New for old

Geraedts, Hilde

Chapter 7

General discussion

Main findings

In this thesis, a home-based physical activity program for older adults stimulating daily physical activity and physical functioning supported by a necklace-worn gait- and posture sensor and a tablet was developed and its feasibility and effectiveness were evaluated. Several aspects of such a program were explored. An indication of the most optimal remote coaching strategy was provided by means of a systematic literature review comparing remote contact strategies in home-based physical activity programs. Results of this systematic review imply that frequent as well as non-frequent remote contact enhance adherence to and the effectiveness of home-based physical activity programs. Remote contact during exercising seems particularly beneficial (Chapter 2).

In a video validation study integrating standardized assessment consisting of sitting, standing, lying and walking, as well as free movement in subject's homes the necklace-worn gait- and posture sensor was evaluated. The sensor-based method was found applicable for daily activity assessment based upon Time-on-Legs (ToL) of frail and non-frail older adults in their home situation (Chapter 3).

Measurement of daily activity by means of the necklace-worn sensor and contact with a coach when following a home-based physical activity program were combined in a six month home-based physical activity program for transitionally frail older adults (Chapter 4, 5 and 6). This intervention study was implemented in forty transitionally frail, community/dwelling older adults. The home-based physical activity program integrated a tablet application for exercise instructions and feedback on performance and daily physical activity (Chapter 4). An important message in the findings of this intervention is that, to be able to let older adults independently work with novel technology in a home-based program, the technology should be one hundred percent reliable for the older person (i.e. adequately providing exercise instructions) as well as for the coach (i.e. adequately providing feedback on exercise adherence and daily physical activity). In addition, weekly contact by telephone was essential to preserve sufficient adherence and effectiveness and was greatly appreciated by participants (Chapter 5). Findings in the intervention therefore do support the conclusion of the systematic review (Chapter 2) that frequent feedback from the coach is essential for the success of home-based physical activity programs. When the technology is reliable and weekly contact is provided, the exercise program showed a (non-)significant beneficial effect on daily physical activity and functional outcomes such as the Timed-Up-and-Go test (TUG), although outcomes were not yet significant. Older adults are also surprisingly appreciative of and able to work with this novel technology and appreciate the technology when made suitable for lay use (Chapter 6).

This general discussion aims to discuss the obtained results in light of the overall aim of this thesis. The main aim was to develop a home-based exercise program for older adults stimulating daily physical activity and physical functioning that integrates remote coaching supported by a necklace-worn gait- and posture sensor and a tablet, and to evaluate its feasibility and effectiveness. The factors of importance when designing such a program will be discussed by addressing the following themes: target group selection; content of the exercise program; technology use; and the motivational strategies driving the intervention. The recommendations henceforth will indicate the most optimal design for a home-based exercise program. In addition, the practical implications of the results in this thesis will be addressed. Finally, the thesis will provide a critical reflection upon our results, recommendations for future research and the conclusions.

Target group

The target group for the intervention in this thesis were transitionally frail older adults: a group of people already experiencing minor deterioration in their daily functioning [1]. The inclusion regarding frailty was based upon the Groningen Frailty Indicator (GFI), a multidisciplinary questionnaire integrating physical as well as psychosocial aspects of frailty [2]. While our subject group indeed was transitionally frail as based upon the results of the GFI (mean score 4.4 ± 0.5), their daily physical activity scores as objectively measured by the sensor as well as self-reported by means of the SQUASH questionnaire and physical test scores on the Sit-to-Stand test (STS), TUG and the Five Times Chair Rise test (CR) indicate them to be less frail than intended [2,3]. A likely explanation is the fact that the GFI is a scale integrating physical and psychosocial aspects of frailty, and probably not completely valid for frailty assessment when only looking into physical frailty [4]. The definition of frailty varies among literature and its characteristics encompass multiple aspects of health, such as physical, social and psychological health [1]. As a result, multiple tools for assessing frailty are available, which all set differing standards [5]. This causes difficulty when using frailty as an inclusion criterion for an exercise-based program. It might be more appropriate to primarily base inclusion on the outcomes of physical tests such as the STS, TUG and the CR tests when assessing frailty as an entrance criterion in exercise programs in future research [4-8].

