setting and in two different healthcare systems. Our findings suggest that the ActiveHip+ mHealth system is feasible in older adults after hip surgery. The health educational and tele-rehabilitation program delivered through the ActiveHip+ mHealth system may improve functional status, physical performance and pain level, which should be tested in appropriately designed randomised controlled trials.

In the present study, the adoption rate was high (78% combining both samples), which is in line with previous studies in the field of tele-rehabilitation.[25] This high adoption rate could be associated with the absence of treatment alternatives due to the COVID-19 restrictions, especially concerning older adults with comorbidities, as our sample.[50] The dropout rate of this study is similar to previous studies.[27] This rate is higher in the Spanish sample (11/47) than in the Belgian sample (1/34). We speculate that differences in the characteristics of the sample, due to restrictions on surgeries during COVID-19[51,52] waves, may explain this discordance in the dropout rate. For instance, the Spanish sample is older than the Belgian sample (78 years vs. 66 years) since it is comprised mostly of people with osteoporotic hip fractures, an orthopaedic disease that usually occur in advanced ages.[53] Hip osteoarthritis is more predominant in the Belgian sample and these patients are typically younger.[54] It should be noted that in the Spanish sample, there were four deaths, in line with previous studies who established a strong relationship of this injury with a high mortality rate.[55]

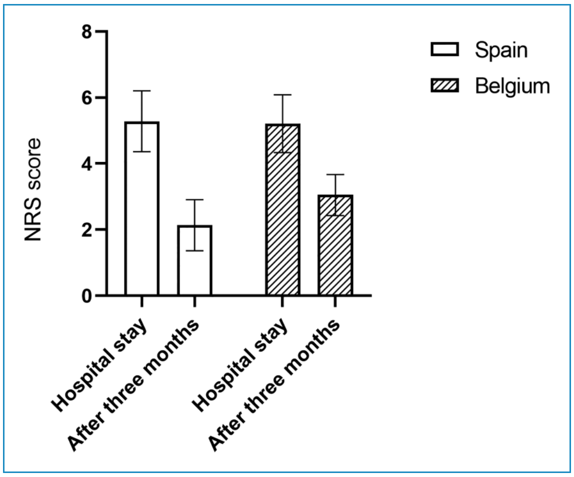

Figure 5. Evolution of older adults' level of pain after using the ActiveHip+ app, divided by country. The level of pain was measured using the numeric rating scale (NRS).

In the present study, the percentage of older adults who regularly used the app was high (74% combining both samples), indicating that the ActiveHip+ is a promising tool to consider in the recovery after hip surgery. The usage rate based on the interactions is similar to the results of previous studies.[27] In comparison to the Spanish sample, the usage ratio of the Belgian sample was higher (64% vs. 84%). As we mentioned before, the Belgian sample is younger and it is associated with higher use of smartphones and, therefore, mHealth systems.[56,57] Regarding the usage rate based on the number of video-recorded sessions of rehabilitation performed is low (25% in Spain, 9% in Belgium). To understand the results, it is important to describe the context of both samples. The Spanish sample was recruited during one of the worst periods of the COVID-19.[58] As some older adults were alone during their hospital stay, explanation and training in the use of the app was done via calls and videocalls, which may negatively affect the usage rate. Moreover, some family caregivers did not go to the older adults' homes to avoid contagion due to the patient's clinical condition after surgery.[59] The key role of caregivers in mHealth use needs to be taken into account. In an older sample as included in this study, it is easier to understand the inferior than expected number of sessions performed in the Spanish sample.[60] Regarding the usage rate in terms of video-recorded sessions performed by Belgian older adults, it is essential to know that the Belgian healthcare system provides patients with a rehabilitation program of 3 to 5 in-person sessions at home per week after the surgery. This means that no further video-recorded sessions are necessary. Despite the fact that the usage rate is lower than expected, 25% is a promising result, especially considering the average age of our sample and the conditions under which this study was conducted. Belgian participants have considered the ActiveHip+ mHealth systems an educational and informative resource. The ActiveHip+ mHealth system was co-created to answer the need of older adults and caregivers to be an active element in the recovery process and receive information.[61,62] This informative use of the ActiveHip+ mHealth system is also shown in the MARS rating of the Belgian users, who scored lower in the informative category than the Spanish sample. We hypothesize that future intervention after the COVID-19 pandemic would have more satisfactory results in terms of usage if the explanation is made in-person during their hospital stay. These results also show the need of developing a close follow-up during the first week of their participation to ensure a better adherence. Furthermore, during the final assessment, older adults and caregivers have explained that once they considered that they were recovered, which they do after about 2 months of using the application, they do not consider the need for further sessions, so they do not continue. This information could be useful for future studies on the use of tele-rehabilitation, which could use shorter periods of rehabilitation and focus more on educational aspects of prevention once they are recovered.

