Chapter 5

An individually tailored home-based exercise program for frail older adults driven by tablet application and mobility monitoring: feasibility and practical implications

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Abstract

Objective
To evaluate feasibility and user opinion of a six-month home-based exercise program supported by a necklace-worn mobility sensor and a tablet application for frail older adults.

Methods
A cohort study. Subjects exercised 3 months with and 3 months without remote coaching. Feasibility was operationalized as adherence to the exercise program and wearing of the sensor, as well as incidents participants reported. Adherence was considered sufficient when it exceeded 70%. User opinion was measured with a questionnaire.

Results
21 subjects completed the trial. Mean adherence to the program was 60.9%. Adherence in completers was almost sufficient and significantly higher than in dropouts (69.2% vs. 49.9%). Adherence was sufficient in completers in the supervised part (75.8%). Mean adherence to wearing of the sensor was 66.7% and significantly higher in completers than in dropouts (75.7 vs. 54.2%). Connectivity-related incidents were most prominent. Incident rates were significantly lower in completers than in dropouts (0.39 vs. 1.19). User opinion of the system was positive.

Conclusion
A home-based exercise program using novel technology seems feasible. The user opinion was positive. With regular coaching and a stable internet connection, this home-based exercise program is promising for daily physical activity stimulation in frail older adults.

Introduction
Due to the ageing of our population, the preservation of health and self-reliance in advancing age is increasingly important [1,2]. Older adults generally are insufficiently physically active to maintain health and physical functioning [3,4]. Stimulation of a physically active lifestyle in advancing age is therefore essential.

Older adults often prefer exercising at home [6], but guidance and motivation is necessary and could previously not be provided adequately in home-based exercise programs [7]. However the development of internet and novel technology, which can be used to enable remote administration of and guidance in home-based exercise programs, has been rising exponentially and could fulfill this need [1,7]. Body-worn sensors for measurement of physical activity are developed on a large scale to accurately and objectively measure daily physical activity, providing a support of personally tailored stimulation of physical activity [8-14]. Recent developments in tablet PC’s and smartphones using mobile internet seem especially suitable for remote contact with an exercise coach stimulating adherence. Text messages, exercise instruction through video contact and contact with a coach that follows one’s achievements on the internet have been successfully implemented [15-17]. Especially motivational contact with a coach seems to be important for adherence. Internet-based platforms integrating body-worn sensors and video instructions through a tablet are promising for allowing older adults to exercise independently [18].

However, older adults often are unwilling to and uncomfortable in using innovative technology, though computer, tablet and smartphone use among older adults and middle-aged individuals is rising steeply [19-22]. Exercise programs using novel technology for older adults have already been reported, though research on features of these novel technologies and problems one might run into when implementing technology in this target group is necessary [18,23,24]. The aim of this study was therefore to assess the feasibility and user opinion on independent use of remote novel technology in a home-based exercise program for older adults.

Methods

Study design
A prospective cohort study. Subjects participated in a six-month home-based exercise program, using a tablet for exercise instructions and a necklace-worn sensor for daily activity registration. In the first three supervised months, subjects were contacted by phone to receive weekly coaching. During the unsupervised last three months, subjects were not contacted by the coach but could call themselves when encountering problems. If issues could not be solved by telephone, the coach performed a home-visit. The study protocol was approved by the Medical Ethical Committee of University Medical Center Groningen (METc number 2013/246). A full in-detail description of the study design is provided elsewhere.
Subjects
Subjects were community-dwelling older adults living in the province of Groningen, the Netherlands. Inclusion criteria included being at least 70 years old and being able to walk at least 10 metres independently or using a walking aid. In addition, subjects had to be transitionally frail as indicated by the Groningen Frailty Indicator (GFI) score of 4 or 5 [26].

Exclusion criteria were physical conditions that hamper safe independent performance of a home-based exercise program or working with a tablet, such as severe visual problems. Subjects were recruited between January and November 2014 by means of advertisement, leaflets and recruitment during Embrace community meetings [27].

Technical components
The sensor was a miniature hybrid sensor containing a 3D-MEMS accelerometer and a barometric pressure sensor, worn as a necklace. Accelerometer data were sampled at 50 Hz with a range of 8g, barometric data were sampled at 25Hz. A micro-SD card was used for storage and exchange of data. The weight of the sensor was about 30 grams and it measures 55 by 25 by 10mm (Philips Research, Eindhoven). Data transfer and battery recharge was performed automatically every day when connecting the sensor to the tablet with a USB-cable during nighttime.

