Co-creation of an mHealth Intervention for Older Adults with Hip Fracture and Family Caregivers: a qualitative study

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24   Introduction

25   Hip fracture results in an older person's loss of independence. Limited healthcare

26   resources make mobile Health (mHealth) an alternative. Engaging key

27   stakeholders in health technology development is essential to overcome existing

28   barriers. The aim of this study was to establish perspectives of older adults with

29   hip fracture, family caregivers and health professionals (stakeholders) on the

30   development of a mHealth system.

31   Methods

32   Qualitative study guided by user-centered design principles with focus groups to

33   engage stakeholders during the development. Seven focus groups were conducted

34   [older adults with hip fracture (n=2), caregivers (n=3), and health providers (n=2)]

35   with 45 participants (14 older adults, 21 caregivers, and 10 health providers).

36   Inclusion criteria were older adults ≥ 65 years who sustained a hip fracture in the

37   previous 3 months; family caregiver of a person with hip fracture; and health

38   providers with 2+ years of clinical experience working older adults with hip

39   fracture. We followed standard methods for focus groups, including recording,

40   transcription, and conducting an inductive content analysis. The same moderator,

41   with clinical and research experience, conducted all focus groups.

42   Results

43   Three themes were generated to consider for a future mHealth intervention: (1)

44   user-friendly design; (2) content to include recovery and prevention information;

45   and (3) implementation factors. Our mHealth system was developed based on

46   feedback from participants.

47   Conclusions

48   Co-creating mHealth technology with stakeholders is essential for uptake and

49   adherence. We provide an overview of the development of ActiveHip+, an

50   mHealth system for the clinical care of older adults with hip fracture.

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PURPOSE

Hip fracture can result in older adults' reduced quality of life resulting from the loss of functional

independence [1], decrease in social participation [2], and the all too common failure to recover

previous function [3]. Dependence in activities of daily living (ADLs) post-hip fracture impacts

caregivers [4] (defined here as family caregivers or caregivers) in countries around the world [5–

7]. Following hip fracture, caregivers frequently become the main support system for older people

after hospital discharge [8,9]. As a result, additional (and often sudden) responsibilities lead to an

increase in caregiver burden [4], stress, and negative consequences for their overall health [10].

Rehabilitation can improve function and ability to complete ADLs after hip fracture

[11,12]. However, limited resources can lead to reduced access to much needed healthcare [11].

Tele-rehabilitation and, in particular mobile Health (mHealth), defined as the use of mobile and

wireless technologies in healthcare [13], is a promising alternative for care provision [14]. In fact,

it has been one of the alternatives used in the orthopaedics services during the COVID-19

pandemic [15,16]. But there are few evaluation studies testing remote delivery of rehabilitation

after hip fracture [17–19]. Despite perceived barriers for older adults to use information and

communication technologies (ICTs), Crotty and colleagues reported tele-rehabilitation as a viable

option for this age group [20]. Family caregivers may be another option to support older people

to use ICTs, and specifically tele-rehabilitation. Family caregiver involvement in rehabilitation

is complex. For example, involving the family may lead to additional burden, while in contrast it

provides an opportunity to respond to caregivers' request for information during the recovery

process [21]. However, less is known for the delivery of information and tele-rehabilitation

through ICTs to older adults with a hip fracture and their family caregivers [17] and further studies

76   should be conducted.

77

78   Despite the fact that during the last years, there has been some research projects about

79   tele-rehabilitation in hip fracture [22–24], further research on this topic is needed. It was

80   previously tested a tele-rehabilitation program for older adults with hip fracture and family

81   caregivers [17,22] delivered through a webpage. Following the results of that study and

82   participants' lived experience reported elsewhere [25] we attempted to upgrade this tele-

83   rehabilitation intervention into a mobile app for easier delivery and adoption. Following a proof-

84   of-concept study, we planned the next step as a co-creation process for the mHealth system, which

85   is considered especially important for future uptake, adoption, usage and sustainability of the

86   solution [26,27].

87

88   The aim of this study was to establish perspectives of older adults with hip fracture,

89   family caregivers and health providers (stakeholders) for the development of an mHealth system

90   designed to improve physical function after hip fracture and reduce caregiver burden. Our

91   secondary aim was to use these perspectives to co-create the ActiveHip+ mHealth system.

92   **METHODS**

93   *Study Design*

94   This was a qualitative study guided by a user-centered design (UCD) framework [28]. We used

95   focus groups to engage stakeholders (older adults, caregivers, providers) in the recovery of older

96   adults with hip fracture. The Ethics Committee of the Research Centre of Granada (CEI-

97   GRANADA) approved this study, and all participants signed a consent form. The study was

98   conducted according to guidelines established by the Helsinki Declaration and Law 14/2007 on

99   Biomedical Research.

100

101 We conducted seven focus groups on January 28-30, 2020 at the Virgen de las Nieves

102 University Hospital. The composition of the focus groups included the following participants: (1)

103 two groups were composed of older adults who had previously sustained a hip fracture; (2) two

104 groups were family caregivers of older adults who had previously sustained a hip fracture; (3)

105 one group included family caregivers; however, the family member was not able to walk

106 independently after hip fracture (≥3 months); and (4) two groups of health providers.

