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Viewpoint

Original Paper

Accuracy and Precision of Three Consumer-Grade Motion Sensors During Overground and Treadmill Walking in People With Parkinson Disease: Cross-Sectional Comparative Study

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Abstract

Background: Wearable motion sensors are gaining popularity for monitoring free-living physical activity among people with Parkinson disease (PD), but more evidence supporting the accuracy and precision of motion sensors for capturing step counts is required in people with PD.

Objective: This study aimed to examine the accuracy and precision of 3 common consumer-grade motion sensors for measuring actual steps taken during prolonged periods of overground and treadmill walking in people with PD.

Methods: A total of 31 ambulatory participants with PD underwent 6-min bouts of overground and treadmill walking at a comfortable speed. Participants wore 3 devices (Garmin Vivosmart 3, Fitbit One, and Fitbit Charge 2 HR), and a single researcher manually counted the actual steps taken. Accuracy and precision were based on absolute and relative metrics, including intraclass correlation coefficients (ICCs) and Bland-Altman plots.

Results: Participants walked 628 steps over ground based on manual counting, and Garmin Vivosmart, Fitbit One, and Fitbit Charge 2 HR devices had absolute (relative) error values of 6 (6/628, 1.0%), 8 (8/628, 1.3%), and 30 (30/628, 4.8%) steps, respectively. ICC values demonstrated excellent agreement between manually counted steps and steps counted by both Garmin Vivosmart (0.97) and Fitbit One (0.98) but poor agreement for Fitbit Charge 2 HR (0.47). The absolute (relative) precision values for Garmin Vivosmart, Fitbit One, and Fitbit Charge 2 HR were 11.1 (11.1/625, 1.8%), 14.7 (14.7/620, 2.4%), and 74.4 (74.4/598, 12.4%) steps, respectively. ICC confidence intervals demonstrated low variability for Garmin Vivosmart (0.96 to 0.99) and Fitbit One (0.93 to 0.99) but high variability for Fitbit Charge 2 HR (–0.57 to 0.74). The Fitbit One device maintained high accuracy and precision values for treadmill walking, but both Garmin Vivosmart and Fitbit Charge 2 HR (the wrist-worn devices) had worse accuracy and precision for treadmill walking.

Conclusions: The waist-worn sensor (Fitbit One) was accurate and precise in measuring steps with overground and treadmill walking. The wrist-worn sensors were accurate and precise only during overground walking. Similar research should inform the application of these devices in clinical research and practice involving patients with PD.

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KEYWORDS

wearable electronic devices; wearable; fitness tracker; accelerometer; reproducibility; Parkinson disease; disabled persons; exercise

Introduction

Background

Wearable motion sensors have been applied for monitoring and promoting free-living ambulatory physical activity based on the outcome of steps taken per unit time among people with Parkinson disease (PD) [1]. Such applications, nevertheless, require evidence supporting the accuracy and precision of the motion sensors for capturing actual steps taken as a metric of ambulation.

We located 2 studies that have examined the accuracy and precision of motion sensors for capturing steps during relatively short 2-min periods of overground walking in patients with PD [2,3]. Assessment during such a short bout of walking does not provide an accurate and precise measurement associated with the energy systems required for free-living, ambulatory physical activity in neurological diseases [4]. The study of motion sensor precision, in particular, requires longer bouts of walking, as step count recordings from motion sensors can be compromised over time by subtle gait disturbances [5] brought about by energetic fatigue that may occur in PD and other neurological diseases. Furthermore, there is a need to determine the accuracy and precision of motion sensors during treadmill walking, as this modality is often prescribed for gait training and physical activity in PD.

Objectives

This study examined the accuracy and precision of 3 common motion sensors (Garmin Vivosmart 3, Fitbit One, and Fitbit Charge 2 HR) for measuring actual steps taken during longer periods of overground and treadmill walking in people with PD.

Methods

Participants

Community-dwelling participants were recruited from local clinics, support groups, and community events. Inclusion criteria were (1) neurologist-confirmed diagnosis of idiopathic PD (presence of bradykinesia plus rigidity and resting tremor), (2) age between 50 and 74 years, (3) physically independent with bilateral symptoms indicative of a Hoehn and Yahr stage 2 or 3 (mild-to-moderate disability) that was confirmed by a neurologist and self-reported by the participant, and (4) ability to walk for 6 min (without an assistive device). Exclusion criteria were (1) motor symptoms because of neuroleptic medication or a stroke, (2) any condition that prevented the participant from being able to follow the protocol or participate safely, and (3) not responsive to dopaminergic medications. Written informed consent was obtained from all participants, and the University Institutional Review Board approved the protocol. The study was conducted in accordance with the principles of ethical human research as defined in the Declaration of Helsinki.

Motion Sensors

We examined the accuracy of 3 consumer-grade motion sensors: Garmin Vivosmart 3 (Garmin), Fitbit One (Fitbit Inc), and Fitbit Charge 2 HR (Fitbit Inc). The devices were worn on the less affected side: the 2 wrist-worn devices (Garmin Vivosmart 3 and Fitbit Charge 2 HR) on the less affected arm and the waist-worn sensor (Fitbit One) on the side of the less affected leg. We chose these monitors based on popularity, availability, and application in the general adult population [5] and people with neurological diseases [6], although Fitbit One is now no longer commercially available.

Overground Protocol

Participants completed one 6-min bout of overground walking around an indoor, oval track marked with cones. Participants were instructed to walk at a comfortable walking speed (CWS) that resembled walking speed undertaken during normal daily activities. The single speed was chosen because people with PD typically reach an average of 64% of peak oxygen consumption while walking at a self-selected treadmill speed and might undergo this speed for treadmill training [7]. Research staff recorded the step count values from the motion sensors immediately before and after the walking bout. One researcher manually recorded the steps taken using a handheld tally counter (ie, direct observation as a gold standard). This researcher underwent 3 months of training for proficiency with a high degree of accuracy, and this was the researcher’s only responsibility during the walking trials. Furthermore, we noted that this training and procedure produces accurate data in our laboratory and focused on participant safety during the study with a minimal amount of study staff available during a test session. The distance participants walked was recorded for determining the CWS for the subsequent treadmill protocol.

Treadmill Protocol

Participants undertook 6 min of walking on a motor-driven treadmill (Trackmaster TMX428, Full Vision). The speed was determined as the CWS from the overground trial. We selected this speed for comparability of accuracy and precision with the overground bout of walking and further recognize that the metabolic demand of CWS corresponds with an intensity of 64% of peak oxygen consumption and is consistent with training zones recommended for PD [7]. The protocols for recording manually counted and device-recorded steps matched the overground protocol.

Procedure

Participants completed the study in a single visit. Participants provided demographic, anthropometric, and clinical information and then completed the Physical Activity Readiness Questionnaire for identifying contraindications for engaging in physical activity. The stage of PD was measured by using the Hoehn and Yahr scale. Motor symptoms were captured via the Movement Disorder Society version of the Motor Examination of the Unified Parkinson’s Disease Rating Scale (MDS-UPDRS-III); both were administered by 2 research staff who completed the MDS-UPDRS training. This was followed by the overground and then treadmill bouts of walking; there was 5 min of rest between bouts. Participants were compensated US $25 upon completing the study.

Data Analysis

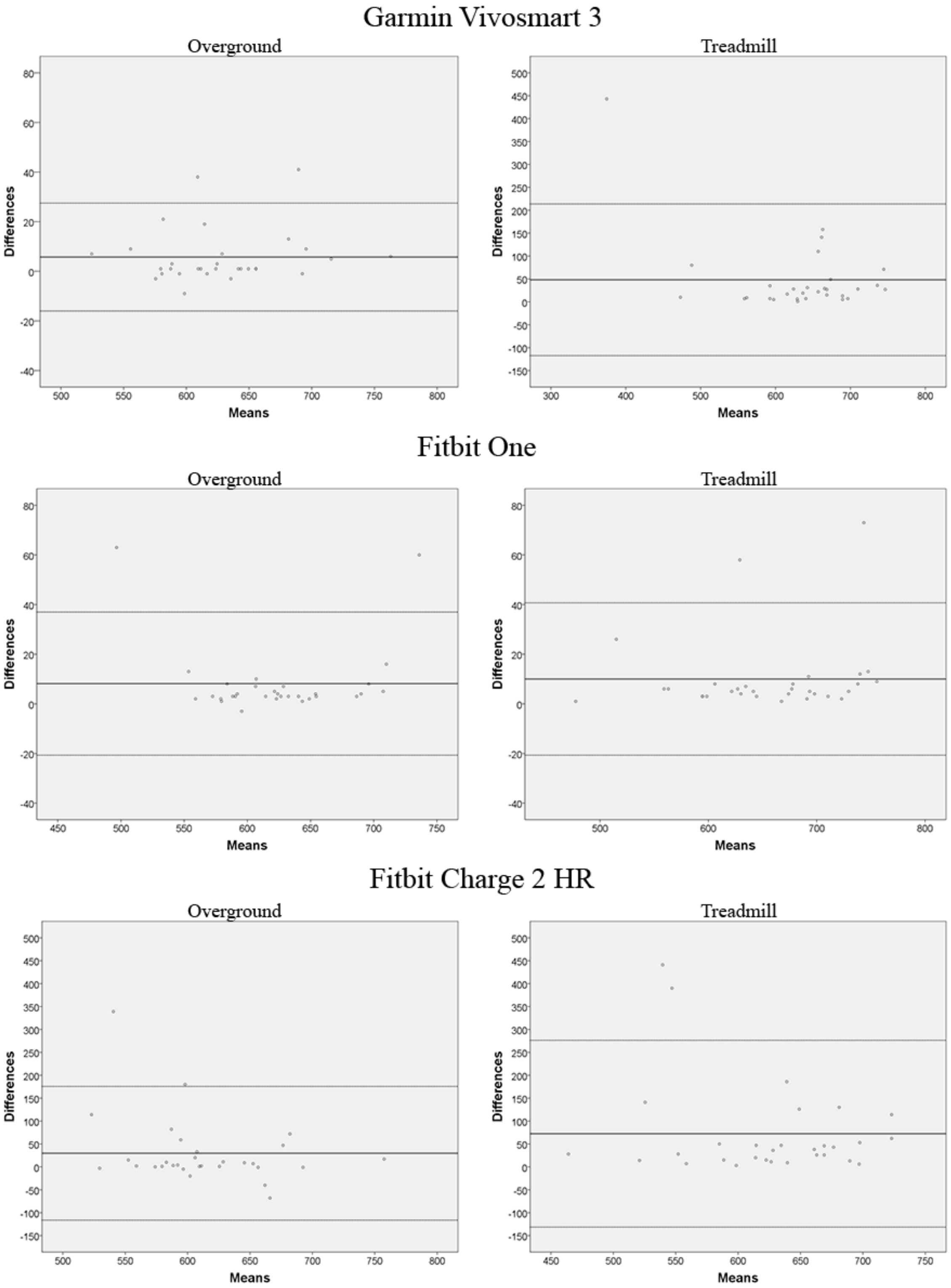
Accuracy and precision were based on absolute and relative metrics [6], including intraclass correlation coefficients

(ICCs2,1) and Bland-Altman plots. Absolute accuracy was measured by the mean difference between device and manually recorded steps. Metrics for relative accuracy included (1) mean percentage error, (2) frequency of large errors, and (3) ICCs using IBM SPSS Statistics version 24 (IBM Corp). The mean percentage error was expressed as the difference between actual (manually counted steps) and observed steps, divided by the actual steps, and multiplied by 100. The frequency of cases for errors was categorized into 1 of 3 categories per device: ≥5%, ≥10%, and ≥25% [6]. The ICCs demonstrated the degree of agreement between manual and device-recorded steps. ICC values were interpreted as follows: less than 0.5=poor, 0.5 to 0.75=moderate, 0.75 to 0.9=good, and greater than 0.9=excellent agreement [8].