Tablet PC
A tablet PC (Dell Latitude 10 tablet; Windows 8 operating system) was provided as a user device, giving exercise instructions by means of videos and distant feedback. Functionality of the tablet PC was adjusted to independent older adult use, with menus and necessary interaction designed as simple as possible. Subjects were able to choose their own level of exercising. Exercises were shown in videos which the subject had to imitate. Each level had a different video showing the full exercise bout. After completing a video, a tailored motivational message as well as sensor-registered graphical feedback on daily activity level during the previous days was provided. Internet connection was provided with mobile internet card inserted in the tablet with 3G- or 4G connection or home WiFi-connection when available. The exercise program was provided by means of an internet-based application running on a distant web server.

Evaluation methods and statistical analysis
Adherence
Adherence to the exercise program was calculated based upon completion of the planned exercise bouts as indicated by watching the online exercise videos. Adherence to wearing the sensor was calculated based on the number of days the sensor was worn with successful collection of data as registered by the sensor locally. Scheduled holidays were excluded from analysis. Adherence was considered sufficient when adherence to the exercise program and to the wearing of the sensor exceeded 70%.

Technical and operational feasibility
An inventory of problems that users ran into when performing the program was made. All phone calls and home visits other than scheduled weekly contacts and measurements were catalogue including reasons of contact. The problems subjects encountered were divided into three categories: technology-related incidents, connectivity-related incidents and participant-induced incidents. Technology-related incidents were for instance malfunctioning of cables or a defect soundcard of the tablet. Connectivity-related incidents were incidents related to low internet coverage or server downtime. Participant-induced incidents were for instance the opening of other web pages due to the inability of subjects to accurately push the correct buttons on Google Chrome. Incidents were assessed regarding number of contacts during the intervention period as well as density of contacts (mean number of contacts per subject per week).

Determinants influencing participation
By means of a questionnaire determinants that might have influenced older adults’ ability to independently perform a home-based exercise program using novel technology were assessed. Questions included age, gender, marital status, prior and current use of computer and smartphone, fall history, chronic conditions and level of frailty (GFI). Prior and current use of Information and communication technology such as PC, smartphone and associated software was assessed by means of a multiple choice question with answer categories “Never used before”, “Occasionally” or “Daily, now or in the past”. Smartphone use was assessed in a dichotomous question “Own a smartphone” or “Do not own a smartphone”. Fall history was assessed by a question stating how many times a person had fallen in the previous year “Never”, “Once” or “Multiple times”.

User evaluation
User evaluation was performed by means of a written questionnaire filled in by the participants after the supervised period (post-test) and again after the unsupervised period (follow-up). This user evaluation questionnaire is an adapted version of the SensAction-AAL subject evaluation form [28]. The questionnaire addressed ease of use of the tablet and sensor, frequency of contact and help from the coach and trust in the correct functioning of the devices. Answer categories varied from “Not agree at all” (0) to “Fully agree” (5) on a Likert scale. A higher mean score on the questionnaire indicated a more positive opinion on the intervention.

Dropouts were also contacted for a short review of the program after ending their participation. In this review, subjects were asked one question: “Rate the program and technology with a mark between 1 and 5, 1 being very ill-performing and not enjoyable and 5 indicating very well-performing and enjoyable”.
Results

Participants
Forty transitionally frail (mean GFI score 4.4 ± 0.5) and independently living participants were included, of which 15 males and 25 females. Mean age at intake was 80.8 ± 4.6 years. All participants experienced one or more chronic conditions or debilitations, most commonly heart failure, diabetes and leg injuries. Twenty-five subjects had prior experience with tablet or laptop, of which twenty-one used such a device on a daily base. One participant owned a smartphone. Subjects’ characteristics are summarized in Table 1.

Table 1. Participant Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total Group (N = 40)</th>
<th>Completers (N = 21)</th>
<th>Dropouts (N = 19)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>15/25</td>
<td>8/13</td>
<td>7/12</td>
<td>0.90</td>
</tr>
<tr>
<td>Age (Year)*</td>
<td>81 ± 4.6</td>
<td>80 ± 4.7</td>
<td>83 ± 4.2</td>
<td>0.06</td>
</tr>
<tr>
<td>GFI (Score)*</td>
<td>4.4 ± 0.50</td>
<td>4.4 ± 0.50</td>
<td>4.5 ± 0.51</td>
<td>0.66</td>
</tr>
<tr>
<td>BMI (Kg/M²)*</td>
<td>27.9 ± 4.1</td>
<td>28.1 ± 4.4</td>
<td>27.6 ± 3.7</td>
<td>0.75</td>
</tr>
<tr>
<td>Computer Experience (Y/N)</td>
<td>25/15</td>
<td>18/3</td>
<td>7/12</td>
<td>&lt;0.0010²</td>
</tr>
<tr>
<td>Smartphone owner (Y/N)</td>
<td>1/39</td>
<td>1/20</td>
<td>0/19</td>
<td>0.04²</td>
</tr>
<tr>
<td>Internet Type (3G/4G/WiFi)</td>
<td>17/11/12</td>
<td>4/6/11</td>
<td>13/5/1</td>
<td>0.04²</td>
</tr>
</tbody>
</table>

*a. Data are expressed in Means ± SD.
*b. Significant difference between Completers and Dropouts at the 0.05 level.