107

108 Focus groups were designed and conducted in partnership between a research team with

109 clinical experience managing recovery after hip fracture, and a team experienced with conducting

110 focus groups. One female experienced moderator (and academic faculty member) conducted all

111 focus groups, and one person took notes. The focus groups were recorded and transcribed [29] in

112 Spanish. Six focus groups were 90 minutes, and one focus group was 60 minutes in duration.

113 Following the content analysis (completed in Spanish), quotations were translated into English

114 by the last author (Spanish native speaker) and discussed with the fifth author (English native

115 speaker) to ensure the translation considered the cultural context of the participants.

116 *Recruitment*

117 We recruited three stakeholder groups: older adults with hip fracture, family caregivers of older

118 adults with hip fracture, and health providers. Older adults were aged 65 years and older, sustained

119 a surgically repaired hip fracture in the previous 3 months, and did not have severe cognitive

120 impairment. Invited caregivers could be adult children, spouses, other relatives, or friends of older

121 adults with a surgically repaired hip fracture in the previous three months. Health providers had

122 two or more years of experience working with people after hip fracture.

123

124 Older adults with hip fracture and family caregivers were invited to participate in the

125 study at their routine follow-up orthopaedic surgeon visit. After consenting to join the study, a

126 research team member telephoned to organize focus group attendance. We telephoned 17 older

127 adults with hip fracture and 23 family caregivers (all relatives of older adults). However, only 14

128 older adults and 21 family caregivers participated in the focus groups. Two older adults did not

129 answer the telephone after several attempts, one older adult was unwell, and two caregivers were

130 not able to attend the focus groups.

131

132   The hospital supervisor (from one publicly funded acute care hospital) invited health

133 providers to enrol in the study. There were 11 health providers enrolled in the study representing:

134 orthopaedic surgery, physical and rehabilitation medicine, endocrinology, nursing, nursing

135 assistant, occupational therapy, physical therapy, and social work. Only one health provider

136 (social worker) was not available to attend the focus group. Thus, 10 health providers in total

137 attended the focus groups. The flowchart of participants is shown in Figure 1.

138

139 *Discussion Guide*

140 The discussion guide for all focus groups had two main topics to identify potential strengths,

141 weaknesses, a strategy followed by previous tele-rehabilitation studies with other populations

142 [30]. During the focus groups, we asked the participants: (i) based on your experience, which

143 factors are most relevant for recovery after hip fracture? (Topic 1) Once they discussed that first

144 topic, we asked them: (ii) how should an mHealth system support recovery and which contents

145 should be included? (Topic 2). In order to adapt it as well as possible to the participants´ requests,

146 based on the design thinking process, we established an open mobile application concept, without

147 test version or mobile app mock-up, to avoid conditioning their opinion during the first steps [31].

148 We intentionally started the discussion by asking participants to comment on their experience

149 with hip fracture, followed by questions related to mHealth systems. We iteratively adjusted the

150 interview guide in the focus groups, as needed. For example, in some focus groups we needed to

151 redirect the questions back to the two topics when the discussion changed to personal experiences

152 with hip fracture, rather than information for the app development. Participants (across focus

153   groups) provided more information for topic 1 and, therefore, for the later focus groups we

154   directed the discussion more towards content relevant to include in the mobile app.

155   *Analysis*

156   After each focus group, the moderator (a professor) and one team member (an occupational

157   therapist with 3 years of research experience in tele-rehabilitation for older adults with hip

158   fracture) independently took notes *(RP-M)* to summarize impressions of the discussion and any

159   major themes. The audiotapes were transcribed within two weeks by one author (a pre-doctoral

160   student) *(RP-M)*. We followed the immersion-crystallization technique: a continuous process

161   whereby researchers are immersed in data via: reading transcripts in detail, discussing reflections

162   on how to analyse data, and identifying patterns and themes [32]. Saturation was achieved for

163   some topics (i.e., information on pain and mobility) in the different focus groups, while other

164   information was exclusively stated in some groups but not in other ones (i.e., information about

165   nutrition). The content analysis [33] was conducted by three authors (the senior author, a physical

166   and occupational therapist with 12 years of research and clinical experience treating older adults

167   with hip fracture, an occupational therapist with 3 years of research experience in mHealth, and

168   a pre-doctoral student) *(PA-V, RP-M and MM-T)*. Two authors *(PA-V and MM-T)* reviewed each

169   of the transcripts independently [33]. Following this step, they both, inductively developed coding

170   categories to examine similarities and differences between stakeholder groups [34]. Next, three

171   authors *(PA-V, RP-M and MM-T)* met twice to discuss and confirm the findings; they also

172   categorized them into three themes [35,36]. The interviews and analyses were conducted in

173   Spanish. The senior author *(PA-V)* translated quotes from Spanish into English. In the final step

174   of the analysis process, another author *(MCA) (a physiotherapist and full professor with clinical*

175   *and research experience in rehabilitation for older adults)* reviewed the themes, categories, and

176   subcategories and discussed them (via email) at length with the first author *(PA-V)*. The results

177   were finalized by the original three authors *(PA-V, RP-M and MM-T)*. We used NVivo 10 (QSR

178   International, Doncaster, Australia) to organize quotes, subcategories, categories, and themes.

RESULTS

Fourteen older adults with hip fracture, 21 family caregivers, and 10 health providers participated in the focus groups. We present a summary of participants' sociodemographic variables in Table 1.

