Feasibility and patient experience of a home-based rehabilitation program driven by a tablet application and mobility monitoring for patients after a total hip arthroplasty

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Abstract

**Background:** Recent developments in technology are promising for providing home-based exercise programs.

**Objective:** The objective of this study is to evaluate the feasibility and patient experience of a home-based rehabilitation program after Total Hip Arthroplasty (THA) delivered by means of videos on a tablet PC and a necklace-worn motion sensor to continuously monitor mobility-related activities.

**Methods:** Thirty independently living patients aged 18-75 who received a THA as treatment for primary or secondary osteoarthritis (OA) were included between December 2015 and February 2017. Patients followed a 12-week exercise program with video instructions on a tablet PC and daily physical activity registration through a motion sensor. Patients were asked to do strengthening and walking exercises at least five days a week. There was weekly phone contact with a physiotherapist. Adherence and technical problems were recorded during the intervention. User evaluation was done in week 4 (T1) and at the end of the program (T2).

**Results:** Twenty-six patients completed the program. Average adherence for exercising five times a week was 92%. Reasons mentioned most often for non-adherence were vacation or a day/weekend off (25%) and work (15%). The total number of technical issues was eight. The average score on the user evaluation questionnaire (range 0-5) was 4.6 at T1 and 4.5 at T2. The highest score was for the subscale “coaching” and the lowest for the subscale “sensor”.

**Conclusions:** A home-based rehabilitation program driven by a tablet application and mobility monitoring seems feasible for THA patients. Adherence was good and patient experience was positive. The novel technology was well accepted. A home-based program could be an alternative for formal physiotherapy.

**Keywords:** Osteoarthritis; total hip arthroplasty; home-based rehabilitation; physiotherapy.
Introduction

Surgical treatment by means of a THA is most often indicated in end stage of hip OA. At present, THA is considered one of the most successful, effective and cost-effective surgical treatments available. This is why a total of 28,658 primary THAs were performed in the Netherlands in 2016 [1]. As in other Western countries, there is an increasing tendency in the Netherlands to perform fast-track surgery, after which people leave the hospital within a few days. The downside is a risk of patients being minimally supported in their rehabilitation process during hospital admission and after discharge. At present postoperative physiotherapy is not always covered by the basic health insurance in the Netherlands [2]. This can ultimately lead to suboptimal recovery [3]. Bandholm and Kehlet emphasize in their paper from 2012 the urge for immediate and intensive postoperative physiotherapy [3]. In addition, research by Austin et al. (2017) shows that this physiotherapy need not take place in a formal setting. A home-based program could work as well [4]. They showed that a home-based rehabilitation program seems to be both safe and efficacious for a majority of patients undergoing THA [4].

In this context it is important to look at how technical innovations can be supportive of such home-based programs. Recent technological developments such as wearable sensors and tablet use with mobile internet are promising for providing home-based programs [5]. The use of objective activity monitoring with wearable sensors can potentially be helpful in strategies aimed at increasing adherence to home-based rehabilitation programs and daily activity [6]. Furthermore, a home-based program can improve adherence, which is often influenced by aspects such as lack of motivation, the effort and costs of traveling, and a preference for the privacy of the home environment [7].

The use of computers and tablets is rising among older adults in the Netherlands [6]. Ownership of tablets among seniors aged 65-75 increased from 28% in 2012 to 60% in 2016 [8]. Although home-based rehabilitation programs may be of great importance, research is needed to optimize those programs that are supported by technology. Aim of this study is therefore to evaluate the feasibility and patient experience of a home-based rehabilitation program after THA, delivered by means of videos on a tablet PC and a necklace-worn motion sensor to continuously monitor mobility-related activities.
Methods

Study design

A six-month prospective cohort study was conducted to test the feasibility and patient experience of a home-based rehabilitation program. Patients participated in a 12-week home-based exercise program after THA, following video instructions on a tablet PC. Physical activity was registered daily through a necklace-worn motion sensor, and patients were contacted weekly by telephone to receive coaching from a physiotherapist. The phone calls were aimed at motivating participants, discussing barriers to exercise and exercise load, as well as answering questions concerning guidelines in terms of movement and load after surgery. Measurements were taken preoperatively (T0) and at 4 weeks (T1), 12 weeks (T2) and 6 months postoperatively (T3). The study was approved by the Medical Ethical Committee of University Medical Center Groningen (METc2014/399).