Our participants in the studies consisted of a diverse group of older adults regarding health, medical conditions and living conditions as well as socio-economic status. The diversity of these participants might raise concerns for the applicability of our results for frail older adults and the generalizability of our results. However, older adults are in general a very diverse group regarding medical and socio-economic status [9]. Thus, the diversity of the subjects included is actually quite representative for the target group of community-dwelling older adults in general. Therefore, while not being specifically applicable to frail older adults, our results do have relevance for/are significant for older adults in general. This diversity of characteristics among older adults however does call for individual tailoring of exercise programs.

Exercise program

The exercise program in our intervention was based upon the Otago Kitchen Table Exercise Program. This program has been used in many home-based exercise programs for older adults. Programs were mainly aimed at fall prevention by means of amelioration of physical performance, and less frequently aimed to enlarge daily physical activity [10,11]. It contains basic strength- as well as balance exercises aimed at ameliorating performance on activities of daily living. The exercise program in our intervention comprised training five times a week on a subject's preferred level out of eighteen exercise levels. The levels started with ten minutes of light exercise and progressed towards forty minutes of moderate exercise using ankle weights if possible for the subject. In that way the exercises accommodated the daily guidelines for health preservation and amelioration in older adults [12]. Level fifteen out of eighteen provided an exercise load representative of these guidelines. End levels of completers varied between level three and eighteen, with forty-three percent reaching level 15 or higher. This exercise regime on average gained a significant positive effect on the outcomes of the STS and the TUG test, and a positive trend in amelioration of daily physical activity and CR tests. When comparing the results to earlier results in literature, it can be concluded that the overall effect on physical activity and performance is mediocre [13]. However, as mentioned in paragraph 2, our participants were physically fitter at baseline than intended. This might have had a ceiling effect on the outcomes of the physical tests in our group due to which the intervention was not able to provide a larger amelioration. With a more suitable target group selection on physical frailty at baseline, results of the intervention might be more prominent.

Illiffe et al. for instance compared a community group-based exercise program (FaME) and a control group (group-based exercising) to a home-based exercise program using the Otago program for a general community group of older adults aged 65 years and over, targeted at enlarging physical activity. The experimental program ameliorated the proportion of their subjects reaching a minimal target of 150 minutes per week of moderate to vigorous daily activity [14]. This is comparable to reaching the fifteenth level in our intervention. Twelve months after the cessation of their intervention, results indicated that only the group-based intervention group still showed significant positive differences regarding physical activity from the control group. The positive differences regarding daily physical activity in the Otago program home-based group were non-significant [14]. These outcomes resemble the outcomes of our intervention.

Optimal technology use in home-based exercise programs for older adults

Current developments in technology provide multiple opportunities to support remote provision, coaching and data collection in home-based physical activity programs. The intervention proposed in this thesis integrated a tablet application, on which participants could play videos showing the exercise routines that they could imitate to complete their exercise bouts. The tablet application collected the data regarding exercise bouts completed on the tablet and daily physical activity data collected by the necklace-worn sensor, providing subjects with feedback on their progress after each exercise bout. Performance on all these aspects should be up to par to effectively support independent training in home-based exercise programs for older adults.

The sensor-based method of daily physical activity assessment

As indicated by the validation studies presented in the current thesis as well as results from studies from adjacent projects [15-18], the sensor-based method used in this project is deemed sufficiently accurate in assessing physical activity in daily life among older adults, and is acceptable to users [19]. When looking into the performance of other sensor-based methods in literature regarding assessment of daily physical activity, mainly step counters and accelerometers have been used with varying performance [13]. On average, mostly the assessment of more vigorous activities such as walking outdoors are recognized well, but the small amounts of light activity such as shuffling around that mainly frail older adults make are recognized poorly [19]. Our sensor algorithm managed to adequately assess physical activity in daily life in frail as well as non-frail older adults, indicating a more suited performance than other sensor-based methods among frail older adults [19]. Besides further tweaking of the sensor-based method regarding assessment of lying, this can therefore be considered a well-suited tool for assessment of daily physical activity among home-based exercise programs for older adults.

The tablet application

In the current intervention, a tablet application was chosen due to the practical nature of a tablet: the touchscreen is very intuitive in use, a tablet format is able to provide a screen that is large enough for most older adults to read and operate, the sensor technology can be supported by tablet software and a tablet is portable so subjects can use the application wherever they feel like training. Indeed, the user evaluation and personal opinions of the subjects indicate that these are aspects older adults generally appreciate in the technology. The tablet application allows precise prescription of exercises and objective collection of exercising behavior and daily physical activity through full exercise bouts on videos that the participants can copy. Participants receive feedback upon exercise behavior after ending an exercise bout as well as visual feedback in a graph regarding their daily physical activity behavior.