Three main themes were generated from the content analysis, as shown in Table 2: (1) **mHealth design and function** (simple, user-friendly design and function); (2) **mHealth content** (content focused on recovery and prevention); and (3) **Implementation factors for mHealth**. Figure 2 and Figure 3 summarize how these themes have been integrated in the ActiveHip+ mHealth system which consist in a mobile app for older adults with hip fracture/caregivers (Figure 2) linked to a web page for health providers (Figure 3). A summary of the technical solutions designed for each issue is provided in the Supplementary Table 1.

mHealth Design and Function

There was a unanimous agreement for a simple and user-friendly app design, with clear information for older adults with hip fracture and caregivers. "*It has to be very simple and easy to use*" (Caregiver 9). There was also agreement information should be delivered using videos and voiceover for better uptake and retention of information. *"… It is easier to learn [how to use a walker] when you watch a video, instead of reading the information about how to use it]"* (health provider 5).

Positive messages were perceived by older adults as encouragement to complete exercises and support recovery. *"The app could be used to send messages of encouragement at the end of each session and also between sessions to encourage them to continue doing the exercises…" (Caregiver 4).* Older adults with hip fracture also stated a positive attitude towards the fall and recovery from the fracture was especially important and a notification system with

204 reinforcement messages could help them to have this attitude. Caregivers suggested ICTs should

205 have prompts and cues, such as reminders for medical appointments and rehabilitation sessions.

206

207   Older adults with hip fracture and caregivers recommended including stories of lived

208 experiences from other older adults with hip fracture. The stories of recovery were perceived as

209 a key motivator for older adults with hip fracture, especially during the first weeks after fracture.

210 *"... Listening to other people who suffered the same can help you to feel a bit better... Mainly*

211 *when you are at the hospital, and you do not know how you will when you come back home..."*

212 (Older adult with hip fracture 3).

213

214   As suggested by participants, a communication system (e.g., text messages and

215 videoconferences) was provided between older adults with hip fracture, caregivers, and health

216 providers to facilitate communication, resolve any concerns, and supervise older adults with hip

217 fracture in their home environment.

218

219   Finally, health providers acknowledged families and older adults with hip fracture are

220 overloaded with information during the acute hospital stay. Thus, the app could provide additional

221 on-demand information for caregivers and older adults after returning home. *"They receive so*

222 *much information and dialogue that they become anxious and disorientated (at the hospital)"*

223 (Health provider 3). A section for answering frequent queries was also suggested.

224 ***How this new information was integrated into the mHealth system***

225   Firstly, the mHealth system was designed with as few sections as possible to make

226 navigation easier. The font and font size were chosen to be easy to read, as well as the audio-

227 visual content, which included a voice-over to facilitate comprehension. Secondly, to encourage

228 older adults with hip fracture and caregivers during the recovery process, some automatic

229 messages of encouragement were programmed after each rehabilitation session. Third, videos in

230 which individuals gave a summary of their lived experience in the hip fracture recovery process

231   were included to motivate older adults and caregivers that it is possible to resume their pre-

232   fracture daily lives. Fourth, a two-way communication system was included in the mHealth

233   system where older adults with hip fracture and caregivers can receive or send messages from/to

234   their healthcare providers to solve possible concerns. Lastly, to allow older adults and, especially,

235   caregivers to access information at a time that suits them best, all content in the mHealth system

236   is available on demand.

237

238   *mHealth Content*

239   Caregivers and health providers suggested the app provide an overview of the recovery process

240   after hip fracture. "*Having more information about the entire process helps make the experience*

241   *more positive*" (Caregiver 7).

242

243   There was an agreement between all three groups for the inclusion of information on pain

244   and mobility, ADLs and home equipment, and nutrition. Pain and mobility were the most

245   common concern expressed by older adults with hip fractures and caregivers. Although older

246   adults with hip fracture reported moderate-intensity pain during the first days (and sometimes

247   weeks) following hip fracture, they refused to have more medication. They explained they were

248   living with other chronic conditions and already had too many pills. Second, health providers

249   suggested including information on ADL equipment and home environmental adaptations to

250   minimize the risk of falls. Finally, for health providers, it was important to include nutrition-

251   related information in general, and specifically for people living with chronic conditions, for

252   example, dysphagia, osteoporosis, and diabetes. "*Several older adults are malnourished when*

253   *they come to the hospital... we have to inform them how to improve their nutrition with clear*

254   *information about the type of foods they should intake, and the app could be a tool used for that*"

255   (Health Provider 1).

256

257   The app was perceived by health providers as an opportunity to provide instructions for

258   completing exercises. Older adults with hip fractures, caregivers and health providers noted

259   different experiences following discharge from the hospital. For some older adults and families,

260   they received either no formal follow-up rehabilitation or some sessions of home-rehabilitation

261   (public or private). Thus, they considered the app as an opportunity to guide older adults with hip

262   fracture with home exercises. *"... I was sent home with a few simple instructions to walk, but they*

263   *did not tell me how much…"* (Older adult with hip fracture 1). They further highlighted exercise

264   must be personalized and monitored by health providers to maximize performance and minimize

265   the risk for injury.

266

267   Finally, in the category of essential app content, caregivers and health providers

268   suggested providing information specific to family caregivers. For the recovery process, there

269   was a suggestion to provide tips and strategies for caregivers to support older adults with hip

270   fracture' mobility at home. For caregivers' health and wellness, there were suggestions to include

271   relevant information to minimize the risk for injury and to engage in lifestyle interventions (e.g.,

272   physical activity, mindfulness, etc.). *"…The caregivers' section could include relaxing exercises,*

273   *mindfulness sessions and recommendations to find time for themselves to perform leisure*

274   *activities*" (Health Provider 1).