Absolute precision was based on the standard deviation of the mean difference between device and manually recorded steps. Relative precision was expressed as the coefficient of variation between device and manually recorded steps and ICC confidence intervals (the strength of agreement between manual and device-recorded steps over repeated measures).

Bland-Altman plots were produced as visual representations of accuracy and precision. Bland-Altman plots represent the difference between manually recorded steps and device-recorded steps against the mean of the 2 methods. As presented in Figure 1, the solid line represents the mean difference between manually counted steps and those obtained from the device (absolute accuracy). The limits of agreement were set at 95%, as represented by the 2 dotted lines (relative precision).

Figure 1. Bland-Altman plots for each motion sensor and walking condition.



Results

Participants

We contacted and screened 71 potential participants, and 38 of them satisfied eligibility criteria. Of those persons, 31 enrolled in and completed the study and were included for analysis; 7 persons declined the invitation for participation. The characteristics of the participants are presented in Table 1. The mean age of diagnosis and representation of males and females were comparable with US prevalence estimates [9]. Moreover, 26 participants had a Hoehn and Yahr score of 2, and 5 participants had a Hoehn and Yahr score of 3. In addition, 16 participants had gait impairments (9=slight and 7=mild), 13 participants had postural deviations (10=mild and 3=moderate), 8 participants had slight freezing of gait (this did not occur during either the overground or treadmill walking trials), and 1 participant had only minor bilateral gait impairment.

Table 1. Demographic and clinical characteristics (n=31).

Characteristics	Mean (SD)	Range
Age (years)	64.3 (6.3)	53-74
Height (cm)	170.3 (8.6)	155-188
Weight (kg)	79.7 (16.5)	54.8-121.5
Body mass index (kg/m^2)	27.5 (4.9)	18.2-38.8
Years postdiagnosis	6.5 (5.2)	1-23
Movement Disorder Society version of the Motor Examination of the Unified Parkinson’s Disease Rating Scale	24 (1)	1-71
Walking speed (m/s)	1.05 (0.16)	0.6-1.3

Data collection was conducted between March 2018 and October 2018. Data from all 31 participants were analyzed, except for 2 trials where a device error occurred. There were no steps recorded in 1 case likely caused by Wi-Fi internet instability while syncing the device with the Android tablet, and the other case resulted from a device that had insufficient battery power.

Accuracy

The absolute and relative metrics of accuracy per device and walking condition are presented in Table 2. Participants walked 628 steps overground based on manual counting, and the devices, Garmin Vivosmart, Fitbit One, and Fitbit Charge 2 HR, deviated from this manually counted value (absolute [relative] error values) by 6 (6/628, 1.0%), 8 (8/628, 1.3%), and 30 (30/628, 4.8%) steps, respectively. These values are visually represented by Bland-Altman plots in Figure 1. There were few cases of larger errors during overground walking for Garmin Vivosmart and Fitbit One, but Fitbit Charge 2 HR had more cases of larger errors (18/30, 60%). ICC values demonstrated excellent agreement between manually counted steps and both Garmin Vivosmart and Fitbit One but poor agreement for Fitbit Charge 2 HR.

Participants walked 660 steps on the treadmill based on manual counting, and the devices, Garmin Vivosmart, Fitbit One, and Fitbit Charge 2 HR, deviated from this value by 48 (48/660, 7.3%), 10 (10/660, 1.5%), and 72 (72/660, 10.9%) steps, respectively. Fitbit One had fewer cases of larger errors compared with Garmin Vivosmart and Fitbit Charge 2 HR. ICC values indicated that Garmin Vivosmart had moderate agreement, Fitbit One had excellent agreement, and Fitbit Charge 2 HR had poor agreement with manually recorded steps.

Table 2. Accuracy of motion sensors while walking at a comfortable speed.

Condition [actual steps, mean (95% CI)] and device	Absolute accuracy		Relative accuracy				
	Mean steps recorded (95% CI)	Mean difference in steps	Percentage error	n≥5% error	n≥10% error	n≥25% error	Intraclass correlation coefficient (2, 1)
Overground, 628 (609-647)							
Garmin Vivosmart 3 (n=30)	625 (606-644)	6	0.9	2	0	0	0.97
Fitbit One (n=31)	620 (600-639)	8	1.3	2	1	0	0.98
Fitbit Charge 2 HR (n=30)	598 (570-625)	30	4.4	10	6	2	0.47
Treadmill, 660 (633-686)							
Garmin Vivosmart 3 (n=30)	609 (568-649)	48	7.4	9	6	2	0.67
Fitbit One (n=31)	650 (624-675)	10	1.5	2	0	0	0.98
Fitbit Charge 2 HR (n=30)	587 (553-621)	72	10.3	16	7	3	0.27

Precision

The absolute and relative precision metrics per device and condition are provided in Table 3. With overground walking, the absolute and relative precision values (SD of mean difference [coefficient of variation]) for Garmin Vivosmart, Fitbit One, and Fitbit Charge 2 HR were 11.1 (11.1/625, 1.8%), 14.7 (14.7/620, 2.4%), and 74.4 (74.4/598, 12.4%), respectively. ICC confidence intervals for both Garmin Vivosmart and Fitbit One included narrow upper and lower limits that exceeded 0.9, indicating low variability and excellent agreement among most measures. Fitbit Charge 2 HR had higher variability with a confidence interval ranging from poor to moderate agreement.

Table 3. Precision of motion sensors while walking at a comfortable speed.

Condition [actual steps, mean (95% CI)] and devices	Absolute precision, mean difference SD	Relative precision	
		Coefficient of variation (%)	Intraclass correlation coefficient (2, 1) CI
Overground, 628 (609-647)			
Garmin Vivosmart 3 (n=30)	11.1	1.8	0.96 to 0.99
Fitbit One (n=31)	14.7	2.4	0.93 to 0.99
Fitbit Charge 2 HR (n=30)	74.4	12.4	–0.57 to 0.74
Treadmill, 660 (633-686)			
Garmin Vivosmart 3 (n=30)	84.5	13.9	0.27 to 0.85
Fitbit One (n=31)	15.7	2.4	0.93 to 0.99
Fitbit Charge 2 HR (n=30)	104	17.7	–0.26 to 0.61

Regarding treadmill walking, the absolute and relative precision values (SD of mean difference [coefficient of variation]) for Garmin Vivosmart, Fitbit One, and Fitbit Charge 2 HR were 84.5 (84.5/609, 13.9%), 15.7 (15.7/650, 2.4%), and 104 (104/587, 17.7%) steps, respectively. ICC confidence intervals demonstrated that Fitbit One had low variability and excellent agreement among most measures, whereas Garmin Vivosmart and Fitbit Charge 2 HR had higher variability as indicated by ICC confidence intervals of 0.27 to 0.85 and −0.26 to 0.61, respectively. This was supported by the Bland-Altman plots, demonstrating higher limits of agreement during treadmill walking compared with overground walking for both Garmin Vivosmart and Fitbit Charge 2 HR but not Fitbit One (Figure 1).

Discussion

Principal Findings

Study findings suggest that a waist-worn sensor (Fitbit One) can provide accurate and precise measurements of actual steps taken during overground or treadmill walking. These findings are consistent with previous treadmill walking research in the general adult population [10] and people with multiple sclerosis [6]. A waist-worn sensor, Fitbit One, can provide accurate and precise records of steps during both overground and treadmill walking. A wrist-worn sensor, Garmin Vivosmart 3, can provide accurate and precise records of step counts during overground walking in patients with PD but has noticeably worse estimates of step counts during treadmill walking. Fitbit Charge 2 HR provided poor estimates of step counts during both walking conditions.

The findings of this study suggest that wrist-worn devices provide noticeably worse measures of accuracy and precision during treadmill walking. One explanation for these findings is that 5 participants had difficulty with walking on a treadmill at a comfortable speed and intermittently used the handrails for support. After visual inspection of the outliers that were identified in the Bland-Altman plots during treadmill walking, 2 of the 3 largest errors in steps for both Garmin Vivosmart 3 and Fitbit Charge 2 HR were recorded in people who temporarily used handrails. Exclusion of these errors from the dataset would certainly lower the mean bias that was observed from the wrist-worn sensors, but this would not explain all the larger errors (>10% mean difference in steps) that were identified for each device. Handrail use was observed temporarily in 33% (2/6) of the larger errors recorded by Garmin Vivosmart 3 and 57% (4/7) of the larger errors recorded by Fitbit Charge 2 HR. No other observable trends were readily identified. Another possible explanation could be that waist-worn sensors are generally more accurate and precise than wrist-worn sensors [11].

Our results support and build on previous investigations of motion sensor accuracy and precision in PD. Regarding accuracy, mean percent errors and ICC values during overground walking for the Fitbit devices were similar with those reported of other Fitbit devices by Wendel et al (Fitbit Surge [wrist worn]: mean percent error=7.8 and ICC=0.38; Fitbit Zip [waist worn]: mean percent error=0.9 and ICC=0.98) [2]. Wendel et al [2] investigated the accuracy of 4 motion sensors (Fitbit Zip, Fitbit Surge, Jawbone Up Move, and Jawbone Up 2) for recording steps compared with manual counting, whereas people with PD underwent 4 trials of walking. Each trial lasted 2 min, and 1 trial was conducted at a CWS. The accuracy results of this study for Garmin Vivosmart 3 were also similar with those reported of Garmin Vivosmart HR by Lamont et al (mean percent error=2.7 and ICC=0.93) [3]. The researchers compared the accuracy of Fitbit Charge HR and Garmin Vivosmart for detecting steps from six 100-step walking trials at different cadences, and these readings were compared with those obtained from an accelerometer (ActivPAL3). However, Lamont et al [3] reported that a similar Fitbit motion sensor (Fitbit Charge HR) had an error rate of 2.8% and ICC of 0.88, which was lower than those reported in this study. A likely explanation for these findings is that participants with PD in this study had bilateral symptoms and a potentially higher amount of gait disturbances, which could have influenced step records over the longer 6-min walking period. Moreover, 44% of participants in the previous study were classified with a Hoehn and Yahr stage of 1, indicating unilateral symptoms [3].