Other options have however been proposed in previous studies. For instance, Rendon et al. implemented a 6-week virtual reality gaming program for community-dwelling older adult veterans to reduce fall risk. In this randomized controlled trial, subjects trained 3 times a week using a Wii Fit for balance games. Results indicated a significant positive effect on the TUG test, indicating a significant positive effect on dynamic balance and thus fall risk [22]. This program was more effective on ameliorating TUG performance than our intervention. One of the factors that might be of influence, is the higher adherence reported. An aspect contributing to the higher adherence and effectiveness, can be the gaming aspect that was included opposed to our intervention. Integrating a game element looks beneficial to keep participants motivated [20,21]. Also, the baseline physical performance level of their participants was lower, which provides a larger possibility for improvement [22]. In another study, applying a biofeedback-based Nintendo Wii training to a general group of older adults for 10 weeks, Jorgensen et al. concluded that the group using the Nintendo Wii training had significantly higher amelioration regarding muscle strength, TUG and chair rise tests than the control group only wearing insoles [23]. There was a high degree of compliance to the Nintendo Wii program [23]. The amelioration regarding TUG and CR was comparable with the amelioration shown in our intervention [23]. In a study by Esculier et al., a small group of Parkinson's patients were provided with a WiiFit and balance board training using visual feedback on stance and movement during balance exercise games. In this 6-week pilot study, significant ameliorations on STS and TUG performance were observed [24]. These short-term results surpass the results of our intervention. The visual feedback system implemented does seem to have a positive influence in the program, and this type of direct feedback upon performance or quality of exercising might be beneficial in our current application as well. In the iStoppFalls project, an Information and Communication Technology-based system to deliver an unsupervised exercise program in older people's homes was developed and tested for feasibility and effectiveness on common fall risk factors [25]. In this program, a visual feedback system on stance and balance was implemented successfully as well. The sensor-based exergaming strategy was implemented among community-dwelling older adults to increase functional status and reduce fall risk [26]. The intervention had a significant positive effect on fall risk outcomes by means of physical functioning amelioration, as expressed by STS performance and muscle strength [26]. Also in this case, an important contributing factor to its success seems to be the objective visual feedback.

To summarize, our results indicate that the sensor technology and application were feasible as a technology platform for the intervention. Further amelioration of the technology to enhance adherence and effectiveness might be found in adding a social or gaming element to the program, and live visual feedback regarding the performance of exercises.

Counseling and motivational strategies

Adherence to and effectiveness on amelioration of health parameters of an exercise program is in general highly influenced by the motivational strategy and design of the coaching involved [27]. Motivating older adults to be physically active has been attempted based on different behavioral (change) theories. The current exercise program and coaching was based on the Social Cognitive Theory (SCT) [28]. Self-efficacy is a key component in the SCT. SCT states that persons learn behaviors through observation, modeling, and motivation such as positive reinforcement. Self-efficacy is defined as "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives" [28]. SCT describes factors such as social support, setting achievable goals and tangible rewards to raise one's self-efficacy and in that way enhance the motivation to adhere [28,29]. These aspects can be implemented quite well in technology-assisted home-based physical activity programs by means of peer interaction, setting reachable targets through personalized tailoring and procuring rewards by means of positive feedback or personal benefits within the program [28,29]. In the current intervention, providing a personally tailored exercise regime with direct feedback as well as daily feedback on exercise behavior and daily activity, social support by the coach and a suitable role model in the form of an older adult performing the exercises in the videos addresses core principles of the SCT [28,30]. Other options that might be beneficial to add to heighten adherence is feedback on objective quality of performance of the exercises. While this was not incorporated in the current application yet, other solutions have successfully provided feedback based upon filming one's exercising or sensor-based feedback [24-26,31-33]. Another aspect from SCT that could be integrated is peer interaction, which has been used successfully in other exercise programs in literature as well [34-36]. To further refine the exercise program and coaching the SCT could be combined with insights from the Stages of Change theory [30]. The stages of change define the steps through which people progress as they make changes and the processes of change people use to make changes [30]. The five stages defined in this theory vary from precontemplating taking up a new behavior, to maintaining a new behavior. Each stage requires a different mode and content of feedback to start up and consolidate the progress. Structured, tailored feedback regarding one's stage of change could be beneficial to enlarge adherence to the exercises. In the current intervention, this feedback was integrated non-structurally during the telephone contacts. To enhance adherence and effectiveness, structured motivational feedback tailored to a participant's stage of change could be integrated in the feedback provided by application.