275   ***How this new information was integrated into the mHealth system?***

276   First, to guide older adults with hip fracture and their caregivers through the whole

277   recovery process, we included information (through infographics, text, and videos) on how to

278   face the first weeks up to how to prevent secondary fractures once older adults have recovered

279   their previous life. Second, we included information not just on rehabilitation but also on pain,

280   support devices, home adaptation, as well as nutrition. Some videos of healthcare providers

281   explaining the management of these aspects were recorded and included in the mHealth system.

282   Third, a rehabilitation program with physical activity and occupational therapy was included to

283   provide older adults and caregivers with a home exercise guide for rehabilitation after the surgery,

284 with a weekly follow-up from the healthcare providers. During the time that the older adults with

285 hip fracture are using the ActiveHip+ mHealth system, they provide feedback about their feelings

286 (effort after pre-recorded rehabilitation sessions, satisfaction with the program, and pain). With

287 this information, healthcare providers adjust the rehabilitation program delivered through the app

288 to adapt it to the older adults' status. Lastly, a specific section for caregivers was included in the

289 mobile application to provide information on the safe management of the older adult with hip

290 fracture during the first weeks of recovery, when the older adult is unable to perform ADLs

291 independently, as well as information on the caregiver's well-being.

292

293 ***Implementation Factors for mHealth***

294 Health providers suggested the app should contain information for older adults with hip fracture

295 and caregivers, but the main users would be caregivers. *"...it would be difficult for the older*

296 *adults [to use the app], however some caregivers could [use the app] if someone explains how it*

297 *[the app] works..."* (Health Provider 2). Further, health providers were concerned about who

298 would train and support the use of the app if it was embedded within clinical practice. There was

299 discussion on the need for hospital strategies to implement an app (including training health

300 providers). *"...but the majority of them look overwhelmed. We will have to teach them how to use*

301 *the app, and we do not have time. Who will do that?"* (Health Provider 8)

302

303 Caregivers and health reinforced the importance of personalized care plans. For example,

304 some caregivers suggested modifying the information for older adults living with other chronic

305 conditions, and the importance of regular follow-up by health providers. *"...Each person is*

306 *different. My mother has heart problems and high blood pressure. She would need specific follow*

307 *up by the physician"* (Caregiver 4).

308

309   Finally, it was recognized the app might not appeal to everyone. All participants agreed

310   there are barriers for older adults to use ICTs. Caregivers further highlighted the lack of internet

311   skills for some older adults. Although some older adults with hip fracture stated low motivation

312   to use smartphones, they also believed they could learn to use them. "*I do not use those devices*

313   (mobiles) *because I do not need it, but I could learn how to use it…*" (Older adult with hip fracture

314   5).

315   ***How this new information was integrated into the mHealth system?***

316   The main concern for the implementation of the mHealth system in the hospital

317   environment was who would use the app and who would explain how to use it. To address this,

318   it was established that although the main beneficiary of the app would be the older adult with hip

319   fracture, the main user would be the caregiver. To facilitate the explanation of use, as well as to

320   make it user-friendly, leaflets were created to explain its use in a summarised way, thus avoiding

321   the need for healthcare providers to spend a lot of time on it.

322   **DISCUSSION**

323   *Principal Results*

324   We present perceptions shared by older adults with hip fracture, family caregivers, and health

325   providers for the development of ActiveHip+, a post-hip fracture mHealth system. Older adults

326   with hip fracture and caregivers described their experiences during the hip fracture recovery

327   process, and the potential benefits of an app to guide them during the recovery. They also

328   highlighted possible difficulties for older people to use ICTs, as well as some strategies to

329   overcome these barriers, being considering essential the need to include caregivers in mHealth

330   training and deployment. Health providers offered rich information on app content, delivery and

331   implementation in a real acute orthopaedic setting. Overall, these results provide a blueprint for

332   the app design and function, essential content, and implementation factors for testing it as a

333   supplement of clinical care in our next study phase.

334   Sociodemographic characteristics of older adults with a hip fracture and caregivers were

335   similar to other studies [4,6,7,37]. Majority of older adults with hip fracture [3], caregivers [4,7],

336   and health providers [38] were women. Most caregivers were middle-aged [6,37] and children of

337   the older adults with hip fracture included in this study [5]. These similarities may lead to an

338   increase in the applicability of the finding in this study for further design and development of

339   mHealth systems in the rehabilitation of a hip fracture.