Adherence
Twenty-one subjects completed the half-year program, nineteen subjects dropped out pre-term: eleven due to internet reception problems, five because of medical reasons not related to the exercise program, two because of illness of their spouse and one deceased. Sixteen of the dropouts quit during the first three months of the trial, three during the last three months. Main adherence to the wearing of the sensor among 3G-, 4G-, and WiFi-users was resp. 62.6 ± 31.8, 83.7 ± 0.04, 60.9 ± 32.5% (p = 0.04)

p were non-significant (p = 0.90). Completers had an adherence of 75.7 ± 27.7% to the daily wear ± 31.9%. In 4G- and WiFi users, this was resp. 60.3 ± 37.5 and 64.9 ± 32.14%. These differences were non-significant (p = 0.90). Completers had an adherence of 75.7 ± 27.7% to the daily wearing of the sensor, while dropouts had a significantly lower adherence of 54.2 ± 31.2% (p = 0.04). Adherence to the wearing of the sensor among 3G-, 4G-, and WiFi-users was resp. 62.6 ± 31.8, 83.7 ± 23.0 and 60.9 ± 31.8% (p = 0.21). Table 2 summarizes the details of adherence to the program.
Subjects received feedback on their performance during their scheduled weekly contacts. There were in total 216 weekly scheduled telephone contacts performed, which lasted between one and two minutes each when no additional motivation or technological assistance was needed. Base load of the weekly contacts was therefore between 216 and 432 minutes in the total intervention. During forty of these contacts motivational strategies regarding the performance were used. The motivational part of these contacts took between two and five minutes each, providing a total additional coaching load between 80 and 200 minutes during the coached part of the intervention. All of the additional motivational contacts needed were in the coached part of the intervention. In twenty-three of these contacts, subjects were advised to adjust their training load. In the other seventeen contacts, subjects received feedback upon their adherence to the program when this seemed to be below par.

### User evaluation

Average score on the user evaluation questionnaire in completers was 4.3 ± 0.4 (range 0-5) at post-test and 4.2 ± 0.2 at follow up assessment. This indicates a positive opinion on the system and application. Subjects indicated to prefer the weekly phone contact with the coach instead of exercising independently (18 out of 21).

Eleven of the dropouts responded to the user evaluation question after their participation. Mean score on this question was 2.00 ± 0.9. Four of these subjects had not dropped out due to the internet reception problems and valued the program significantly more positive than the subjects that had dropped out due to the internet reception problems, resp. 2.8 ± 1.0 vs. 1.6 ± 0.5 (p = 0.03).

### Discussion

The current study provides insight into the feasibility of a home-based exercise program using a body-worn sensor and a tablet application. Mean adherence to the exercises was 60.9 ± 32.5%, which does not reach our goal of 70% for adherence to the exercises to be considered sufficient. However, completers did reach the 70% adherence to the program in the coached part of the adherence, as opposed to a non-sufficient adherence in the non-coached part of the intervention. This indicates that the weekly coaching by telephone is an important feature in keeping subjects exercising sufficiently. This is in line with earlier findings in literature depicting coach contact as an important factor influencing adherence [29]. Data reports on wearing of the sensor almost reached 70% in general, and did reach the 70% level in completers. Our reported adherence rates are however lower than earlier reported studies in the field [18]. This can be explained by the significantly longer intervention time in our study, which invites non-adherence more than short trials [18,30], but adherence was probably mostly influenced by stability of the system which was often compromised by connectivity issues.

The use of mobile internet connections has drawbacks, illustrated by the high connectivity-related incident rate. In more rural areas such as where this study was performed the 3G-coverage was often very low. Internet pages not loading due to minimal reception caused discontentment amongst participants, with 52.6% of the dropout caused directly by malfunction of the 3G-reception in remote areas. Since especially these remotely living older adults might benefit from remotely coached home-based exercise programs due to lack of exercise facilities nearby [18], it is important to tackle this. A solution found was switching to a different provider with a higher reception density.