Study population

A total of 30 independently living patients aged 18-75 who received a THA as treatment for primary or secondary OA were included. Patients were waiting for a THA at either Martini Hospital Groningen or Medical Center Leeuwarden in the Netherlands. Exclusion criteria were: (1) revision surgery, (2) medical conditions that disallow independent living, (3) cognitive impairment, and (4) inability to sufficiently read and understand Dutch. Patients were included in the period December 2015 to February 2017, and were required to sign a written informed consent form in order to be able to participate.

Rehabilitation program

The duration of the program was 12 weeks. Patients started the program within seven days after the surgery. Patients performed exercises independently at home using the tablet PC for instructions. The program included strengthening and walking exercises based on increasing muscle force, balance and functionality. The exercises comprised movements that trained abductors, flexors and extensors of the affected hip. The content of the program was based on previous research [9, 10] and on guidelines from the American Association of Orthopaedic Surgeons. For the rest, the program was designed in line with the most recent guidelines from the Royal Dutch Society for Physical Therapy [11].

Patients were asked to exercise at least five days a week, with rest days on Thursday and Sunday. Strengthening exercises were performed three times a week. The instructions for the exercises were provided by videos on the tablet PC which the patient had to imitate. The sessions started with exercise bouts of 10 minutes which progressively went up to 45 minutes during the 12
weeks of the program. The first step-in level of the program consisted of light and easy exercises. Difficulty and exercise duration were increased across levels very gradually. The exercise burden increased by adding more repetitions, more exercises and longer training time as well as by incorporating the use of ankle weights. Instructions for the walking exercises had no video and showed a descriptive message only. Patients started by walking three 5-minute blocks each day, progressing up to a total of 30 minutes walking per day.

At the end of the week patients were asked questions on the tablet PC about perceived pain and perceived intensity of the exercises. A score of self-reported intensity lower than 4 (scale 0-10) was used as an indicator that a patient could train at a higher level. There was weekly telephone support from a physiotherapist. During this phone call the physiotherapist and the patient evaluated the progress and agreed on whether to train at a higher level. The program consisted of 12 levels, each week intended for a level of increasing difficulty.

During the intervention the physiotherapist made three home visits. On the first visit participants received an explanation about the exercises and use of the tablet. The second and third visits were respectively at weeks 4 and 12 postoperatively, and included physical tests and filling out questionnaires.

Technical applications

Tablet PC

Patients received exercise instructions through a tablet PC, a Dell Latitude 10 running the Windows 8 operating system. Exercise instructions were provided by means of a web-based application. The application provided exercise instructions and gave participants feedback on their training performance. Exercise completion and application use were recorded to track adherence. The application was designed to be as easy as possible so people with no tablet experience could participate. Internet connection was provided by the subjects’ own home Wi-Fi.

The physiotherapist used a coach application that showed daily registration of completion degree or interruption of exercise bouts. Answers on the evaluation questions (about pain and perceived intensity) were also shown at the end of the week. The physiotherapist was able to change the level of the exercises through this application.

Sensor

The necklace-worn sensor (see Figure 1) weighed about 30 gr and measured 55x25x10 mm (Research prototype, Philips Research, Eindhoven, The Netherlands) [6]. The sensor device included a miniature hybrid sensor containing a 3D-MEMS accelerometer and a barometric pressure sensor. Accelerometry 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. Subjects were asked to wear the sensor in the daytime during the 12-week program and to connect the sensor to the tablet manually using a USB cable for data transfer and battery charging every night [6].

![Motion Sensor](image)

**Figure 1:** the necklace-worn motion sensor

**Evaluation methods**

**Patient characteristics**

Preoperative demographic data, height, weight, medical history, and pre- and postoperative complications were recorded. Factors that might have influenced patients’ ability to independently perform a home-based program using novel technology were assessed by means of a questionnaire. Questions were also asked about previous and current use of personal computers and smartphones.