340

341   *mHealth Design and Function*

342   All stakeholders in our study recommended to create the ActiveHip+ mobile application

343   following a user-friendly mobile app design, with useful content for communication and

344   information sharing, which has been reported in previous work analysing the implementation of

345   mHealth systems in different health conditions [26,39]. The need to develop a user interface

346   design with appropriate visual objects, such as large buttons that can be distinguished from other

347   resources, or the use of font size adjusted to the needs of older adults were previously highlighted

348   [40]. The participants in our study also made suggestions for the app to increase uptake of health

349   technology and reduce the frustration during the use of the app [26,41], which was previously

350   tied to the need to develop a clear navigational structure and an interface aligned with the

351   expectations of older adults [40,42]. The specific recommendations for older adults with hip

352   fracture were mainly focused on the contents and the delivery modes such as, short videos,

353   infographics, positive messaging, and older adults stories to improve user experiences [43]. One

354   of the main contributions of the participants in this study was the request to include a specific

355   section for caregivers in the app, which was a major design feature that was added to the

356   ActiveHip+ mHealth system. To our knowledge, there was only a previous study providing

357   information for both older adults with hip fracture and their family caregivers, but the specific

358   contents for family caregivers were very limited, and the information was provided through a

359   website [25]. In this earlier study, caregivers received, during the hospital stay, some instructions

360   on safe management during transfers and basic mobility. After hospital discharge, caregivers

361   received a website with some videos with general recommendations for the recovery process.

362   However, according to the results of the present study, older adults with hip fracture and

363   caregivers are overloaded with information during the hospital stay, but need information once

364   they are in their own home. Therefore, we deliver through our mHealth system a comprehensive

365   educational programme with information focused on health promotion both for older adults with

366   hip fracture and specifically for caregivers. We provide caregivers with information on how to

367   protect them from back pain during care, strategies to prevent mental health problems and a wide

368   range of examples on how to support the development of ADLs. This extensive information needs

369   to be on-demand so that they can adapt it to their everyday situations, and can refer to it whenever

370   they want [44]. mHealth solutions offer the opportunity to overcome potential communication

371   barriers [45], and via remote information sharing between older adults with hip fracture and health

372   providers [38]. Nevertheless, the success of the mHealth solutions to improve communication and

373   information sharing is linked with the use of behaviour strategies [46], such as, personalization

374   (i.e., text messages, videoconferences), tailoring (i.e., positive messages, reminders for medical

375   appointments), health behaviour benefits (i.e., nutrition and physical activity), providing

376   instruction (i.e., pre-recorded rehabilitation sessions), or providing materials for education.

377   Including all above suggestions, is a way of supporting mHealth adoption and maintained use by

378   stakeholders [47–49], which is one of the biggest barriers to face in this kind of intervention [50].

379

380   *mHealth Content*

381   In the current study, stakeholders suggested the creation of specific contents to guide and support

382   older adults with hip fracture and their family caregivers through the recovery process for hip

383   fracture [43]. They emphasized the need to personalizing the contents of the ActiveHip+ app and

384   connecting it to resources usually delivered by health providers, such as, written information at

385   hospital discharge (i.e. exercise and nutritional recommendations and medication) [25]. Previous

386 literature highlights the importance of older adults' knowledge and skill development to self-

387 manage their health and the difficulties to adequately achieve older adults' empowerment (defined

388 as "process through which people gain greater control over decisions and actions affecting their

389 health" by World Health Organization) [51] during the short length of acute hospitalization [52].

390 mHealth solutions may contribute to older adults with a hip fracture' functional recovery [25],

391 increase health literacy, and help people gain greater control over their health-related decisions

392 and actions [45]. Beyond older adults, caregivers request more active involvement in the hospital

393 discharge planning process [9], and requested knowledge and skill development to manage the

394 new situation after the hip fracture [8].

395

396 *Implementation factors for mHealth*

397 In this study, participants expressed some concerns for older adults using the app. Although there

398 are perceived barriers using ICTs [53], there is also support for remote delivery of health care in

399 older populations [20,54]. There was a positive research experience for a tele-rehabilitation

400 program post hip fracture [25]. However, in this previous trial, family caregivers facilitated the

401 online program. In this non-randomized (choice-based) intervention, family caregivers expressed

402 a high level of satisfaction for the tele-rehabilitation program and older adults with hip fracture

403 experienced an improvement in functional recovery [25]. Overall, the past and present findings

404 suggest remote care delivery may not work for all older adults after hip fracture, but it may be a

405 viable option for some people, with or without additional support from family members [25].

406 However, integration of, and training for, any new mHealth into clinical practice must be

407 considered as key factors for their usability, adoption, and sustainability [43] both for older adults

408 and health providers. In addition, the provision of personalized action plans must be considered

409 to increase adherence and satisfaction of older adults with hip fracture and caregivers [52].

410 Moreover, due to the COVID-19 pandemic, the development of mHealth systems is perceived as

411 acceptable [55], since the delivery of orthopaedic trauma face-to-face care has suffered a decrease

412   in the resources available [56].

413

414   *Strengths and Limitations*

415   The main strength of this study is the findings from the lived experience from multiple key

416   stakeholder perspectives: older adults, caregivers, and health providers. We captured their

417   feedback (both positive and negative) based on real-world experience with hip fracture recovery.

418   Although we observed similarities of responses across stakeholder groups, the nuances provided

419   from the different groups imparted a rich understanding of experiences and perceptions. We also

420   have some study limitations. First, despite our best efforts to recruit a representative sample of

421   older adults with hip fracture, we were not able to capture the experiences and mHealth

422   perceptions of older adults with impairments after hip fracture. However, we conducted a focus

423   group with family caregivers of older adults with functional impairments. Second, as the different

424   profiles of participants were not mixed in the focus groups, some issues that were mentioned in

425   some groups but not in others were not discussed by all. For example, nutrition was something

426   that was not mentioned in the older adults with hip fracture group. A final check mixing

427   participants could have been used. However, a pilot version of the mHealth system was tested by

428   a representative group of stakeholders who participated in the focus groups to add any suggestions

429   before starting to test it. Third, all participants were from a region of Spain. Therefore, findings

430   may not be generalizable to other populations.