Trends observed for accuracy were mirrored by results for precision. In this study, ICC confidence intervals (95%) for Fitbit Charge 2 HR and Garmin Vivosmart 3 were −0.57 to 0.74 and 0.96 to 0.99, respectively. These matched the ICC confidence intervals reported by Wendel et al [2] for Fitbit Surge and Zip (95% CI 0.06-0.64 and CI 0.96-0.99, respectively). Lamont et al [3] reported ICC confidence intervals for Fitbit Charge HR and Garmin Vivosmart HR of 0.76 to 0.94 and 0.85 to 0.97, respectively. Together, these findings demonstrate that motion sensors, particularly waist-worn devices, can be used to accurately and precisely record steps during overground walking. However, deviations in accuracy and precision may be influenced by PD-related symptoms or gait disturbances.

Our results further support the use of Fitbit and Garmin motion sensors for detecting steps at a CWS and provide evidence demonstrating the usefulness of these devices in the context of the treadmill and longer walking bouts. The examination of a 6-min walking bout is important, as the first 2 to 3 min of walking typically reflects a mixture of anaerobic and aerobic metabolic processes, and the metabolic processes after this period represent aerobic work (ie, the participant has achieved steady state). This may better reflect prolonged walking in daily life as evidenced in other neurological diseases, such as multiple sclerosis [4]. Moreover, the findings of this study further support the use of hip-worn sensors as reported by Wendel et al [2]. This is critical because the commercial availability of waist-worn motion sensors is now rather limited (Fitbit has even discontinued production of Fitbit One), whereas wrist-worn sensors have surged in popularity over recent years.

In summary, there are studies that support the use of a variety of consumer motion sensors for detecting steps in PD. On the basis of the findings of this study and those reported previously [2,3], waist-worn and certain wrist-worn motion sensors can provide accurate and precise records of steps during overground walking. Nevertheless, people with PD might undertake treadmill walking for home-based physical activity, and handrail use is common. These results suggest that the wrist-worn devices would not be ideal for self-monitoring physical activity in this context.

Study Limitations

Walking was performed under controlled conditions that may not resemble real-world factors that can influence walking, such as the terrain, obstacles, and weather. This study examined single bouts of overground and treadmill walking at a CWS versus examining step counts at various speeds (eg, slow, normal, and fast). Actual steps were manually counted by only 1 research staff member, and this might have introduced error into the gold standard measure of steps taken. Participants were ambulatory and physically independent. The findings may not be generalizable to people with PD at higher disability levels who have balance deficits and/or use assistive devices, such as canes and walkers.

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Conflicts of Interest

None declared.

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Abbreviations

CWS: comfortable walking speed
ICC: intraclass correlation coefficient
MDS-UPDRS: Movement Disorder Society version of the Unified Parkinson’s Disease Rating Scale
NIH: National Institutes of Health
PD: Parkinson disease

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Original Paper

The Practical Work of Ensuring the Effective Use of Serious Games in a Rehabilitation Clinic: Qualitative Study

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Abstract

Background: Many rehabilitation clinics adopted serious games to support their physiotherapy sessions. Serious games can monitor and provide feedback on exercises and are expected to improve therapy and help professionals deal with more patients. However, there is little understanding of the impacts of serious games on the actual work of physiotherapists.

Objective: This study aimed to understand the impact of an electromyography-based serious game on the practical work of physiotherapists.

Methods: This study used observation sessions in an outpatient rehabilitation clinic that recently started using a serious game based on electromyography sensors. In total, 44 observation sessions were performed, involving 3 physiotherapists and 22 patients. Observation sessions were documented by audio recordings or fieldnotes and were analyzed for themes using thematic analysis.

Results: The findings of this study showed that physiotherapists played an important role in enabling the serious game to work. Physiotherapists briefed patients, calibrated the system, prescribed exercises, and supported patients while they played the serious game, all of which amounted to relevant labor.

Conclusions: The results of this work challenge the idea that serious games reduce the work of physiotherapists and call for an overall analysis of the different impacts a serious game can have. Adopting a serious game that creates more work can be entirely acceptable, provided the clinical outcomes or other advantages enabled by the serious game are strong; however, those impacts will have to be assessed on a case-by-case basis. Moreover, this work motivates the technology development community to better investigate physiotherapists and their context, offering implications for technology design.

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KEYWORDS

serious games; exergames; physiotherapy rehabilitation; practical rehabilitation work; qualitative research

Introduction

Motivation and Overview

Demographic changes in the last few decades have been challenging physiotherapists and health care institutions in Western countries. As people age, they are more prone to falls, strokes, and cardiac diseases [1], all of which can trigger the need for physical rehabilitation and add pressure on rehabilitation clinics to deal with more patients. In the context of full-service clinics and multitasking professionals, serious games for physical rehabilitation were seen as a way to improve therapy and help physiotherapists deal with an increasing number of patients.

Serious games are game systems with nonentertainment purposes [2] that can be used to support or motivate activities, in this case, physical rehabilitation. Serious games are not new in the rehabilitation context and have been developed to (1) increase therapy dosage [3-5], (2) engage patients in activities that motivate them to persist in therapy [6-8], or (3) enable correct exercise performance at home [4,9,10]. Reading the literature on serious games for rehabilitation, we get the idea that physiotherapists would be lightly involved if at all in serious games [10,11] and that they would even be free to attend more patients [12,13]. In this vision, the therapist would still “attach the technology to the patient, and/or to operate the technology” [11], but serious games would continue the therapeutic intervention from there.

The vision that serious games would not require physiotherapists or even remove work from these therapists seemed to be too idealistic. We know from other health care settings that technology does not usually remove work but rather redistributes and reshapes existing activities [14]. Thus, we were curious to understand how the work of physiotherapists was impacted with the introduction of serious games.

This paper describes how physiotherapists set up and accompany the execution of a serious game based on electromyography sensors. Drawing on insights from 44 observation sessions conducted in an outpatient rehabilitation clinic, we argue that physiotherapists who used the serious game performed numerous activities that amounted to relevant work.

The contribution of this paper is two-fold. First, it presents an ethnographic description of the work of physiotherapists in setting up and supporting the execution of a serious game in a rehabilitation clinic, which shows labor and an active role from these professionals. Second, the paper offers design implications that follow from recognizing the work of physiotherapists in supporting serious games. We expect to inspire the technology development community to better account for the role and work of physiotherapists when designing serious games for rehabilitation. Moreover, we try to ensure physiotherapy professionals are aware that serious games can require an active role from them to achieve the promised benefits to engagement or intervention efficacy.

Background

The literature on serious games for rehabilitation, which includes exergames, virtual reality, or interactive video games, has been growing in the past years [15]. We know as a community that serious games can help treat conditions such as Parkinson disease [10,16] and stroke [17,18] and help improve balance or exercise for different patients [19,20]. Most publications on serious games have focused on designing or initially assessing the impact of serious games [15]. As serious games aimed to support therapy, many studies focused on assessing medical outcomes and the quality of the exercise performed with the technological systems [16,17,20]. Qualitative studies tended to focus on the experiences of patients using serious games in controlled settings or at home [10,19,21].

The experiences of physiotherapists with serious games received little attention. The few studies that assessed the experience of therapists with serious games in clinics mention that they play a role in setting up [22,23], training [24], providing feedback or assistance during the games [24], and cleaning up or maintaining systems [22]. Although these activities are mentioned in some studies, there is little detail about what physiotherapists actually do and the impact it has on their overall work. This is especially concerning because according to Markus et al [22], who timed different activities of physiotherapists in setting up and playing serious games in a burn care unit, playing the game accounted for solely 22% of the time of the therapists, whereas setting up, training, cleaning, and maintaining the system occupied the remaining time.

The role of therapists in serious games for home rehabilitation is also rarely discussed. Some papers mention that physiotherapists are involved in setting up the game [25] or instructing patients to perform the game [4], but most papers we find seem to expect a reduced role from physiotherapists [10,16,21]. Although the patient can be instructed and monitored by a serious game, the initial diagnosis and follow-up assessments are most likely performed by a physiotherapist. Thus, we believe that the work of physiotherapists in this setting is somehow unacknowledged or hidden.

Although prior work evaluating serious games paid little attention to the work and role of physiotherapists, studies discussing the perspectives of physiotherapists on these interventions painted a different picture. Drawing on focus groups or workshops with physiotherapists, different studies argue that therapists would likely be required to set up the system for patients, which was a concern as therapists are often overloaded with different activities [26,27]. The same studies concluded that therapists would need to reserve time to learn to use a serious game and test on themselves, to know how to orient patients in clinical practice. Moreover, studies point to the expectation of having therapists involved in personalizing exercise for the patients [3,8,27]. According to these works, therapists would be the ones choosing exercises, difficulty, and tools that better fit the characteristics and interests of the patients.

On the whole, there is a reduced understanding of the role and work of physiotherapists in enabling serious games. Although some studies mentioned that therapists were involved in activities, what therapists did is mostly hidden. This paper will help address this issue by discussing the practices of physiotherapists in enabling serious games.

Methods

Overview

To understand how physiotherapists set up and use a serious game in their clinical practice, we observed physiotherapy sessions in an outpatient rehabilitation clinic. The observation was conducted by the first author, who ranged from being a spectator not intervening during physiotherapy sessions with patients to actively inquiring patients and therapists once the rehabilitation session was finished. The observation took place in the clinic’s gymnasium, where 2 to 3 physiotherapists care for a set of patients at the same time. The gymnasium was well equipped for supporting physiotherapy sessions, including examination beds, Pilates balls, treadmills, weights, and computers, in addition to the serious game we were studying. The outpatient rehabilitation clinic was part of a large public rehabilitation center located in the north of Portugal.

The initial goal of the observation was to understand how patients, carers, and therapists used the serious game in clinical practice, but as the study advanced, we started focusing on the practical work that was required to make the system work. As part of the fieldwork, we also conducted interviews with patients to understand their experience with the serious game, but that is out of the scope of this paper.