**Adherence**

Adherence to the rehabilitation program was evaluated based on completion of the planned exercises as indicated by watching the exercise videos and reading the instruction messages. Program adherence was considered sufficient when it exceeded 70%. Reasons why patients did not perform the planned exercises were recorded by the physiotherapist during the weekly phone calls.

**User evaluation**

User evaluation was performed with a questionnaire adapted from the SensAction-AAL subject evaluation form [12]. The questionnaire contained questions about the user experience, perceived intensity of the intervention, coaching, wearing of the sensor, and acceptability of the technology. Answer categories ranged on a Likert scale from 0 (“Do not agree at all”) to 5 (“Fully agree”). A higher score indicated a more positive opinion. At the end of the questionnaire patients were able to write down other suggestions or comments. The user evaluation was done in week 4 (T1) and at the end of the program (T2).

**Technical problems**

Technical issues that interrupted the execution of the program were logged during the program. All
phone calls and extra home visits were registered along with the reasons for these calls or visits.

**Statistical analysis**

Statistical analyses were performed with IBM SPSS Statistics 22.0 (IBM, Amonk, NY). Descriptive statistics were used to portray the main characteristics of the research group.
Results

Demographic characteristics

Nine men and 21 women participated in the study. Mean age was 64 ± 6.7 years. Table 1 shows an overview of the demographic characteristics. Seven patients were living alone and the others were living with a partner and/or children. Eight patients had undergone a THA on the other hip in the past. Eight patients had back problems and five had rheumatic complaints. All patients had previous computer experience and 25 owned a smartphone.

Table 1: Demographic characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N=30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), mean (SD)</td>
<td>64 (6.7)</td>
</tr>
<tr>
<td>Gender, male/female</td>
<td>9/21</td>
</tr>
<tr>
<td>Length (cm), mean (SD)</td>
<td>175 (7.2)</td>
</tr>
<tr>
<td>Body weight (kg), mean (SD)</td>
<td>79.8 (13.9)</td>
</tr>
</tbody>
</table>

Education

| Low, n(%)                | 13 (43%) |
| Middle, n(%)             | 4 (13%)  |
| High, n(%)               | 13 (43%) |
| Employed, n(%)           | 17 (57%) |

Living situation

| Living alone, n(%)       | 7 (23%)  |
| With partner, n(%)       | 20 (67%) |
| With partner and children, n(%) | 2 (7%) |
| With children, n(%)      | 1 (3%)   |

Computer experience

| Daily, n(%)               | 25 (83%) |
| Sometimes, n(%)           | 5 (17%)  |
| Smartphone owners, n(%)   | 25 (83%) |
| Surgical approach, posterolateral/anterior | 22/8 |
| Previous THA other hip, n(%) | 8 (27%) |

Adherence

A total of 26 patients completed the program. Four patients dropped out in the first two weeks: three patients dropped out because of severe back pain, preference to visit a regular physical therapist and reoperation after a fall, and the fourth patient performed postoperatively worse than expected. This patient was insecure, needed more direct personal coaching and went to a regular physical therapist. Because of sustained back pain two patients finished the program two and four weeks before the official end and went to a regular physical therapist. There were no exercise-induced injuries. Of the
26 patients who completed the program, three did not participate in the six-month measurement because of surgery of the other hip (THA and a fracture) and illness.

For all patients, average adherence to exercising five times a week was 92%. For all weeks the adherence was sufficient (> 70%), except for the strengthening exercises on week 12 (Table 2).

After week 8 there was a decrease in adherence. Adherence for the strengthening and walking exercises was comparable, except for weeks 9 and 12: for both these weeks adherence to the walking exercises was higher than adherence to the strengthening exercises. During the intervention self-reported perceived pain decreased from 4.1 in week 1 to 1.6 in week 12. Self-reported perceived intensity of the exercises decreased from 4.6 in week 1 to 2.1 in week 12. A score of self-reported intensity <4 was used as an indicator that a patient could train at a higher level. These results correspond with the fact that not raising the exercise level at the end of the week mostly occurred in the first four weeks of the program.