431   **CONCLUSIONS**

432   Older adults with hip fracture, family caregivers, and health providers identified key elements for

433   the design of a mHealth system, function and contents, and factors to consider for future testing

434   in a clinical trial setting. All the above elements were included in the mHealth prototype

435   developed considering the perspectives of the main stakeholders.

436

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577   veloping+Grounded+Theory&ots=6jO7PwbAV1&sig=JCfk0j_Qqw_G9JwxYHh

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663

669   **Figure 1.** Flowchart description of the recruitment process of the participants of the

670   focus groups carried out for the co-creation of the ActiveHip+ mHealth system.

671   **Figure 1 Alt text:** Figure with 3 boxes describing how many participants of each group

672   (older adults, caregivers and health providers) were available for the focus group, why

673   some of them were not included in the focus group and the final number of participants

674   in each group.

675   **Figure 2.** Examples of the ActiveHip+ content for older adults and caregivers

676   integrated from the stakeholder perspectives.

677   **Figure 2 Alt text:** Figure with a smartphone from which 9 images emerge describing

678   some of the functionalities of the app of the ActiveHip+ project for older adults with hip

679   fracture, such as the rehabilitation section or the video call.

680

681   **Figure 3.** Examples of the ActiveHip+ content for health providers integrated from the

682   stakeholder perspectives.

683   **Figure 3 Alt text:** Figure with a laptop from which 6 images emerge describing some of

684   the functionalities of the ActiveHip+ project's website for healthcare professionals, such

685   as the agenda or the video call.

Table 1. Characteristics of focus group participants

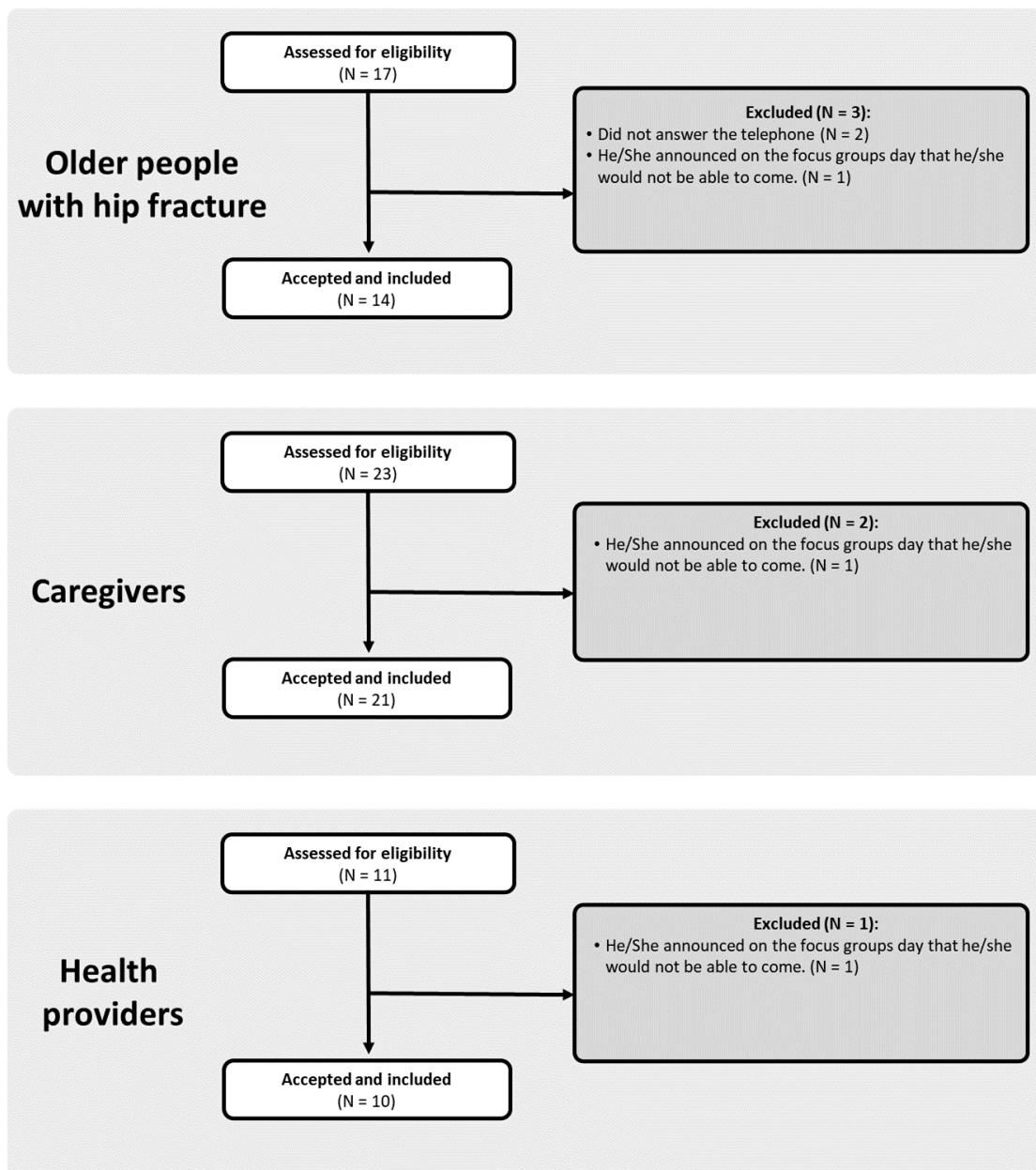| Characteristics	*N* (%)		
	Older adults with hip fracture (*N*=14)	**Caregivers** (*N*=21)	**Health providers** (*N*=10)
Sex			
Female	10 (71)	13 (62)	8 (80)
Male	4 (29)	8 (38)	2 (20)
Age; Mean (SD) and range			
	76.36 (7.70) 66-92	59.71(14.61) 32-84	43.22 (6.65) 35-53
Education level			
Primary school	10 (72)	3 (14)	0 (0)
Secondary school	3 (21)	12 (57)	1 (10)
College or university	1 (7)	4 (19)	4 (40)
Masters or doctoral degree	0 (0)	2 (10)	5 (50)
Relationship older adult and caregiver			
Husband/Wife		6 (29)	
Son/Daughter		13 (62)	
Brother/Sister		2 (9)	
Health providers			
Endocrinologist			1 (10)
Nurse			2 (20)
Nursing assistant			1 (10)
Occupational therapist			2 (20)
Orthopedic surgeon			1 (10)
Physiatrist			1 (10)
Physical therapist			2 (20)