In total, 44 observation sessions were performed with 22 patients and 3 physiotherapists. The physiotherapists, 1 male and 2 females, had a Master’s degree in Physiotherapy and 11 to 15 years of experience in rehabilitation (see Table 1). None of the physiotherapists had experience with electromyography- or sensor-based interventions before experiencing eleRehab; however, they had used the Wii Fit with some patients in the past. With regard to technology use, all physiotherapists had smartphones, and there were computers in the gym to support some interventions, so we are led to believe that the physiotherapists were receptive to using digital technologies in their personal and professional lives. Before using the system in clinical practice, the 3 physiotherapists received multiple sessions of professional training from a physiotherapist experienced in using eleRehab who worked for the company that developed a part of eleRehab. When we observed the physiotherapists, they were already able to use the system in clinical practice.

The recruitment of the patients was performed by their physiotherapist, taking into consideration the characteristics of the patient, their ongoing intervention plan, and the fit of the system to the rehabilitation plan. There were 12 male and 10 female participants. No participant had university training, some had high school diplomas, and others only attended primary school education. Their ages ranged from 21 to 58 years, and they were doing physical rehabilitation to recover functionality and return to their work and everyday lives (see Table 2). The patients neither had experience with electromyography games nor usually played games regularly in their free time. Most patients had smartphones, but participants were not heavy technology users, restricting their use to a small number of apps.

We conducted a total of 44 observation sessions. The first 20 observation sessions were audio recorded to enable detailed analysis. After 20 sessions, we achieved meaning saturation [28] but continued observation sessions, making fieldnotes to comply with project objectives. The sessions with eleRehab lasted between 60 and 90 min (average 78 min), and we recorded a total of 26 hours of audio recordings. Audio recordings were transcribed verbatim, enriched with fieldnotes, and coded for themes using thematic analysis [29]. We tried to remain as open as possible to the themes that were salient in the data and, thus, coded the different observation sessions iteratively. Moreover, we leveraged constant comparison [30] to advance the analysis, making use of the differences between observation instances, patients, and physiotherapists. The Scrivener writing software (Literature & Latte) supported the coding process.

Regarding ethics, we obtained written informed consent from all physiotherapists and patient participants. In each case, we started by presenting the researchers involved, the project and its goals, and the reasons for the observation. We cleared any doubts the participants could have, and only then did the participants sign the informed consent form.

Table 1. Characteristics of physiotherapists.

Physiotherapist	Age (years)	Gender	Work experience (years)	Experience with electromyography
Physiotherapist 1	34	Female	11	None
Physiotherapist 2	33	Male	11	None
Physiotherapist 3	36	Female	15	None

Table 2. Characteristics of patients involved.

Patient	Age (years)	Gender	Rehabilitation trigger	First session	Second session
Patient 1	47	Male	Myocardial infarction	Physiotherapist 1	Physiotherapist 2
Patient 2	20	Female	Spina bifida	Physiotherapist 1 and Physiotherapist 2	Physiotherapist 3
Patient 3	28	Male	Stroke	Physiotherapist 2	Physiotherapist 1
Patient 4	58	Male	Stroke	Physiotherapist 2	Physiotherapist 2
Patient 5	44	Female	Poliomyelitis and sciatica	Physiotherapist 1	Physiotherapist 1
Patient 6	35	Female	Stroke	Physiotherapist 2	Physiotherapist 3
Patient 7	56	Female	Head trauma	Physiotherapist 1 and Physiotherapist 2	Physiotherapist 3
Patient 8	42	Male	Stroke	Physiotherapist 1 and Physiotherapist 2	Physiotherapist 3
Patient 9	32	Female	—[a]	Physiotherapist 2	Physiotherapist 3
Patient 10	55	Male	Shoulder prosthetics	Physiotherapist 2	Physiotherapist 3
Patient 11	49	Female	Cervical prosthesis	Physiotherapist 1	Physiotherapist 2
Patient 12	37	Male	Dilated cardiomyopathy	Physiotherapist 1	Physiotherapist 2
Patient 13	49	Female	Breast cancer	Physiotherapist 1	Physiotherapist 2 and Physiotherapist 3
Patient 14	44	Male	Head trauma	Physiotherapist 1	Physiotherapist 2
Patient 15	40	Female	Breast cancer	Physiotherapist 1	Physiotherapist 2
Patient 16	47	Female	Spinal cord injury	Physiotherapist 2	Physiotherapist 2 and Physiotherapist 3
Patient 17	42	Male	Head trauma	Physiotherapist 2	Physiotherapist 2
Patient 18	44	Male	Cerebral angioma	Physiotherapist 2	Physiotherapist 2
Patient 19	51	Male	Stroke	Physiotherapist 3	Physiotherapist 3
Patient 20	47	Male	Cerebral angioma	Physiotherapist 3	Physiotherapist 3
Patient 21	29	Male	Head trauma	Physiotherapist 3	Physiotherapist 2
Patient 22	36	Female	Head trauma	Physiotherapist 3	Physiotherapist 2

[a] Missing data.

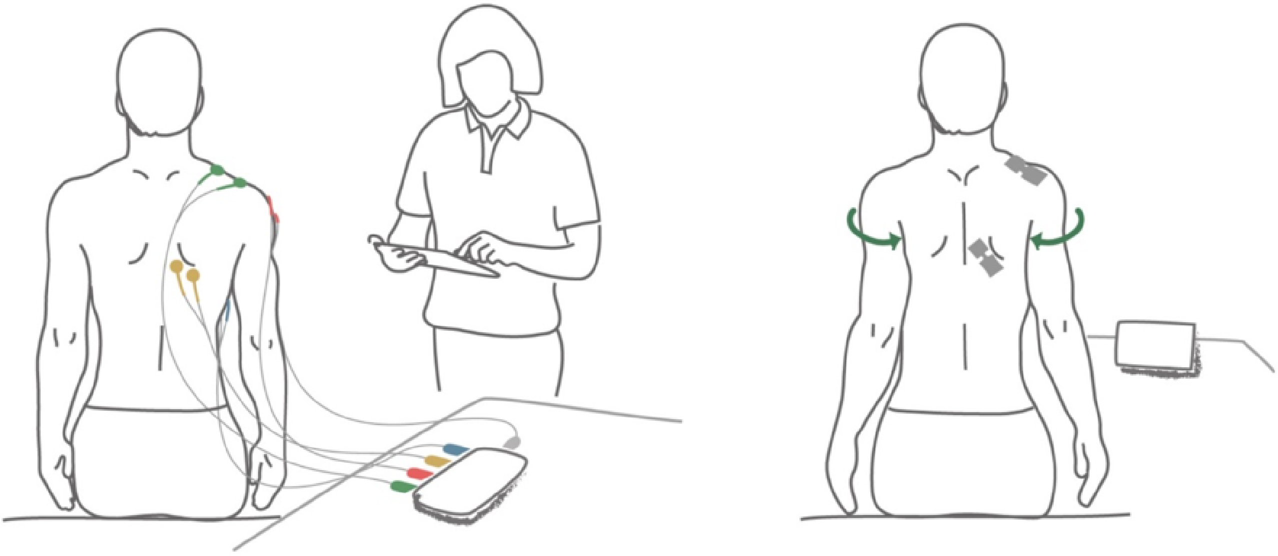
The eleRehab System

The serious game we studied in the clinic, here named eleRehab, was targeted at the rehabilitation of muscles from the shoulder. Patients wore two sensors in the back and performed exercises in front of a smartphone, where a game was displayed. The games had elevating platforms, labyrinths, and opening gates, which *forced* patients to perform contractions and relaxations of their muscles for a certain period. In terms of environment requirements, the game was expected to be played in a well-lit room because of the small form factor of the smartphone screen, but there were no requirements regarding ambient noise, as the game featured no sound effects or music.

Physiotherapists had separate sensors for calibrating the system to the patient, the calibration octopus, and a tablet device for prescribing the number of series and exercises for each patient. The calibration octopus is named this way because it has 4 cables that divide into 8 electrical leads (see left part of Figure 1). Communication between sensors and tablet/smartphone is performed using Bluetooth, and the electronic prescriptions of exercises were stored in the cloud. In a typical usage of the eleRehab, physiotherapists calibrated the system for a specific patient using the calibration octopus and prescribed exercises with their tablet. Only after this, would they attach sensors to the back of the patient and have them play the serious game (see right part of Figure 1).

eleRehab explores electromyography or the measurement of electric current from the muscles. Each time we move our muscles, we send an electric charge from the brain to the muscle, and the current is stronger when we apply more strength to an exercise. The difference in current measured at a particular muscle enables eleRehab to know when the person is flexing or relaxing the muscle, and in this way, the system can monitor and provide feedback on the execution of exercises to the patient.

Figure 1. The eleRehab system. Left figure shows a physiotherapist calibrating the system for the patient using the calibration octopus and a tablet. Right figure shows the patient wearing sensors on the back and playing the game on the smartphone.



Most components of the system were developed by a medical device company that creates sensor-based tools for physiotherapy clinics. The game itself was designed by a team at Fraunhofer Portugal AICOS, of which the authors are part of. The development of the system followed a user-centered design approach with multiple phases of design, usability testing, and pilots. The results presented in this paper refer solely to the evaluation of the overall system in the clinic.

Results

The fieldwork presented here describes the practical work required to set up and play eleRehab in a rehabilitation clinic. We describe four main themes or activities, namely, briefing the patient, calibrating the system, prescribing exercises, and playing the serious game.

Briefing the Patient

The physiotherapy sessions with the serious game started with the therapist explaining the treatment procedure to the patient. Therapists explained to patients that they would perform exercises using a serious game and that the session would have two parts. First, therapists would connect and calibrate sensors to personalize the game for the patient. Second, the patient would play the game while performing specific exercises. Therapists explained that the system could sense when their muscles contracted and relaxed and would use this information to control the game. However, it needed to be personalized to each person’s body and thus required calibration. The therapists also mentioned that the game would improve the mobility, strength, or coordination, depending on the issue they were treating and the patient’s case. As the system targeted shoulder rehabilitation, therapists politely asked the patient to undress the upper part of their body, as they would need to connect the calibration octopus sensors shortly after. The goal of briefing the patient was two-fold. The therapists wanted to explain the procedure to the patients so that they would be informed and feel in control of what was happening at the clinic. At the same time, the therapists felt that they had to explain the system to the patients to obtain an appropriate performance, as patients would better engage with the game if they understood how it worked and how to perform at their best.

Calibrating the System

Calibrating sensors is a complex activity that is composed of several steps. The physiotherapist starts by creating a profile for the patient on their tablet. Therapists enter the name, email, and weight of the patient, and they signal the shoulder to be treated next. After creating an account, the profile is listed in the tablet app, and therapists can choose it when starting a rehabilitation session. In any case, physiotherapists usually went over the information of the patient’s profile to confirm it was updated.