With regard to the acceptability of the app, measured once users finish the 12-weeks program, the results of the two samples were different. This may be due to the existence of family caregivers found in Spain but not in Belgium and who were able to support the use of mHealth. Also, the usefulness of the app when in-person rehabilitation was not available. The result (3.99/5 combining both samples) is over the limit of 3.73 established in previous articles measuring the quality of different mHealth apps to be considered a good app.[63] In addition, letting users evaluate the mobile app support some of the suggestions to explore the opinion of key stakeholders to improve mHealth interventions.[64]

Due to the differences in the two samples detailed throughout this study, there were differences in pre-intervention functional status through the ActiveHip+ mHealth system. Despite these differences, we found statistically significant improvements in functional status and physical performance according to FIM and SPPB, respectively, in both groups. This is in line with previous studies in this field.[27,34,65] For example, Li et al.[34] obtained significant improvements in the ADL performance compared with the control group. Similarly, Kalron et al.[65] showed improvements in different mobility tests comparing the results of their tele-rehabilitation intervention group with the control group. Moreover, Ortiz et al.,[27] in a predecessor of the current ActiveHip+ study, showed that the tele-rehabilitation participants reported higher scores in their functional status measured by FIM and physical performance measured with the Timed Up and Go test compared with the older adults allocated to the control group. However, an unexpected finding of this study was a greater recovery in the Spanish sample in terms of SPPB score. This could be explained by the higher number of video-recorded sessions performed by the Spanish older adults, which were focussed on the tests included in the SPPB (balance, walking and standing up) among others, whereas in Belgium there is no standard in-person rehabilitation, so it is possible that the exercises the patients performed at home were different. On the other hand, the significant decrease measured by the NRS support previous results shown by Azma et al.,[66] where people with osteoarthritis showed a statistically significant lower level of pain after a tele-rehab intervention. While our results seem to be promising, they should be carefully interpreted due to the limitations of the present feasibility study. Thus, appropriately designed randomised controlled trials are required to accurately test the effects of the ActiveHip+ mHealth system in clinical outcomes.

The present study has limitations. First, this study was designed to test the feasibility of the ActiveHip+ mHealth system. The potential effects of the intervention in clinical outcomes should be carefully interpreted because of several reasons, including for instance the inclusion of a relatively small and heterogeneous sample. Thus, the implementation of the ActiveHip+ mHealth system is not recommended until its effectiveness has been demonstrated in appropriately designed randomised controlled trials. Second, the app was available in mobile phones only and not in tablets. Third, the inability to record older adults' pain medication may have affected the data reported in this study. Third, a further limitation of this study has been the technical problems encountered, associated with the pilot phase of the app. Lastly, it has not been possible to measure the time spent using the different sections of the app other than the tele-rehabilitation section. This study also has strengths. First, the feasibility of the intervention has been demonstrated in two considerably different healthcare systems. Second, to our knowledge, this is the first study testing the feasibility of a mHealth system created to deliver a health educational and tele-rehabilitation program for the recovery of older adults with hip fracture and hip replacement.