However, evidence-based integration of motivational strategies in home-based physical activity programs and serious games using novel technology is not yet common practice [20]. Many applications do not use a theoretically based motivational strategy [20]. As stated in the systematic review (Chapter 2) in this thesis as well, efforts should be made to further explore optimal use of motivational strategies in these programs to enlarge adherence and effectiveness [13].

Opportunities for society and health care

As people in our society on average become older and the number of older adults in society grows, so called dual aging, the issue of age-related morbidity also grows [37,38]. Mainly the burden of chronic diseases such as cardiovascular diseases, diabetes, osteoarthritis and obesity grows, burdening patients in their physical functioning and quality of life as well as health care resources [37,38]. With the still growing shortage of resources in health care due to the dual ageing of our society, a need for tools that can make health care more efficient arises [37,38]. Especially technology that enables patients to become more self-supporting in their health behavior is growing in popularity and possibilities [39]. Within this thesis, the tools that have been developed can assist in health care in multiple domains. The development of a sensor-based method for accurate objective assessment of daily physical activity among older adults is relevant for health care providers that need objective assessment of daily physical activity in this target group in order to be able to accurately stimulate these people to become more active and in that way stimulate their health and prevent further decline in physical functioning [13,19]. This sensor-based method is, in contrast to many other assessment tools, sensitive to the small amount of low-activity movements older adults generally make.

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Integration of this sensor-based method in the tablet application providing an individually tailored exercise program can be of use in many target groups. On the one hand general community-based prevention programs could make use of this application to stimulate a healthy lifestyle and prevent physical decline and disease. Such strategies integrating technology for remote assessment of vital markers such as for instance blood pressure or glucose levels have been successfully implemented in diabetes and cardiovascular disease programs [40-43]. On the other hand health care providers can use this application as a tool to support rehabilitation at home. This has for instance already been started in the implementation of an upgraded version of the application in a rehabilitation program for Total Hip Arthroplasty (THA) patients at UMCG. With the implementation of fast track surgeries and the minimization of coverage of expenses for postoperative physiotherapy, using such a tablet application could be an effective way to heighten post-operative physical functioning and quality of life in THA patients by providing a platform for physiotherapy instructions during rehabilitation at home. This intervention integrates a slightly different set-up than the intervention presented in this thesis. In addition to the coaching strategy, rehabilitating patients are provided the opportunity to use a Social Gym environment on their tablet with scheduled training appointments in which they can view if their fellow patients are present at the training. This program already combines several aspects that were introduced in the previous section regarding motivational strategies. A possible addition to further add to the social aspect for motivating participants to adhere is the opportunity to send fellow participants messages and communicate with the coach through a message board and email service. These features are already possible with regards to the technology, but the options are not yet in use in that intervention. In future research using this technology, these options should be implemented in the motivational strategy. The technology platform used in this intervention could in future be implemented amongst a broad spectrum of other target groups in rehabilitation as well, such as for instance cardiac- or transplantation surgery. Also, chronic health monitoring and guidance could be provided among for instance community-dwelling older adults that require health monitoring but are not limited in their functioning enough yet to move to an older adults' home. The remote health monitoring and interaction opportunities this platform provides could stall the necessity to move into an older adults' home further. Many health professionals might benefit from this platform, such as for instance physiotherapists prescribing daily exercise routines at home or general practitioners or visiting nurses caring for diabetes patients. Opportunities for integration of this kind of interventions into the health care system should be further investigated.

Critical afterthoughts

The application presented in this thesis was well-received by the participants that were provided with a reliable internet connection, as indicated by the high scores on the user evaluation questionnaire regarding the exercise program and the technology among the completers. Also, the application managed to collect exercise behavior and daily physical activity data well, providing feedback to the participants itself and objective information for the remote coach to monitor the progress.

This provides a valuable tool to assist in interventions heightening health care' efficiency. However, there are still some critical issues to be addressed. In all the considerations for type, mode and frequency of contact and design of technology that are presented in this thesis, we might consider anew whether it would be wise to use technology for contact and support for the specific persons that are training in future programs. In discussion with the participants of the studies in this thesis, it turned out that most people value the interpersonal contact through telephone or live visits in interventions most. Especially the people that were living further away from their families or were more hampered in their ability to go outdoors could really appreciate the social contact that the researchers provided. The telephone contact was greatly appreciated, as illustrated by the significantly higher adherence in the supervised training period than the non-supervised period among the completers in the intervention trial. This is in line with earlier research, in which regular telephone contact was indicated as an important factor for enlarging adherence [13]. Live visits in our intervention were appreciated as well, even when that meant the training was not running smoothly regarding for instance technology. In these visits, further encouragement could be delivered by addressing goals, drawbacks and fears regarding the training. In other words: never underestimate the motivational value of a shared cup of coffee!