The second step of calibration is to attach the calibration octopus sensors to the patient (left part of Figure 1). To do so, physiotherapists locate each muscle, attach 2 disposable electrodes to it, and connect 2 leads from the calibration octopus to the electrodes of the patient. Connecting the leads to the patient requires palpation and sometimes asking the patient to perform movements that *reveal* the muscle. This process can take some time when muscles are under adipose tissue or when they have irregular electric responses because of the lesion of the patient. eleRehab requires leads to be placed in the lower trapezius, upper trapezius, anterior deltoid, and anterior serratus. After attaching the leads to each muscle, the last one called *earth* lead is connected to the clavicle of the patient. The placement of the leads is performed with the aid of the tablet because they are numbered from 1 to 4, and each number is related to a specific muscle. Through the app, the physiotherapist knows to which muscle each number belongs. Moreover, the placement of the leads in each muscle needs to be within a fixed distance. When playing the game, patients will wear a sensor that has a fixed length, and if the leads of the calibration octopus are not distanced similarly, problems may arise during game execution. For this reason, physiotherapists place the leads of the calibration octopus in the muscle, at a distance that is the same as the distance they will have in the patients' sensors (right image in Figure 1).

After connecting the calibration octopus, the physiotherapist is ready to measure the electric response of the muscles. Physiotherapists first measure the electric response of the muscles while performing specific exercises and then add resistance to capture the maximum electric response of the muscles. The patients performed three exercises: frontal arm extension, lateral arm extension, and diagonal arm extension. The physiotherapist explains and exemplifies each exercise and instructs the tablet app when to start collecting data. The app makes a sound to notify both the physiotherapist and the patient to start the exercise movement and, after that, collects data about the muscle's electric response. The measurement of electric response is repeated when therapists believe the exercise was not correctly executed. During the first time therapists used eleRehab, they asked patients to repeat exercises multiple times to compare the electrical response of different trials. However, as they gained confidence that repeated measures yield similar values, therapists stopped asking patients to repeat exercises.

The muscle acquisition with resistance follows. This time, the physiotherapist asks patients to repeat the 3-arm extensions mentioned above, but this time, they apply force contrary to the movement of the patient. The goal of this collection is to find the maximum contraction values for each muscle, so therapists can prescribe exercises that are appropriate to the patient's muscles.

Having performed the above-mentioned steps, the system is calibrated for that specific patient. The calibration process might be required some days later, as the maximum electric response of the muscles may change, aligned with one's rehabilitation.

Prescribing Exercises

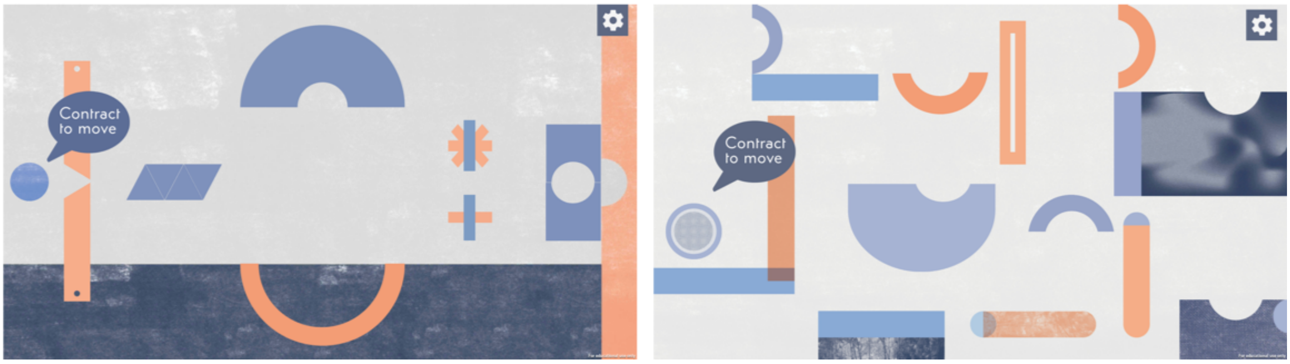
Once the system is calibrated, physiotherapists can prescribe exercises for a patient. Physiotherapists first choose an exercise from a list and then ask patients to perform the exercise to personalize its characteristics. Although patients perform an exercise, therapists observe the contraction and relaxation values of the involved muscles and define upper and lower thresholds for exercises. For example, in an exercise where the patient pulls the shoulders back, as in the left image of Figure 2, patients will contract the lower trapezius and relax the upper trapezius and will have upper and lower thresholds to know when the muscle is contracted or relaxed. During the serious game execution, the person will be able to advance the game when their lower trapezius is above a particular threshold value and when their upper trapezius is below a particular threshold value. Thus, it is crucial that the values are appropriate for the patient. Moreover, and as mentioned before, thresholds may need to be updated as patients advance in their rehabilitation process.

After choosing thresholds, physiotherapists assess if they are appropriate for the patient. To do so, they ask the patient to perform an exercise for 10 seconds. If they are able to keep the muscles contracted/relaxed over/under a certain threshold, thresholds are appropriate. If patients cannot keep the exercise, the physiotherapist may ask the patient to repeat the exercise or adjust the thresholds. The idea is that the exercises slightly challenge patients, but they cannot become overexerted with effort as that can be detrimental to the rehabilitation.

The tablet app of the physiotherapist plays an essential role in adjusting thresholds. Each muscle has a bar that is updated in real time in the tablet app to reflect the increase or decrease of the electric response of the muscle. Moreover, the bar is green when the execution is under/over the expected threshold and red when that is not the case. Although the tablet app was thought as an assistant to the physiotherapist, it is often shown to the patient to improve the execution of the exercise (see Figure 2). Physiotherapists give tips to improve the execution, and whenever a bar turns red, the physiotherapist explains why and what was the problem in the execution of the exercise to enhance the autocorrection by the patient. Moreover, physiotherapists encourage patients to perform exercises incorrectly, so they can see bars getting red and learn how to correct their exercises by themselves.

Once thresholds are properly defined for each exercise, physiotherapists can change the number of sets, the number of repetitions, the execution time of each repetition, and the rest time between sets. They can also select the sensors to be used by the patient to play the game. Then, physiotherapists associate the prescription of the patient to an email address. Patients play the serious game in a smartphone by logging in with an email address. In principle, patients' prescriptions would be associated with their email address, but during all therapy sessions, the prescriptions were sent to the same email address, the one configured on the smartphone of the clinic, to avoid log-in issues and speed up the process.

Figure 2. Screenshots from the serious game used by the patients. Left screen displays the game of the platforms, which opens gates as patients contract or relax muscles. Right screen displays a labyrinth where a ball is sent over the scenario as contractions and relaxations are performed at the right time.



After finishing the prescription, the physiotherapist marks with a pen the muscles of the patient where the sensor should be attached.

Using a Serious Game

Performing a prescribed exercise also needs some preparation (see Figure 3). If the calibration octopus is still attached, physiotherapists need to remove the leads of the octopus and all the electrodes connected to the patient's body. They also need to arrange a table, a mirror, and a support cushion for the patient to successfully play the serious game. Very often, physiotherapists will bring power plugs to connect the smartphone too, to avoid running out of battery while the patient plays the serious game.

Once these preparations have been pursued, physiotherapists remind the types of exercises patients will perform, what sensors they will attach to the body, how to turn on those sensors, and how patients will control the game in the end. Physiotherapists then open the smartphone app and hand the smartphone to the patient, so that they are proficient in running the system and, thus, are potentially able to use eleRehab at home.

The app begins by asking the patient to connect the smartphone to the sensors. Patients turn on the sensors, according to the physiotherapists' instructions. Then the app shows the location of the muscle where to place the sensors. Patients usually try to place the sensors on their back by themselves, yet it can be difficult because of the location or their movement restrictions. The physiotherapist often corrected the placement of the sensors and asked if the patient had someone at home who could put the sensors on the marks made with the pen. The smartphone app then explains to the patient the exercise that they need to perform through a video and a textual description. Then, the game proceeds.

During the execution of the game, the therapist was often next to the patient observing the exercise execution. When patients played the game without difficulties, the physiotherapist did not intervene much, but if they faced difficulties in proceeding, the therapist would provide feedback on how to improve the exercise being performed. In some cases, the electrodes would detach, and the physiotherapist had to intervene again by placing the sensors in the muscle. The goal of the physiotherapist was to prepare patients to use the system at home autonomously; thus, they tried to refrain from intervening during the execution of the serious game.

When patients had more than one exercise prescribed, it was common to change the setup of the game. In these situations, the therapist was the one bringing other materials that were needed (eg, a Pilates ball, a step, or a cushion).

Figure 3. Physiotherapists often use their tablet application to explain to patients how to perform exercises correctly. Notice the calibration octopus in the pocket of the patient on both pictures, and the hand of the therapist correcting the exercise as the patient performs it, on the right image.

Discussion

Principal Findings

The findings presented above show that physiotherapists played an important role in enabling the serious game eleRehab to work. Physiotherapists briefed patients, calibrated the system, prescribed exercises, and supported patients while they played the serious game (see Figure 4). These results challenge the idea that physiotherapists have a reduced role in enabling serious games or that these interventions would provide some free time for the professionals to attend more patients.

Setting up a system that draws on electromyography, such as eleRehab, can take more time than a serious game that relies on inertial sensors or cameras because of the time calibrating the system to detect the muscle response of the patient. However, we would still expect physiotherapists to be actively involved in monitoring exercises in serious games based on inertial sensors or cameras because these systems can have issues in assessing the quality of the performed exercises. In any case, we can conclude that serious games may give more work to the physiotherapist than what was initially expected, and therefore, understanding therapists' work and practices is fundamental to create a system that suits the activities of these professionals.

The active role of physiotherapists in enabling serious games is not inherently negative. If a specific serious game helps increase therapy dosage, sustain motivation, and/or enable the correct performance of exercises, it can be completely worth using, even if the serious game requires physiotherapists to invest time in making it work. This means that the most important question to ask when assessing a serious game is whether it can yield improvements to the therapy activities, not if the serious game will free time for the physiotherapists to attend more patients.

The activities uncovered in this paper align with previous studies investigating the use of serious games in clinics, which argued that physiotherapists were involved in setting up, training, offering feedback, and maintenance [22-24]. To this body of work, we add that physiotherapists are involved in arranging elements in the space where support exercise activities are performed, such as getting tables, cushions, and balls. Moreover, we explained the steps that are involved in successfully achieving these categories of activities.

All patients played the game in the clinic, but they could have taken it home with them. In that situation, the physiotherapist would have taken care of the setup and prepared patients to perform the exercises in autonomy, as expected in previous work [4,25]. The participant role of physiotherapists in preparing home rehabilitation games challenges another accepted idea that patients set up and play rehabilitation games by themselves at home. Considering that therapists are needed to evaluate patients, prescribe therapies, and personalize exercises [3,8,27], it seems unlikely that a game would enable therapy out of the box. Thus, we may observe similar activities of setting up and training before patients start using a serious game at home.