Conclusion

This study showed that a mHealth system is a feasible option in the recovery of older adults after hip surgery. While our results in clinical outcomes seem to be promising, they should be carefully interpreted due to the limitations of the present feasibility study. Thus, appropriately designed randomised controlled trials are required to accurately test the effects of the ActiveHip+ mHealth system in clinical outcomes in older adults after hip surgery.

Acknowledgements: This is part of the PhD Thesis entitled Telerehabilitación y educación sanitaria para personas mayores con fracturas de cadera y sus cuidadores informales; factibilidad y efectividad del programa ActiveHip+. This PhD Thesis has been conducted in the Doctoral Programme in Biomedicine (B11/56/1) of the University of Granada, Spain.

Contributorship: All authors made a substantial contribution to the concept or design of the work; or acquisition, analysis or interpretation of data. PA-V conceived the study. RP-M and PA-V researched literature. RP-M, FE-L, PM-G, MM-T KG, KC, JdB and PA-V were involved in protocol development and obtaining ethical approval. RP-M, MM-T and JdB carried out the patient recruitment. RP-M and PM-G were involved in the data analysis. RP-M wrote the first draft of the manuscript. All authors reviewed and edited the manuscript critically for important intellectual content, and approved the final version of the manuscript.

Declaration of Conflicting Interests: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval: This study was approved by the Ethics Committee of Research Ethics Committee Granada (CEI Granada), the Ethics Committee of Katholieke Universiteit Leuven and AZ Delta. The study was conducted according to guidelines established by the Helsinki Declaration and Las 14/2007 on Biomedical Research.

Funding: The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The project Activating older people after a hip fracture (ActiveHip+) has been supported by EIT Health (210752). FE-L was supported by the Spanish Ministry of Science and Innovation (RYC2021-034311-I).

Guarantor: PA-V.

Informed consent: All participants signed a consent form.

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References

1. Yoshimura N, Muraki S, Nakamura K, et al. Epidemiology of the locomotive syndrome: the research on osteoarthritis/osteoporosis against disability study 2005–2015. *Mod Rheumatol* 2017; 27: 1–7.
2. Litomericky S. Ageing and health. *Studia Pneumologica et Phtiseologica Cechoslovaca* 1990; 50: 584–588.
3. James SL, Abate D, Abate KH, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 354 Diseases and Injuries for 195 countries and territories, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; 392: 1789–1858.
4. Kingsbury SR, Gross HJ, Isherwood G, et al. Osteoarthritis in Europe: impact on health status, work productivity and use of pharmacotherapies in five European countries. *Rheumatology (Oxford)* 2014; 53: 937–947.