Following this conclusion, the question arises: Just because we can develop and use novel technology for older adults, does that automatically mean we should? One could imagine that with the development of technology providing assistance in training, the abovementioned personal contact with a coach disappears. It could be more affordable for health care to provide patients with an app instead of providing an exercise coach or physiotherapist for an hour a week. In light of the economic health care challenge caused by the graying of our society [37,38], this is an interesting course for health care organizations in for instance rehabilitation or preventive strategies. Efforts have already been undertaken to minimalize necessary contact in for instance revalidation processes and fast track surgery [44,45]. However, with the loneliness and loss of social contacts that often are reported among older adults [46], this might cause older persons to lose a substantial part of their social contact. In a group of people already prone to loss of social interaction and often dependent of caregivers for social interaction [47], enlarging the use of technology as a total replacement for live social interaction would not be wise. Loneliness is one of the factors undermining functioning, wellbeing and quality of life among older adults [48-50]. Further minimalizing social contact therefore also might bring on unexpected health care costs due to higher loneliness, raising the question whether minimalizing social contact would actually be beneficial for health care. An opportunity to contribute to lowering loneliness can however also be provided by remote technology: in a technology platform a social component can be added, such as is provided in currently popular internet platforms such as Facebook. In recent research, solutions have been proposed providing participants with the possibility to for instance send other participants messages, keep track of other's progress, or even join a virtual training group with other fellow participants present [34-36]. Integrating a social component to home-based independent training, these exercise programs can not only stimulate physical health but also psychological health.

Recommendations for future research

The studies in this thesis accentuate the promise of home-based physical activity programs supported by sensor technology and tablet applications and provided insight into the design of those programs regarding for instance contact intensity. However, the work is not finished at this moment. The current prospective cohort study provides a valuable first insight into adherence and effectiveness of the program, but to provide more solid evidence for effectiveness of the program in enlarging daily physical activity and functional performance a Randomized Controlled Trial is indispensable. In addition, cost-effectiveness of the program should be explored. For that, a comparison of the costs engaged in the program and costs of usual care is of interest. Furthermore several set-ups for future research regarding this home-based physical activity program would be interesting: one could compare the effectiveness of the intervention when using the technology to the same intervention not supported by technology to specifically investigate the additional benefits or downsides of the use of the necklace-worn sensor and the tablet application. Several set-ups regarding the elements of the coaching strategy and –frequency should also be considered, to determine the most optimal coaching. An interesting aspect to further quantify raised here is the amount of coaching contact and set-up: is it better to let people train fully on their own or would the addition of a virtual group training be beneficial? In that respect, what would be more stimulating: working with coaching through a virtual or actual coach, or by integrating a social component by means of peer contact, or a combination of both? Last, a more thorough, structured integration of behavioral strategies in home-based exercise programs using remote technology should be further explored.

Conclusions

The main aim of this thesis was to develop a home-based exercise program for older adults stimulating daily physical activity and physical functioning that integrates remote coaching supported by a necklace-worn gait- and posture sensor and a tablet, and to evaluate its feasibility and effectiveness. It can be concluded that the home-based exercise program was found feasible and promising regarding amelioration of daily physical activity and physical functioning. Most important factors influencing effectiveness of such programs are accurate selection of the target group, remote contact and the motivational strategy. In order to further enlarge adherence and effectiveness, a strategy integrating regular remote contact with a coach throughout the total duration of the program should be adopted and a social interaction or game strategy would be beneficial to stimulate social interaction. These programs are not fully independent from human interaction: regular contact with a coach seems to be necessary to preserve adherence and effectiveness. The technology is a promising tool to support independent home-based exercising, but one should keep in mind that technology cannot fully compensate for actual human interaction. A valuable addition to these programs would be a social component by means of for instance allowing peer contact. Optimal design and effectiveness of home-based physical activity programs for older adults using novel technology and integration of theoretically based motivational strategies should still be further investigated, but this thesis provides evidence for the relevance of such efforts.

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