Figure 4. Patient playing the eleRehab serious game with a smartphone and two sensors worn on the back to monitor exercises. Notice the table, Pilates ball, and other materials supporting exercise execution and the active role of the physiotherapist in supporting the patient in playing the serious game.

Limitations

This paper was based on observations of a small group of physiotherapists who recently started to use the eleRehab in their clinical practice. These professionals spent a long time setting up the system (typically three or four times the time spent playing), which would likely be reduced as these professionals gained experience in using the system or chose longer exercises/games in their practice. Moreover, the patients who were involved in the study were especially complex as they often presented irregular muscle responses, caused by the complex neurological consequences of the diseases they suffered from. It would be *easier* for professionals to calibrate the system for other patients. Nevertheless, because eleRehab depends on a calibration phase to measure the muscle response, it is likely that a moderate calibration period will always exist and require professionals to be actively involved in it.

The characteristics of the serious game we observed also had an impact on the results, as electromyography games require calibration of the sensors and prescription of the exercises is a requirement in electromyography-based games to enable the game to work properly for the patient. However, as we explained above, we would expect an active role and engagement of physiotherapists in serious games that did not include a systematic calibration, for example, to monitor the quality of the performed exercises.

Implications

Recognizing the work of physiotherapists in making serious games work in practice has important implications for the design of these systems. We discuss the three most obvious implications: (1) accept that serious games may add work, (2) involve physiotherapists during the whole design process, (3) involve physiotherapists during the whole design process, and (4) focus on the practical activities and context of physiotherapists.

Accept That Serious Games May Add Work

Our fieldwork shows that the serious game added work to the physiotherapists. As therapists wanted to use eleRehab, they needed to engage in numerous activities to set up, calibrate, and run the system. eleRehab might have lengthy setup processes because it relies on electromyography to capture exercise execution, but other serious games are also likely to generate work for physiotherapists. By recognizing that serious games do not always reduce work, as is usually mentioned in the literature [22,26,27], the technology design community will be better able to provide a balanced perspective on the impact of serious games. Moreover, we will be better able to investigate the work burden of serious games, if we consider that there is a good chance that serious games will create work for those involved in setting up and using them.

Involve Physiotherapists During the Whole Design Process

The crucial role of physiotherapists in enabling eleRehab calls for a greater involvement of therapists in the design of serious games. Although the technology design community acknowledges the importance of learning from health care professionals when designing technologies for health care [31,32], the role of physiotherapists in the design of serious games seems to be restricted. For example, from the set of studies cited in this paper, most involved physiotherapists only when defining the concept or requirements of the games or selecting the exercises to include [6,7,11,21]. Other studies only include the physiotherapist in the last phases of the design of the system. For instance, Duarte et al [33] developed a serious game for rehabilitation, which also included a mobile interface for the physiotherapist to monitor and define game parameters without involving them from the beginning. Including physiotherapists at different points will ensure that serious games fit their activities and clinical processes in the best way possible, even if games end up adding some work activities. Moreover, therapists can be crucial in the acceptance and implementation of serious games in a clinical context as they set up and explain how to use systems to the patients.

Focus on the Practical Activities and Context of Physiotherapists

This paper offered some examples of strategies of physiotherapists to practically support the execution of the game. Using tables and cushions for supporting the smartphone, using the tablet visualizations for increasing knowledge of the patient about the game, and always employing the same email to avoid log-in issues were some examples of practical strategies. These insights remind us that there is much to learn about how physiotherapists use serious games in practice to inform the design of serious games. Theories on appropriation mention that the design of technologies does not end in the designer's hands but rather in the way technology is appropriated in situ by its users [34]. By investigating physiotherapists' practical activities and context, the technology design community should be inspired to support efficient ways of dealing with serious games in practice and, in this way, better design serious games for those contexts.

Conclusions and Future Work

This paper described how physiotherapists made a serious game work in an outpatient rehabilitation clinic. It was clear that physiotherapists engaged in several activities to enable patients to use the technology successfully. Our results challenge the idea that serious games require a reduced role of physiotherapists, showing different activities people needed to do because they used the serious game eleRehab. Moreover, we present implications that can better shape serious games to fit physiotherapists' work and context.

In the future, we will continue observing the usage of eleRehab. We will have a chance to interview patients and physiotherapists, and we plan to contrast their perspectives on the serious game, as it is implemented in that particular clinic. We will also investigate how patients and physiotherapists make the system work when they take it home with them.

Moreover, we see interest in investigating how other serious games are used in practice to understand which activities are commonly generated by serious games when they reach the clinic.

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Conflicts of Interest

None declared.

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Original Paper

A Mobile App Directory of Occupational Therapists Who Provide Home Modifications: Development and Preliminary Usability Evaluation

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Abstract

Background: Home modifications provided by occupational therapists (OTs) are effective in improving daily activity performance and reducing fall risk among community-dwelling older adults. However, the prevalence of home modification is low. One reason is the lack of a centralized database of OTs who provide home modifications.

Objective: This study aimed to develop and test the usability of a mobile app directory of OTs who provide home modifications in the United States.

Methods: In phase 1, a prototype was developed by identifying OTs who provide home modifications through keyword Web searches. Referral information was confirmed by phone or email. In phase 2, community-dwelling older adults aged older than 65 years and OTs currently working in the United States were purposefully recruited to participate in a single usability test of the mobile app, Home Modifications for Aging and Disability Directory of Referrals (Home Maddirs). Participants completed the System Usability Scale (SUS) and semistructured interview questions. Interview data were coded, and themes were derived using a grounded theory approach.

Results: In phase 1, referral information for 101 OTs across 49 states was confirmed. In phase 2, 6 OTs (mean clinical experience 4.3 years, SD 1.6 years) and 6 older adults (mean age 72.8 years, SD 5.0 years) participated. The mean SUS score for OTs was 91.7 (SD 8.0; out of 100), indicating good usability. The mean SUS score for older adults was 71.7 (SD 27.1), indicating considerable variability in usability. In addition, the SUS scores indicated that the app is acceptable to OTs and may be acceptable to some older adults. For OTs, self-reported barriers to acceptability and usability included the need for more information on the scope of referral services. For older adults, barriers included high cognitive load, lack of operational skills, and the need to accommodate sensory changes. For both groups, facilitators of acceptability and usability included perceived usefulness, social support, and multiple options to access information.

Conclusions: Home Maddirs demonstrates good preliminary acceptability and usability to OTs. Older adults' perceptions regarding acceptability and usability varied considerably, partly based on prior experience using mobile apps. Results will be used to make improvements to this promising new tool for increasing older adults' access to home modifications.

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KEYWORDS

mHealth; mobile app; occupational therapist; occupational therapy; older adult; user-computer interface

Introduction

Background

Difficulties performing activities of daily living (ADLs), such as bathing, dressing, or toileting, place older adults at increased risk for adverse outcomes, including poorer health and frailty, premature institutionalization, and mortality [1-4]. Approximately 30% of community-dwelling older adults have difficulty performing one or more ADLs [5,6]. With the number of Americans aged older than 65 years projected to rise from 49 million to 98 million between 2016 and 2060, the number of older adults living with ADL limitations is expected to surge [7]. Accordingly, *Healthy People 2020* outlined an urgent goal to reduce the adverse outcomes of daily activity limitations among older adults as a national health priority [8].

Evidence-based home modifications delivered by occupational therapists (OTs) are an effective intervention to improve older adult's safety and independence when performing ADLs [9-16]. The goal of home modifications is to reduce environmental barriers in an older adult's home to match declining physiological competencies associated with increasing age and medical conditions. Home modification interventions may include training older adults and caregivers to use compensatory strategies and adaptive equipment to facilitate safer performance and increased independence in ADLs [9,11]. Home modifications may also include recommendations for major structural changes to a home (eg, addition of grab bars or a curbless shower) and the removal of environmental hazards to reduce the risk of falls and prevent serious resulting injuries [17]. OTs are essential to evidence-based evaluation and delivery of home modifications because they possess the biomedical and psychosocial knowledge, skills, and training to accurately assess an older person's physiological competencies (eg, cognitive, motor, and sensory functions), evaluate social and physical environmental barriers impeding ADL performance, identify home modifications that reduce the mismatch between personal competencies and environmental demands, train older adults and caregivers in the correct and safe use of home modifications, and assess intervention outcomes to ensure ADL limitations have been reduced [18]. In the United States, home modifications and the accompanying services provided by OTs are often privately funded, although grant funding may be available from state or local governments, public programs, or nonprofit organizations to help cover the cost of home modifications for low-income individuals [19].

However, many older adults continue to lack access to evidence-based home modifications, in part, because of the lack of information on OTs who provide home modifications [19-22]. Older adults, family members, caregivers, social service coordinators, and health care professionals may lack awareness of locally available OTs who can provide home modifications to help facilitate an older adult's safe return home after hospital discharge or to promote aging in place [22]. This lack of information may delay and even preclude the delivery of home modifications when they are needed most to improve safety and independence in ADL performance and reduce the risk of long-term adverse health outcomes for older adults [12,19,22-24]. Directories of resources for home modifications exist, including the *National Directory of Home Modification and Repair Resources* and *Eldercare Locator* [25,26]. Existing directories, however, lack comprehensive referral information on OTs who deliver home modifications as part of their database of resources. Therefore, there is a need to develop a centralized, publicly accessible database of information on OTs who provide home modifications to increase intervention access, improve care coordination, and reduce care delivery delays for older adults who are discharged from health care facilities back to independent living and for those seeking to maintain independent living or age in place.

Objectives

To address this challenge, this study sought to develop a mobile app as a centralized database containing referral information for OTs in the United States who provide home modifications and to preliminarily evaluate its acceptability and usability for OTs and older adults. In this paper, we present the methods and results of developing a prototype of the mobile app (phase 1) and usability testing to inform iterative improvements to the prototype (phase 2). The objective of the mobile app, named Home Modifications for Aging and Disability Directory of Referrals (Home Maddirs), is to aid older adults, family members, caregivers, social service coordinators, and health care providers in identifying local OTs who provide home modifications. We hypothesized that the mobile directory would be acceptable and usable to OTs and community-dwelling older adults.

Methods

Phase 1: Prototype Development

A previously published protocol for health-related directory development was adapted to develop a prototype of the mobile app [27]. To identify OTs for inclusion in the directory, keyword Web searches were conducted between October 2018 and March 2019 using Web search engines (Google and LinkedIn) for the following terms, where all 50 US states and Puerto Rico were included as search terms: ("home modification" OR "home assessment") AND "occupational therapist" AND "[state/territory]."