Table 2: Overview of adherence and self-reported perceived pain and intensity during the 12-week rehabilitation program, mean (SD).

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adherence total (%)</td>
<td>96.4 (9.5)</td>
<td>96.7 (8.3)</td>
<td>98.8 (4.3)</td>
<td>96.9 (6.8)</td>
<td>97.3 (6.0)</td>
</tr>
<tr>
<td>Adherence to strengthening exercises (%)</td>
<td>96.5 (10.4)</td>
<td>96.3 (10.6)</td>
<td>98.7 (6.5)</td>
<td>97.5 (9.0)</td>
<td>97.5 (9.0)</td>
</tr>
<tr>
<td>Adherence to walking exercises (%)</td>
<td>96.4 (13.1)</td>
<td>97.2 (10.6)</td>
<td>99.0 (4.9)</td>
<td>96.2 (11.6)</td>
<td>97.1 (8.1)</td>
</tr>
<tr>
<td>Self-reported perceived pain a</td>
<td>4.1 (2.0)</td>
<td>3.6 (1.7)</td>
<td>3.0 (1.9)</td>
<td>2.9 (2.2)</td>
<td>2.2 (2.3)</td>
</tr>
<tr>
<td>Self-reported perceived intensity b</td>
<td>4.6 (2.6)</td>
<td>5.0 (1.9)</td>
<td>3.9 (2.1)</td>
<td>3.0 (2.0)</td>
<td>2.7 (2.3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Week 7</th>
<th>Week 8</th>
<th>Week 9</th>
<th>Week 10</th>
<th>Week 11</th>
<th>Week 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adherence total (%)</td>
<td>96.5 (6.9)</td>
<td>94.6 (9.0)</td>
<td>87.6 (22.2)</td>
<td>82.8 (28.4)</td>
<td>85.4 (22.5)</td>
</tr>
<tr>
<td>Adherence to strengthening exercises (%)</td>
<td>97.5 (9.0)</td>
<td>93.7 (13.3)</td>
<td>84.1 (25.6)</td>
<td>82.8 (30.5)</td>
<td>83.5 (24.0)</td>
</tr>
<tr>
<td>Adherence to walking exercises (%)</td>
<td>95.2 (12.3)</td>
<td>96.2 (13.6)</td>
<td>93 (22.3)</td>
<td>83.0 (30.4)</td>
<td>88.0 (24.9)</td>
</tr>
<tr>
<td>Self-reported perceived pain a</td>
<td>2.0 (1.6)</td>
<td>1.9 (2.1)</td>
<td>1.6 (1.9)</td>
<td>1.9 (1.8)</td>
<td>1.5 (1.1)</td>
</tr>
<tr>
<td>Self-reported perceived intensity b</td>
<td>2.2 (1.9)</td>
<td>2.1 (2.0)</td>
<td>2.3 (1.8)</td>
<td>2.3 (1.8)</td>
<td>2.3 (1.8)</td>
</tr>
</tbody>
</table>

a when rating perceived pain on a 0-10 scale at the end of the week (0 = no pain, 10 = worst possible pain)
b when rating perceived intensity of the exercises on a 0-10 scale at the end of the week (0 = rest, 10 = maximal)
Table 3 shows the reasons for non-adherence. Participants failed to comply with training due to vacation or a day or weekend off 25% of the time. Work was also mentioned often as a reason for not exercising (15%), as well as internet connectivity problems (10%). Holidays, days off and work were mentioned mainly in the last three weeks of the intervention. Not exercising because of a social activity was mentioned on all weeks, while pain/muscle pain related to the THA was mentioned mainly in the first two weeks.