5. Arokoski MH, Haara M, Helminen HJ, et al. Physical function in men with and without hip osteoarthritis. *Arch Phys Med Rehabil* 2004; 85: 574–581.
6. Byers Kraus V and Tonia L. Osteoarthritis: a serious disease. *Osteoarthritis Res Soc Int* 2016: 1–103.
7. Keenan AM, Mckenna SP, Doward LC, et al. Development and validation of a needs-based quality of life instrument for osteoarthritis. *Arthritis Rheum* 2008; 59: 841–848.
8. Hunter DJ and Bierma-Zeinstra S. Osteoarthritis. *Lancet* 2019; 393: 1745–1759.
9. Malik AT, Alexander JH, Li DD, et al. What are the costs of hip osteoarthritis in the year prior to a total hip arthroplasty? *J Arthroplasty* 2020; 35: 313–317.e1.
10. Arslan IG, Damen J, de Wilde M, et al. Estimating incidence and prevalence of hip osteoarthritis using electronic health records: a population-based cohort study. *Osteoarthr Cartil* 2022; 30: 843–851.
11. Kanis JA, Norton N, Harvey NC, et al. SCOPE 2021: a new scorecard for osteoporosis in Europe. Arch Osteoporos 2021; 16: 82.
12. Guzon-Illescas O, Perez Fernandez E, Crespí Villarias N, et al. Mortality after osteoporotic hip fracture: incidence, trends, and associated factors. *J Orthop Surg Res* 2019; 14: 203.
13. Dyer SM, Crotty M, Fairhall N, et al. A critical review of the long-term disability outcomes following hip fracture. *BMC Geriatr* 2016; 16: 158.
14. Pivec R, Johnson AJ, Mears SC, et al. Hip arthroplasty. *Lancet (London, England)* 2012; 380: 1768–1777.
15. De Rui M, Veronese N, Manzato E, et al. Role of comprehensive geriatric assessment in the management of osteoporotic hip fracture in the elderly: an overview. *Disabil Rehabil* 2013; 35: 758–765.
16. McDonough CM, Harris-Hayes M, Kristensen MT, et al. Physical therapy management of older adults with hip fracture. *J Orthop Sport Phys Ther* 2021; 51: CPG1–CPG81.
17. Sharareh B and Schwarzkopf R. Effectiveness of telemedical applications in postoperative follow-up after total joint arthroplasty. *J Arthroplasty* 2014; 29: 918–922.e1.
18. Bruyère O, Ethgen O, Neuprez A, et al. Health-related quality of life after total knee or hip replacement for osteoarthritis: a 7-year prospective study. *Arch Orthop Trauma Surg* 2012; 132: 1583–1587.
19. Perracini MR, Kristensen MT, Cunningham C, et al. Physiotherapy following fragility fractures. *Injury* 2018; 49: 1413–1417.
20. Wang KC, Xiao R, Cheung ZB, et al. Early mortality after hip fracture surgery in COVID-19 patients: a systematic review and meta-analysis. *J Orthop* 2020; 22: 584–591.
21. Ryu S. Mhealth: new horizons for health through Mobile technologies: based on the findings of the second global survey on eHealth (global observatory for eHealth series, volume 3). *Healthc Inform Res* 2012; 18: 231.
22. Pastora-Bernal JM, Martín-Valero R, Barón-López FJ, et al. Evidence of benefit of telerehabitation after orthopedic surgery: a systematic review. *J Med Internet Res* 2017; 19: e142.
23. Barbosa MT, Sousa CS, Morais-Almeida M, et al. Telemedicine in COPD: an overview by topics. *COPD J Chronic Obstr Pulm Dis* 2020; 17: 601–617.
24. Freire AN, Guerra RO, Alvarado B, et al. Validity and reliability of the short physical performance battery in two diverse older adult populations in Quebec and Brazil. *J Aging Health* 2012; 24: 863–878.