For each search query, the first author (AN) reviewed the top 300 search results or the maximum number of search results returned, whichever was first reached, to identify OTs who provided home modifications for inclusion in the directory. Snowball sampling was used to identify additional OTs by soliciting referrals from (1) OTs previously identified through Web searches; (2) responses to posts on Web community forums belonging to the *American Occupational Therapy Association's Home & Community Special Interest Section* and the *Home Modification Occupational Therapy Alliance* (HMOTA); and (3) cross-referencing two other existing resource databases related to home modifications, the *National Directory of Home Modification and Repair Resources* and *Eldercare Locator* [25,26].

Current clinical practice guidelines and a clinical reasoning guideline for the delivery of home modifications by OTs were used to define basic data fields and build search filters into the mobile app [28,29]. Basic data fields for referral sources included organization or business name, address, telephone number, email, website, specific populations served (eg, children and older adults), home modification services provided (eg, home evaluation, consultation, construction, project management, and caregiver training), payment methods or insurances accepted, and languages available for service provision. The names of businesses or organizations were incorporated, instead of the names of individual providers, to improve sustainability by reducing the impact of provider turnover. A built-in form to collect submissions from app users for new database entries and updates to current entries was also added to facilitate future updates to the directory. Information for each data field was initially retrieved from publicly available information online. Referral information was confirmed by self-report over email or phone call with each therapist.

Phase 2: Usability Testing

Participants

To evaluate the preliminary acceptability and usability of the mobile app, usability tests were conducted with community-dwelling older adults and OTs as targeted end user groups. Older adults (n=6) and OTs (n=6) were recruited by purposeful sampling from a list of local contacts obtained from clinical research coordinators at the Participation, Environment and Performance Laboratory and the Community Practice Clinic at the Washington University School of Medicine (St Louis, Missouri, USA). A sample size of 8 to 10 is recommended to detect 80% of usability problems [30].

Inclusion Criteria

Community-dwelling older adults were recruited if they (1) were aged 65 years or older, (2) could speak English, (3) could live independently in a noninstitutionalized setting, and (4) self-reported no health concerns about using a mobile app other than lack of experience. OTs were included if they (1) could speak English and (2) currently worked as a licensed OT in the United States (part time, full time, per diem, or self-employed).

Exclusion Criteria

OTs not currently working were excluded to retrieve feedback regarding app acceptability and usability informed by current clinical practice experience.

Usability Testing Procedures

The authors asked the institutional review board (IRB) at the Washington University School of Medicine in St Louis to review all study procedures, and the IRB verified that the study qualified for IRB exemption as a quality improvement initiative (IRB study ID number: 201901022). Participants were screened by phone or email to assess eligibility and coordinate attendance at a single usability testing session. Older adults and OTs participated individually in a single, 45-min test session. All usability tests were performed in a naturalistic setting [31]. Older adults were visited in their home, whereas OTs were visited in their clinical workplace setting to conduct all testing procedures. This approach eliminated the need for older adults to access transportation (supporting inclusive recruitment of older adults with a wider range of physical capabilities and socioeconomic backgrounds) and accommodated clinicians' busy work schedules.

Verbal consent was obtained from all participants at the start of each session after explaining its purpose and structure. A script was read aloud to describe the general purpose of the mobile app, but no further instructions were provided on how to use the app. Participants were instructed to perform a set of five task scenarios using the app on a mobile tablet device (Apple iPad 4). Tasks scenarios consisted of representative tasks expected to be typically performed by end users. These tasks were to (1) identify the name of the OT nearest to your current location who provides home modifications, (2) identify the name of the home modification funding source nearest to your current location, (3) search for the list of all OTs within 200 miles of your current location who provide home modifications, (4) search for the list of all home modification funding sources within your state, and (5) search for the list of all home modification funding sources for people with low income in your state. In addition to identifying OTs, referral information for funding sources to receive financial assistance for home modifications was also incorporated into the directory and was tested in tandem during usability testing. Instructions for each task were provided orally and in writing.

A concurrent think-aloud protocol was used to obtain insights into usability problems that participants experienced [30,32-34]. Participants were instructed to simultaneously verbalize their mental thought processes as they performed each task scenario. The test administrator (AN) was not allowed to provide assistance during tasks and was only allowed to use one of the two probes during the test session: (1) "Keep talking" after 15 seconds of silence to encourage participants to continue verbalizing their thoughts and (2) "Um-hum," "oh," or "okay," to affirm active listening [34]. The maximum amount of time allowed for each task scenario was 5 min, after which the participant was instructed to move on to the next task.

Outcome Measures

A mixed method approach was used to assess primary outcomes of acceptability and usability of Home Maddirs with the following outcome measures: (1) *task accuracy* (the rate of successful task completion calculated as the number of tasks completed successfully divided by the total number of tasks undertaken × 100), (2) *task efficiency* (time to complete each task in seconds, starting from the time the participant finishes receiving instructions to the time they found their answer and finished reviewing it), (3) *error rate* (number of errors per task, where errors are defined as unintended actions, such as miss clicks), (4) *types of errors* (qualitative descriptions of errors), and (5) *perceived task difficulty* (immediately after each task scenario, participants were asked, "Overall, how difficult or easy did you find this task?"; they responded using a 7-point Likert scale, ranging from 1=very difficult to 7=very easy) [35].

System Usability Scale

The System Usability Scale (SUS) is a valid and reliable 10-item questionnaire that has been used extensively to evaluate the usability of a wide range of technologies, systems, and services, including mobile apps [36]. The SUS was further selected as a usability measure because of the ease with which participants would be able to understand its questions in the context of the study's usability testing scenarios. Questions on the SUS are rated on a 5-point Likert scale, ranging from 1=strongly disagree to 5=strongly agree, and summed to generate a total usability score. Total usability scores on the SUS range from 0 to 100, where higher scores indicate greater acceptability and usability (ie, greater ease of use, ease of learning to use, and self-confidence in using the mobile app). SUS scores below 70 indicate a mobile app considered to be unacceptable by respondents, whereas scores above 70 indicate good acceptability and usability, and scores above 90 indicate excellent usability [36,37].

Qualitative Interview Data

Older adults' and OTs' subjective evaluations of acceptability and usability of the mobile app were collected through responses to open-ended interview questions. A semistructured interview guide was developed by the research team to obtain qualitative feedback on barriers and facilitators to acceptability and usability. Interview questions included (1) "What made it easy or difficult for you to use the app?," (2) "What did you like or dislike about the app design?," and (3) "What could be changed to make it easier for you to use the app?." OTs were additionally asked questions to probe for barriers and facilitators to adoption of the mobile app in their clinical practice setting. These questions included (1) "Could you foresee yourself or others using the app in your practice setting?," (2) "What difficulties do you foresee with using the app in your practice setting?," and (3) "What would make it easier for professionals to use the app in your practice setting?."

Demographics

Older adults self-reported their age, gender, marital status, race/ethnicity, and education. OTs self-reported their age, gender, race/ethnicity, education, current clinical practice setting, and years of clinical work experience. Both older adults and OTs were asked to rate their prior extent of mobile app usage measured using three items adapted from the smartphone usage subscale of the Media and Technology Usage and Attitudes Scale and on a 6-point scale with the following question: "In the last month, how much time did you spend using mobile apps?," which was rated from 1=less than 1 hour, 2=1 to 2 hours, 3=2 to 4 hours, 4=4 to 6 hours, 5=6 to 10 hours, to 6=more than 10 hours [38,39].

Data Analysis

All usability test sessions were audiotaped, and mobile device screens were screen recorded throughout testing. All data were deidentified before storage and analysis. Descriptive statistics of participant demographics and quantitative measures of acceptability and usability were calculated using SPSS version 24.0 (IBM, New York, USA). Qualitative interview responses were transcribed verbatim. The first author (AN) coded all qualitative interview data using content coding analysis. A constant comparative method based on the grounded theory approach was used so that interview transcripts were continually reevaluated for themes emerging from consistencies and differences in coded terms [40-44]. Themes were clustered into categories of barriers and facilitators to acceptability and usability. Categories, themes, and their associated codes were developed and documented using NVivo version 12.0 (QSR International, Melbourne, Australia). Member checking was used to enhance the trustworthiness of findings, whereby themes were shared with participants by phone or email for respondent validation [45,46].

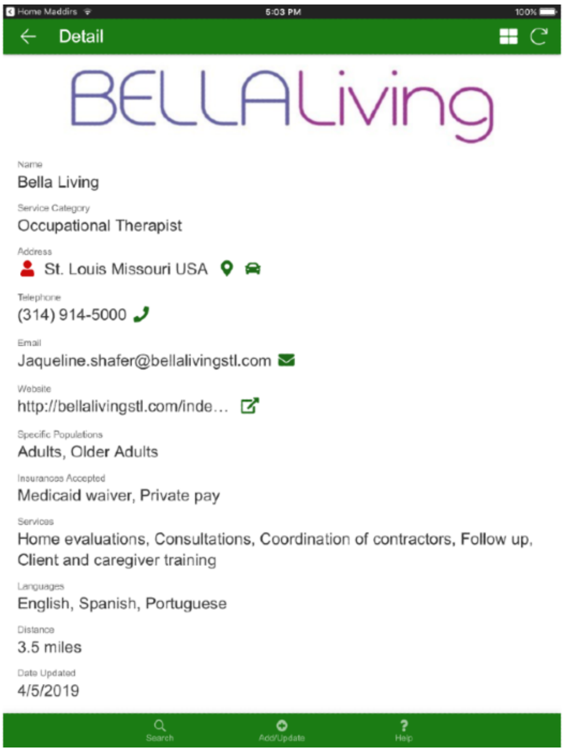
Results

Phase 1: Prototype Development

In total, 148 prospective directory entries were identified from keyword Web searches, responses to online community forum posts, and snowball sampling. Of these, 118 prospective entries responded to outreach by email or phone (80% response rate). Referral information for 101 OTs was confirmed and incorporated into the mobile directory. Reasons for which prospective entries responded but were not included in the directory were as follows: seven organizations that employ OTs who do not provide home modifications, five organizations that do not employ OTs (eg, they were solely home builders), 4 OTs who had retired from providing home modifications, and 1 OT who had not yet started providing home modifications but was planning to do so in the near future.

The app uses geolocation services on a mobile device to curate referral information based on geographic distance from the app user and other relevant decision-making factors selected, such as insurance or payment methods accepted, patient populations served, and the scope of home modification services provided. Figure 1 shows an example of how an OT's provider information is displayed as an entry in the directory, which includes their business name, business address, business telephone number, business email, business website, specific patient populations served (eg, children, adults, or older adults), insurances accepted, home modification services provided (eg, consultation, home evaluation, coordination of contractors, and follow-up on contractors' work), languages in which services are provided, and distance from the location of the mobile device to the provider's address.