687

Table 2. Post-Hip Fracture mHealth Themes, Categories, and Subcategories

Themes	Categories	Subcategories	Groups providing that information
mHealth Design and Function	Simple and user-friendly	Clear messages Easy to use Videos and voiceover	Older adults with hip fracture and caregivers All the groups Older adults with hip fracture and caregivers
	Positive messaging	Attitude for the recovery process Encourage older adults to complete exercise	All the groups All the groups
	Prompts and cues	Medical appointments Rehabilitation sessions	Caregivers and health providers All the groups
	Lived experience with hip fracture examples	Key motivator Older adults attitude to the recovery process	Older adults with hip fracture and caregivers Older adults with hip fracture and caregivers
	Communication system with health providers	Messages Videoconferences	Older adults with hip fracture and caregivers Caregivers and health providers
	On-demand Information	Much information in a short time frame for older adults and caregivers Frequently asked questions	All the groups All the groups
mHealth Content	Roadmap of hip fracture recovery journey	Useful information on the recovery process	All the groups
	Specific information on different topics	Information on pain and mobility	All the groups All the groups

28

		ADLs and home equipment Nutrition	Health providers and caregivers
	Exercise Instructions	Personalized exercises	Older adults with hip fracture and caregivers
		Follow-up by health providers	All the groups
		Supervision to optimize exercise performance	All the groups
	Caregivers' health resources	Training to mobilize with older adults at home	Caregivers and health providers
		Suggestions to minimize the risk of injury and recommendations for healthy lifestyles	Health providers
		Stretching and relaxing exercises, mindfulness sessions	Caregivers and health providers
Implementation Factors for mHealth	Caregiver as the main users	Knowledge and skill development	All the groups
	Health providers' role	Training and policy changes	All the groups
	Personalized action plans	Consideration of each person characteristics and comorbidities	All the groups
		Individualized follow-up	All the groups
	Some people will not use the app	Increasing age and low motivation	All the groups
		Limited skills to use ICTs	All the groups

688

689 **Supplementary Table 1.** Technical solutions included for the stakeholders' needs

| Themes	Needs to address	Technical solutions included
mHealth design and function	Simple and-user friendly design	− Easy navigation in the app. − Easy to read font.
	Clear information	− Videos with voice-over to ease understanding. − Videos permanently available on-demand.
	Positive messages	− Automatic encouraging message system. − Videos relating stories of lived experience.
	Prompts and cues	− An agenda to include reminders for medical appointments and rehabilitation sessions
	Communication with health providers	− Communication system between health providers and users.

mHealth content	Information about the entire recovery process	− Information through videos, text and infographics about:
		  o General aspects (e.g., pain, mobility).
		  o Use of supporting devices and environmental adaptations.
		  o Medication.
		  o Nutrition.
		  o Prevention of secondary fractures.

	Rehabilitation guide	− Rehabilitation program adapted to the type of surgery − Adaptation of the level of difficulty of the rehabilitation program. − Alerts system for the monitorization after each rehabilitation session.

	Specific information for caregivers	− Information for caregivers about:
		    Safe management of the older adult with a hip fracture.
		
		    Promotion of their own well-being.

Implementation factors for mHealth	Barriers for older adults to use the app	− Caregivers would be main users of the app to support older adults.
	Easy training in the use of the app	− Simple and-user friendly design. − To provide users with a leaflet summarising the use of the app.
	Personalized care plans	− Information not only focused on hip fracture.

FIGURES

691
692 **Figure 1.** Flowchart description of the recruitment process of the participants of the

693 focus groups carried out for the co-creation of the ActiveHip+ mHealth system.