25. Lozano-Lozano M, Cantarero-Villanueva I, Martin-Martin L, et al. A mobile system to improve quality of life via energy balance in breast cancer survivors (BENECA mHealth): prospective test-retest quasiexperimental feasibility sudy. *JMIR mHealth uHealth* 2019; 7: e14136.
26. Gilboa Y, Maeir T, Karni S, et al. Effectiveness of a telerehabilitation intervention to improve performance and reduce morbidity for people post hip fracture – study protocol for a randomized controlled trial. *BMC Geriatr* 2019; 19: 135.
27. Ortiz-Piña M, Molina-Garcia P, Femia P, et al. Effects of tele-rehabilitation compared with home-based in-person rehabilitation for older adult's function after hip fracture. *Int J Environ Res Public Health* 2021; 18: 5493.
28. Vesterby MS, Pedersen PU, Laursen M, et al. Telemedicine support shortens length of stay after fast-track hip replacement. *New Pub Med Journals Sweden* 2016; 88: 41–47.
29. Eichler S, Salzwedel A, Rabe S, et al. The effectiveness of telerehabilitation as a supplement to rehabilitation in patients after total knee or hip replacement: randomized controlled trial. *JMIR Rehabil Assist Technol* 2019; 6: e14236.
30. Nelson M, Bourke M, Crossley K, et al. Telerehabilitation is non-inferior to usual care following total hip replacement – a randomized controlled non-inferiority trial. *Physiother (United Kingdom)* 2020; 107: 19–27.
31. Colomina J, Drudis R, Torra M, et al. Implementing mHealth-enabled integrated care for Complex chronic patients with osteoarthritis undergoing primary hip or knee arthroplasty: prospective, two-arm, parallel trial. *J Med Internet Res* 2021; 23: e28320. https//www.jmir.org/2021/9/e28320.
32. Stauber A, Schüßler N, Palmdorf S, et al. RECOVER-E – a mobile app for patients undergoing total knee or hip replacement: study protocol. *BMC Musculoskelet Disord* 2020; 21: 71.
33. Zhang Y, Zhang Y, Li Z, et al. Effect of home-based telerehabilitation on the postoperative rehabilitation outcome of hip fracture in the aging population. *Orthop Surg* 2022; 14: 1768–1777.
34. Li CTL, Hung GKN, Fong KNK, et al. Effects of home-based occupational therapy telerehabilitation via smartphone for outpatients after hip fracture surgery: A feasibility randomised controlled study. *J Telemed Telecare* 2022; 28: 239–247.
35. van Gemert-Pijnen JEWC, Nijland N, van Limburg M, et al. A holistic framework to improve the uptake and impact of eHealth technologies. *J Med Internet Res* 2011; 13: e111.
36. Mora-Traverso M, Molina-Garcia P, Prieto-Moreno R, et al. An m-health telerehabilitation and health education program on physical performance in patients with hip fracture and their family caregivers: study protocol for the ActiveHip+ randomized controlled trial. *Res Nurs Health* 2022; 45: 287–299.
37. Stoyanov SR, Hides L, Kavanagh DJ, et al. Mobile app rating scale: a new tool for assessing the quality of health Mobile apps. *JMIR Mhealth Uhealth* 2015; 3: e27. https//mhealth.jmir.org/2015/1/e27.
38. Krol MW, de Boer D, Delnoij DM, et al. The Net Promoter Score – an asset to patient experience surveys? *Heal Expect* 2015; 18: 3099–3109.
39. Ottenbacher KJ, Hsu Y, Granger CV, et al. The reliability of the functional independence measure: a quantitative review. *Arch Phys Med Rehabil* 1996; 77: 1226–1232.