**Table 3: Overview of the reasons for non-adherence**

<table>
<thead>
<tr>
<th>Reasons for non-adherence</th>
<th>N(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holiday/vacation or day/weekend off</td>
<td>33 (25%)</td>
</tr>
<tr>
<td>Work</td>
<td>20 (15%)</td>
</tr>
<tr>
<td>Social activity: birthday, family visit, national holiday</td>
<td>20 (15%)</td>
</tr>
<tr>
<td>(Muscle)pain related to the THA</td>
<td>14 (10%)</td>
</tr>
<tr>
<td>Pain not related to the THA</td>
<td>13 (10%)</td>
</tr>
<tr>
<td>Internet problems</td>
<td>13 (10%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>9 (7%)</td>
</tr>
<tr>
<td>Forgot to do the exercises</td>
<td>6 (4%)</td>
</tr>
<tr>
<td>Application or tablet did not work</td>
<td>3 (2%)</td>
</tr>
<tr>
<td>No motivation to train</td>
<td>2 (1%)</td>
</tr>
<tr>
<td>Disease/ Illness</td>
<td>1 (1%)</td>
</tr>
</tbody>
</table>

Five patients (19%) completed all levels of the program. Eleven patients (42%) reached level 11 and five patients (19%) reached level 10. Two patients (8%) reached level 9 and three patients (12%) reached level 8 of the program. Not raising the exercise level at the end of the week mostly occurred in the first four weeks of the program. Staying on the same level occurred 23 times (72%) in weeks 1-4 and nine times (28%) after week 4.

The total number of technical issues was eight. Five issues included errors in the server of the application. These problems were mostly solved within a few hours, so people were able to complete the exercises for that day. Three issues required an extra home visit to be solved: an unstable Wi-Fi connection, a broken tablet PC and a disconnection of the sensor and the tablet PC.

**User evaluation**

The average score on the user evaluation questionnaire (range 0-5) was 4.6 at T1 and 4.5 at T2. The highest score was for the subscale “coaching” and the lowest score was for “sensor” (Table 4). For the subscale “rehabilitation program” the highest scores were given for the statements “The rehabilitation program is effective for improving muscle strength”, “The instructions for the exercises were clear” and “I would recommend this rehabilitation program to other patients”. Lowest scores (although > 4.0) were given for the statements: “The rehabilitation program is
effective for improving my walking pattern” and “The level of the exercises was adapted to my possibilities”.

Table 4: Results of the user evaluation questionnaire.

<table>
<thead>
<tr>
<th>Subscale</th>
<th>T1 (n=26), mean (SD)</th>
<th>T2 (n=26), mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rehabilitation program</td>
<td>4.58 (0.66)</td>
<td>4.59 (0.65)</td>
</tr>
<tr>
<td>Coaching</td>
<td>4.88 (0.38)</td>
<td>4.85 (0.48)</td>
</tr>
<tr>
<td>Sensor</td>
<td>4.11 (1.00)</td>
<td>3.99 (1.07)</td>
</tr>
<tr>
<td>Tablet PC</td>
<td>4.77 (0.50)</td>
<td>4.74 (0.55)</td>
</tr>
</tbody>
</table>

Note. Answer options varied from “Do not agree at all” (0) to “Fully agree” (5) on a Likert scale. A higher score on the questionnaire indicated a more positive opinion on the intervention.

Nineteen patients gave suggestions for improvements or other comments at the end of the user evaluation questionnaire. Nine patients mentioned that they liked being able to rehabilitate from home (and that they did not have to travel), and felt motivated by the rehabilitation program. Four patients would have liked an extra home visit in the first few weeks to check performance of the exercises (mentioned by two patients) and the walking pattern (mentioned by two patients). Five patients recommended more diversity in the exercises. Seven patients mentioned that the duration of the program was a bit too long, especially when they felt their recovery was complete and they had started working again. Eight patients reported that they experienced the daily wearing of the sensor as uncomfortable, because the sensor was big (mentioned by four patients) and because the cord was irritating (mentioned by four patients).
Discussion

The results of this study provide support for the feasibility of a home-based tele-monitored rehabilitation program for patients after a THA. Adherence to the program was good, user evaluation was positive, and there were only eight technical issues during the intervention.

A total of 30 patients were included in the study and 26 patients completed the program. Because of pre-existing back pain two patients finished the program two and four weeks before the official end. The back pain was unrelated to the intervention. There were no exercise-induced injuries during the intervention. This indicates that patients after THA can perform a rehabilitation program safely at home. Previous studies also concluded that unsupervised home exercise is safe for a majority of THA patients [4, 13].