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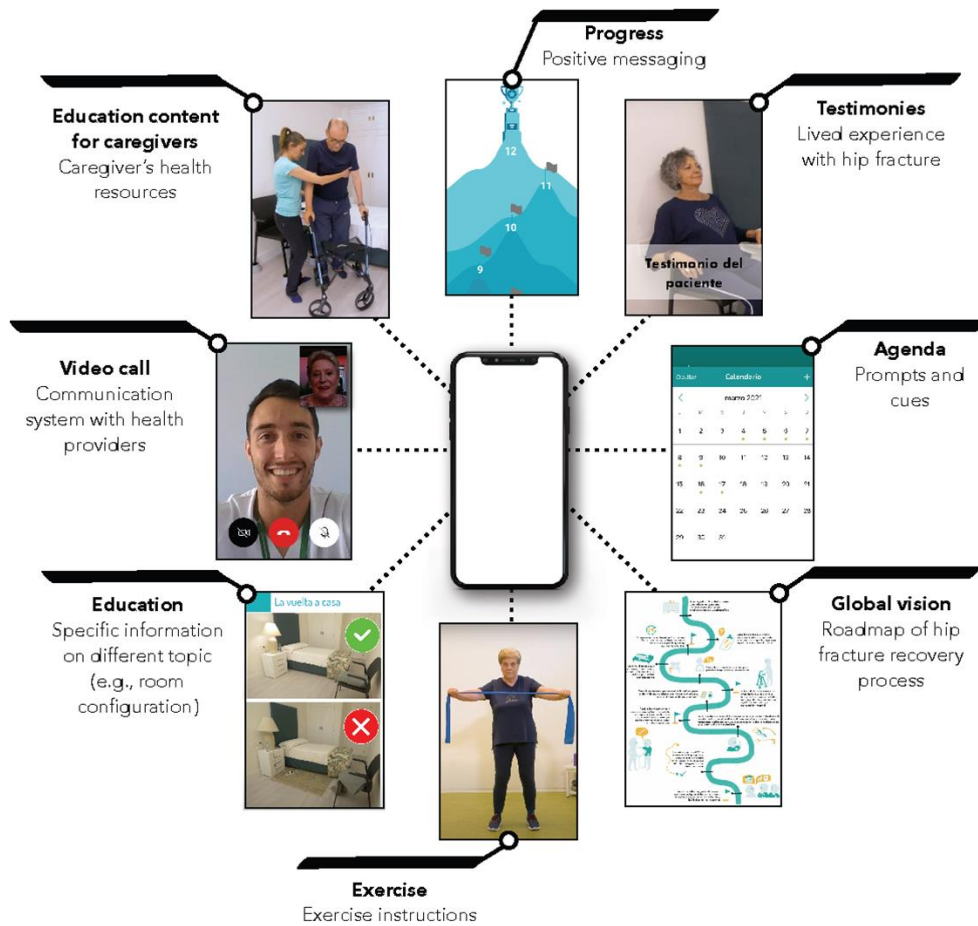
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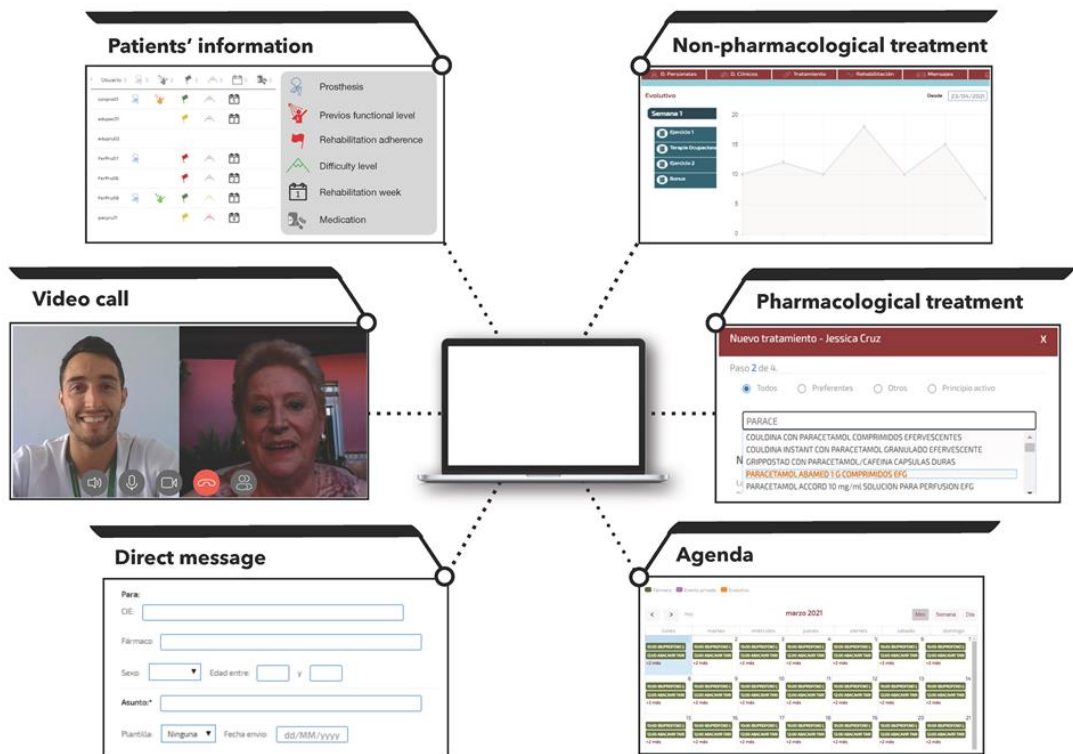
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Figure 3. Examples of the ActiveHip+ content for health providers integrated from the stakeholder perspectives.

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