40. Hobart JC, Lamping DL, Freeman JA, et al. Evidence-based measurement: which disability scale for neurologic rehabilitation? *Neurology* 2001; 57: 639–644.
41. Wang C-Y, Graham JE, Karmarkar AM, et al. FIM Motor scores for classifying community discharge after inpatient rehabilitation for hip fracture. *PM&R* 2014; 6: 493–497.
42. Zidén L, Frandin K and Kreuter M. Home rehabilitation after hip fracture. A randomized controlled study on balance confidence, physical function and everyday activities. *Clin Rehabil* 2008; 22: 1019–1033.
43. Guralnik JM, Simonsick EM, Ferrucci L, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol* 1994; 49: 85–94.
44. Salpakoski A, Törmäkangas T, Edgren J, et al. Effects of a multicomponent home-based physical rehabilitation program on mobility recovery after hip fracture: a randomized controlled trial. *J Am Med Dir Assoc* 2014; 15: 361–368.
45. Latham NK, Harris BA, Bean JF, et al. Effect of a home-based exercise program on functional recovery following rehabilitation after hip fracture: a randomized clinical trial. *JAMA – J Am Med Assoc* 2014; 311: 700–708.
46. Gómez Montes JF, Curcio CL, Alvarado B, et al. Validity and reliability of the short physical performance battery (SPPB): a pilot study on mobility in the Colombian Andes. *Colomb Médica C* 2013; 44: 165.
47. Hawker GA, Mian S, Kendzerska T, et al. Measures of adult pain: visual analog scale for pain (VAS pain), numeric rating scale for pain (NRS pain), McGill pain questionnaire (MPQ), short-form McGill pain questionnaire (SF-MPQ), chronic pain grade scale (CPGS), short form-36 bodily pain scale (SF-36 BPS), and measure of intermittent and constant osteoarthritis pain (ICOAP). *Arthritis Care Res (Hoboken)* 2011; 63: S240–S252.
48. Blom G. Transformations of the binomial, negative binomial, Poisson and χ 2 distributions. *Biometrika* 1954; 41: 302.
49. Molina-Garcia P, Plaza-Florido A, Mora-Gonzalez J, et al. Role of physical fitness and functional movement in the body posture of children with overweight/obesity. *Gait Posture* 2020; 80: 331–338.
50. Bucki FM, Clay MB, Tobiczyk H, et al. Scoping review of telehealth for musculoskeletal disorders: applications for the COVID-19 pandemic. *J Manipulative Physiol Ther* 2021; 44: 558–565.
51. Kort NP, Zagra L, Barrena EG, et al. Resuming hip and knee arthroplasty after COVID-19: ethical implications for wellbeing, safety and the economy. *Hip Int* 2020; 30: 492–499.
52. Nuñez JH, Sallent A, Lakhani K, et al. Impact of the COVID-19 pandemic on an emergency traumatology service: experience at a tertiary trauma centre in Spain. *Injury* 2020; 51: 1414–1418.
53. Zhang C, Feng J, Wang S, et al. Incidence of and trends in hip fracture among adults in urban China: a nationwide retrospective cohort study. *PLOS Med* 2020; 17: e1003180.
54. Fang M, Noiseux N, Linson E, et al. The effect of advancing age on total joint replacement outcomes. *Geriatr Orthop Surg Rehabil* 2015; 6: 173.
55. Downey C, Kelly M and Quinlan JF. Changing trends in the mortality rate at 1-year post hip fracture – a systematic review. *World J Orthop* 2019; 10: 166.
56. Kurlander JE, Kullgren JT, Adams MA, et al. Interest in and concerns about telehealth among adults aged 50 to 80 years. *Am J Manag Care* 2021; 27: 415–422.
57. Hansen H, Bieler T, Beyer N, et al. Supervised pulmonary tele-rehabilitation versus pulmonary rehabilitation in severe COPD: a randomised multicentre trial. *Thorax* 2020; 75: 413–421.
58. Soriano V, Ganado-Pinilla P, Sanchez-Santos M, et al. Main differences between the first and second waves of COVID-19 in Madrid, Spain. *Int J Infect Dis* 2021; 105: 374–376.
59. Fingerman KL, Ng YT, Zhang S, et al. Living alone during COVID-19: social contact and emotional well-being among older adults. *J Gerontol Ser B Psychol Sci Soc Sci* 2021; 76: e116.
60. Ramsden Marston H, Genoe R, Freeman S, et al. Older adults' perceptions of ICT: main findings from the Technology In Later Life (TILL) Study. Healthcare 2019; 7: 86.
61. Wolff JL, Freedman VA, Mulcahy JF, et al. Family caregivers' experiences with health care workers in the care of older adults with activity limitations. *JAMA Netw Open* 2020; 3: e1919866.
62. Mrklas KJ, Barber T, Campbell-Scherer D, et al. Co-design in the development of a mobile health app for the management of knee osteoarthritis by patients and physicians: qualitative study. *JMIR Mhealth Uhealth* 2020; 8: e17893.
63. Salazar A, de Sola H, Failde I, et al. Measuring the quality of mobile apps for the management of pain: systematic search and evaluation using the mobile app rating scale. *JMIR Mhealth Uhealth* 2018; 6: e10718.
64. Ko YJ, Hwang JM and Baek SH. The development of a mobile application for older adults for rehabilitation instructions after hip fracture surgery. 2021; 12: 1–7.
65. Kalron A, Tawil H, Peleg-Shani S, et al. Effect of telerehabilitation on mobility in people after hip surgery: a pilot feasibility study. *Int J Rehabil Res* 2018; 41: 244–250.
66. Azma K, RezaSoltani Z, Rezaeimoghaddam F, et al. Efficacy of tele-rehabilitation compared with office-based physical therapy in patients with knee osteoarthritis: a randomized clinical trial. *J Telemed Telecare* 2018; 24: 560–565.