### Table 3. Incidents

<table>
<thead>
<tr>
<th></th>
<th>Total Group (N = 40)</th>
<th>Completers (N = 21)</th>
<th>Dropouts (N = 19)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology-related</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount</td>
<td>109</td>
<td>80</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Density (mean/subj/week)</td>
<td>0.20 ± 0.5</td>
<td>0.16 ± 0.2</td>
<td>0.24 ± 0.4</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Connectivity-related</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount</td>
<td>111</td>
<td>51</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Density (mean/subj/week)</td>
<td>0.36 ± 0.3</td>
<td>0.15 ± 0.3</td>
<td>0.58 ± 0.5</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Participant-induced</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount</td>
<td>29</td>
<td>22</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Density (mean/subj/week)</td>
<td>0.07 ± 0.1</td>
<td>0.05 ± 0.08</td>
<td>0.08 ± 0.2</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>249</td>
<td>153</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>Density (mean/subj/week)</td>
<td>0.78 ± 0.8</td>
<td>0.39 ± 0.5</td>
<td>1.19 ± 0.8</td>
<td>0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>3G-Users (N = 17)</th>
<th>4G-Users (N = 11)</th>
<th>WiFi-Users (N = 12)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology-related</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount</td>
<td>22</td>
<td>29</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>Density (mean/PP/week)</td>
<td>0.23 ± 0.3</td>
<td>0.22 ± 0.4</td>
<td>0.18 ± 0.4</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Connectivity-related</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount</td>
<td>50</td>
<td>25</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Density (mean/PP/week)</td>
<td>0.74 ± 0.5</td>
<td>0.21 ± 0.4</td>
<td>0.17 ± 0.4</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Participant-induced</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Density (mean/PP/week)</td>
<td>0.03 ± 0.1</td>
<td>0.07 ± 0.2</td>
<td>0.05 ± 0.1</td>
<td>0.88</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>78</td>
<td>61</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Density (mean/PP/week)</td>
<td>1.30 ± 0.8</td>
<td>0.45 ± 0.3</td>
<td>0.43 ± 0.7</td>
<td>0.01</td>
</tr>
</tbody>
</table>

a. Data are expressed in Means ± SD.

b. Significant difference between Completers and Dropouts at the 0.05 level.
therefore be depicted as a very major influence on adherence to home-based exercise programs supported by an internet-reliant application.

Subjects who completed the intervention were very enthusiastic about working with the technology. The rating of 4.3 out of 5 at the questionnaire regarding the appreciation of the tablet, sensor, coaching and exercise program can be considered very positive. However, the questionnaire was performed at posttest and follow up measurements and therefore dropouts did not complete the questionnaire, providing a significant positive bias. The eleven dropout subjects able and agreeing to cooperate with the phone review question indicated the program low on average, indicating that these dropouts were not pleased by the performance of the application. Of these eleven subjects, seven dropped out primarily due to the unstable performance of the internet. The four subjects that did not drop out due to the unstable internet had a significantly more positive view on the application than the dropouts related to internet problems. This indicates that the internet instability was very determining in user opinion among dropouts.

The coach load in this intervention was small when technology was stable, with a base load of 1 to 2 minutes per week per person when running smoothly to 2 to 5 minutes per person a week for additional coaching by telephone when subjects need to be motivated to adjust their training load or keep adherent. The additional effort of weekly telephone contact can therefore be seen as a small but necessary investment for the exercise program. It can be expected that, when provided with ideal circumstances by means of a stable internet connection and regular coaching, adherence to the exercises and wearing of the sensor will reach the sufficient level threshold of 70%.

The design of the current study has some major strengths. First, the exercise program lasted six months. This is a fairly long period for an exercise intervention in this field, which can provide an indication of the long-term adherence to the program. Second, forty subjects in an extensive intervention like this is a substantial subject pool in this field. In addition, with a mean age of 80.8 years and a very diverse medical background, subjects can be considered very representative for a general sample of older adults in the community. Also, subjects were diverse regarding background and prior experience with technology, providing information on feasibility for lay users as well as more experienced users.

However, there is a limitation in this study due to the problems regarding connectivity. The unreliable internet connection most probably caused feasibility and adherence of the application to be underrated. An intervention period fully supported by a stable internet connection might provide more reliable insight in the performance of the system itself.

In conclusion, a home-based exercise program using novel technology for older adults seems feasible. Adherence was sufficient among the completers in the coached part of the intervention, indicating regular coaching as a positive influence on adherence. Dropout, adherence and user opinion were strongly influenced by stability of the internet connection and system. Especially switching to a more stable and better internet provider did significantly improve adherence. The coach load regarding weekly coaching when subjects were provided with a stable internet connection and system was low. The older adult subjects completing the program were positive about using the novel technology in performing the exercise program.

References
2. ACL website; Available at: http://www.aoa.acl.gov/Aging_Statistics/index.aspx Accessed at 02/12/2014