Average adherence to exercise five times a week was 92%, which was higher than our goal of 70%. However, we must note that after week 8 there was a decrease. Overall, our adherence rate is higher than those of similar 12-week programs, such as those used by Chang et al. (2017) and Mikkelsen et al. (2012) [14, 15], who reported an adherence rate of 73% and 77% respectively. These two home-based rehabilitation programs were not supported by technology. Our adherence rate was comparable with the 99% rate for the eight week home-based program combined with weekly institutional exercise sessions used by Steinhilber et al. (2012) [16]. This suggests that weekly phone contact combined with use of technology have the potential to replace supervised exercise sessions.

The reasons mentioned most often for non-adherence were vacation (or a day/weekend off) and work. Both reasons were mentioned mainly in the last three weeks of the intervention, which explains the decrease in adherence after week 8. Some people even suggested that the program could be shortened. Internet problems concerned 10% of the reasons for non-adherence, although this applied only for two patients in a short period (6-7 days).

Patients were positive about the program, giving an average score of 4.6 (range 0-5) at T1 and 4.5 at T2 on the user evaluation questionnaire. Patients liked that they could rehabilitate from home (and that they did not have to travel), and felt motivated by the program. The remote support by weekly phone contact with the coach was appreciated by the patients. The importance of the weekly phone contact is in line with a previous study reporting that motivation and coaching is an important parameter for home-based exercise performance and enhanced adherence [17].

The rehabilitation program consisted of 12 levels, for every week one level. Despite the various levels offered, five patients suggested more diversity in the exercises. Four patients would have liked an extra home visit in the first few weeks to check performance of the exercises and their walking pattern. These comments correspond with the lowest scores in the subscale “rehabilitation program” of the evaluation questionnaire for the statements: “The rehabilitation program is
effective for improving my walking pattern” and “The level of the exercises was adapted to my possibilities”. Seven patients mentioned that the program duration was a bit too long. Six of these patients started working again after 6 to 8 weeks postoperatively. It appears difficult to combine the program with work, even though patients could choose for themselves the time of day to exercise. A recommended adjustment is a more individualized program with additional exercise diversity and when necessary extra support, possibly in the form of a home visit, to improve the walking pattern. Another recommendation is adjusting the duration of the program to patients’ goal achievement.

Patients were positive about the technology and gave an average score of 4.8 and 4.1 respectively (range 0-5) for use of the tablet and sensor. All patients used their own home Wi-Fi. Previous research of Geraedts et al. (2017) reported that adherence to their home-based exercise program and dropping out were strongly influenced by the stability of the mobile internet connection [18]. Based on our study and that of Geraerdts et al. (2017), it can be concluded that Wi-Fi is preferred over mobile internet connection. All patients had previous computer experience and most patients owned a smartphone. The present study shows that it is feasible for this patient group to use novel technology in a home-based rehabilitation program.

The study of Austin et al. (2017) provided support for unsupervised home exercise as an effective rehabilitation strategy for most THA patients and its cost effectiveness as compared to formal physiotherapy. The study suggests that because of cost effectiveness, a home-based program should be used as a standard of routine care after THA. However, some patients may benefit more from formal physiotherapy, for instance some seniors or people with poor preoperative functional status. More research is needed to identify which patient populations benefit more from supervised rehabilitation.

A limitation of the study was the small number of patients, although this was a deliberate choice to test the feasibility of the program for the first time. In addition, patients who had agreed to participate in the study had some computer experience already and were probably more motivated than the average patient, which led to some bias. Nonetheless, the wide variety in educational level, age, and living and work situation seem to have provided a representative group.

Conclusion

A home-based rehabilitation program driven by a tablet application and mobility monitoring seems feasible for THA patients. Adherence to the program was good and patient experience was positive. The novel technology was accepted well. A home-based rehabilitation program could be an alternative to formal physiotherapy.
Acknowledgments

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Conflicts of interest
None declared.

Abbreviations
OA: osteoarthritis
THA: total hip arthroplasty

References