Figure 1. Home Modifications for Aging and Disability Directory of Referrals user interface displaying a single directory entry.



Name
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Specific Populations
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Insurances Accepted
Medicaid waiver, Private pay

Services
Home evaluations, Consultations, Coordination of contractors, Follow up, Client and caregiver training

Languages
English, Spanish, Portuguese

Distance
3.5 miles

Date Updated
4/5/2019

Phase 2: Usability Testing

Demographics

Demographics of OTs and older adults who participated in usability testing are shown in Table 1. OTs reported currently working in a wide range of clinical practice settings, including acute care (n=1), inpatient rehabilitation (n=2), outpatient/community practice clinic (n=2), and private practice specifically providing home modifications (n=1). Therapists' mean clinical experience was 4.3 (SD 1.6) years. Participants' prior extent of mobile app usage is shown in Table 2.

Table 1. Demographics of participants who participated in usability testing.

Characteristic	Occupational therapists (n=6)	Older adults (n=6)
Age (years)		
Mean (SD)	35.7 (9.8)	72.8 (5.0)
Range	28-54	67-81
Gender, n (%)		
Female	6 (100)	6 (100)
Race, n (%)		
White	6 (100)	1 (17)
African American	0 (0)	5 (83)
Education, n (%)		
High school/general educational development	0 (0)	1 (17)
Some college	0 (0)	2 (33)
College degree	6 (100)	3 (50)
Marital status, n (%)		
Married	N/A[a]	1 (17)
Single	N/A	3 (50)
Widowed	N/A	2 (33)

[a] N/A: not applicable.

Table 2. Participants' extent of prior mobile app usage.

Media and Technology Usage and Attitudes Scale question[a]	Occupational therapists (n=6)	Older adults (n=6)
How often do you search for information on a mobile phone/tablet, n		
Never	0	3
Several times a week	0	2
Several times a day	4	0
Once an hour	1	0
All the time	1	1
How often do you get directions or use GPS on a mobile phone/tablet, n		
Never	0	2
Once a month	0	3
Several times a month	0	1
Once a week	1	0
Several times a week	3	0
All the time	2	0
How often do you use apps for any purpose on a mobile phone/tablet, n		
Never	0	2
Once a week	0	1
Several times a week	0	1
Once a day	0	1
Several times a day	3	0
Several times an hour	1	0
All the time	2	1
In the last month, how much time did you spend using apps for any purpose on a mobile phone/tablet, n		
<1 hour	1	3
2-4 hours	0	1
4-6 hours	0	2
>10 hours	5	0

[a] All response categories for each question are not listed; only those that received at least one participant response are listed.

Quantitative Outcomes

Quantitative usability metrics are shown in Table 3. Percent task completion ranged from 0% to 100% for older adults. Specifically, 2 older adults were unable to successfully complete any task scenarios—one consistently took longer than the allowed 5 min per task, whereas the other attempted but gave up early on tasks citing that it was too difficult. Compared with other older adult participants, these 2 older adults were observed to be older and had less prior experience using mobile apps. Their data were excluded from the calculation of older adult's average task efficiency but included in all other usability measures.

Table 3. Quantitative usability metrics.

Measure	Occupational therapists (n=6), mean (SD)	Older adults (n=6), mean (SD)
System Usability Scale score	91.7 (8.0)	71.7 (27.1)
Percent task completion	93 (16)	60 (49)
Average task efficiency[a] (seconds per task)	40.7 (32.2)	97.5 (57.4)
Average error rate (errors per task)	0.7 (0.5)	1.9 (1.9)
Average task perceived difficulty (1=very difficult and 7=very easy)	6.6 (0.4)	4.6 (2.2)

[a] Excludes instances of task scenarios that were not completed successfully.

Qualitative Outcomes

Qualitative themes derived from screen recordings and interview transcripts are summarized in Table 4.

Error Types

Errors experienced by both OTs and older adults included miss clicks on various app features and the addition of search filters that overly limited search results (eg, selecting to filter by both the state and the geographical distance from the user when asked to search for all resources in one's state). Older adults additionally experienced more frequent and diverse types of errors, including difficulty understanding how to initiate the search function, difficulty accurately interpreting the meaning of search results (eg, not knowing which search result was geographically closest to them despite distances being labeled), difficulty scrolling on a touch screen device, and difficulty remaining oriented while scrolling or navigating between views within the app.

Table 4. Qualitative themes of errors, barriers, and facilitators of acceptability and usability.

Category	Occupational therapists	Older adults
Error types	• Miss clicks within app • Extra search filters added to search query	• Miss clicks within app • Extra search filters added to search query • Difficulty initiating search function • Difficulty interpreting search results • Difficulty scrolling using touch screen • Difficulty navigating between views within the app
Barriers to acceptability and usability	• Need for more information on scope of referral services	• High cognitive load of user interface • Need to reduce jargon • Lack of operational skills • Need to accommodate age-related sensory changes
Facilitators of acceptability and usability	• Perceived usefulness • Social support (ie, technical support guidance) • Time to practice to gain familiarity • Multiple options to access information	• Perceived usefulness • Social support (ie, assistance from family, caregivers, and health care providers) • Time to practice to gain familiarity • Multiple options to access information

Barriers to Acceptability and Usability

Barriers to acceptability and usability conveyed by OTs included the need for more information regarding the scope of home modification services provided by referrals listed in the directory:

> *I guess I can go in and click online but if it had just a little list of some of the things that they do from their information page so I can quickly decide if it fits.* [Occupational therapist 2]

Barriers experienced by older adults included high cognitive load presented by the prototype's user interface. For example, older adults commented that the presence of a map accompanying search results added unnecessary complexity:

> *I don't mind the map being there but I don't see the reason for the map being there...I think the map is fine, I just, it's kind of distracting because I'm looking for something on the map when I could have just gone over here [to the other side of the screen].* [Older adult 1]

To reduce cognitive load, older adults also pointed to the need to reduce jargon and use terminology that resonates with consumer needs and services they would seek:

> *Definitely the services, you know, you have to phrase them in such a way that it's something like – "Oh yeah, I think that's something I need."* [Older adult 5]

The majority of older adults pointed to their lack of experience using mobile devices and apps as a barrier. They emphasized their limited skills to operate mobile apps in general, difficulty defining an efficient search strategy to search the directory, and needing more instruction on how to use the app initially:

> *If I had [a mobile device] that I could just get all to myself and maybe have some kind of booklet that I could read to learn, you know. Some instruction, you know.* [Older adult 4]

Older adults also suggested the need for design changes to increasingly accommodate age-related sensory changes, for example, increasing font size to accommodate decreased near visual acuity:

> *The writing was too little. I usually have to increase the size of the screen. This is too little for me.* [Older adult 3]

Facilitators of Acceptability and Usability

Most OTs and older adults perceived the mobile app to be useful as a facilitator of acceptability and usability:

> *Yeah, like right now, I feel like some of those referrals, we never were making them. Like we can tell patients to follow up on them or we'll tell case management and they'll try to get some of that set up for the discharge process, but I think because of the lack of knowledge of where to send them, sometimes those people might unintentionally fall through the cracks, so this would be a really nice tool for them to*

> *easily access where they could send them or increase their accessibility to that information to potentially help for discharge.* [Occupational therapist 5]

> *The information that I was looking for was clear in order to get to where I wanted to be, you know. So, I found the occupational therapist and that's what I needed, and I found it, you know. And the contact was right there, all I had to do was call.* [Older adult 2]

Both OTs and older adults cited social support and time to practice to gain familiarity with the app as effective means to enhance acceptability and usability. For example, OTs stated that social support in the form of additional technical support would be useful:

> *I think the "Help" section should be like "I'm stuck what do I do?" Tech stuff like "I'm stuck, I can't find what I'm looking for," or maybe adding in there like what if my internet connection isn't working. I mean you assume that they would have some idea of how to use the tablet, but those are the things I would include for the user maybe things less about OT and more about how to use the app or troubleshooting like to turn on your "location services" on your tablet or phone so that way you have a way to fix the problem if there's some technical problem.* [Occupational therapist 2]

In contrast, older adults stated that social support from another person (eg, family member, caregiver, or health care professional) would be beneficial:

> *I would have to have a teacher, you know...then each day, I could practice what I learned from my instruction.* [Older adult 4]

Finally, both OTs and older adults suggested that multiple options to access information (eg, on a mobile device or a computer) would facilitate acceptability and usability. OTs specifically stated that having options to access information on either a mobile device or a computer would increase use by offering flexibility to accommodate diverse clinical environments and workflows:

> *We do have iPads at our disposal but I don't know if it's something that can also be done – I more often have my laptop than my iPad so I don't know if it's something that could be accessible through both.* [Occupational therapist 5]

In contrast, older adults stated that accessing the directory on a website with a computer mouse and keyboard would help facilitate usage because of the greater ease of navigation using a mouse compared with the touch screen:

> *You need a mouse real bad...the touch screen thing I just don't like it.* [Older adult 3]

Discussion

Principal Findings

The principal findings of this study are the development of a centralized database of OTs who provide home modifications that is accessible as a mobile app, Home Maddirs, and preliminary evidence to suggest that the mobile app is acceptable and usable to OTs. OTs who participated in the study worked in a wide range of clinical practice settings and generally perceived the app to be easy to use and useful for increasing access to referral information. Mobile health (mHealth) apps are increasingly being used by health care providers to improve clinical workflow efficiency and as novel interventions to improve diverse health outcomes for patients [47-49]. Previous studies have explored the acceptability and usability of mHealth apps for OTs to facilitate clinical decision making for assistive equipment provision, movement activities for children with disabilities, and wheelchair training [50-52]. To the authors' knowledge, this is the first study to develop and preliminarily evaluate an mHealth solution for increasing access to occupational therapy services related to home modifications.

Usability testing further suggested that the mobile app may be acceptable and usable to some older adults but that considerable variation exists among older adults' perceptions. Although some older adults found the mobile app easy to use, others perceived it to be difficult to use, which appeared to be influenced by the older adult's prior experience and comfort with using mobile apps. Previous studies have shown promising results demonstrating the acceptability of mHealth interventions among community-dwelling older adults [48,53]. Acceptability and usability of mHealth interventions, however, are attenuated by older adults' prior experience using mobile apps, which influences their self-efficacy toward using mobile apps [54,55]. Qualitative themes arising from our interviews of older adults are consistent with the literature that suggests older adults, particularly those with less experience using mobile apps, would benefit from social support from caregivers and health care professionals to promote adoption and engagement with mHealth interventions [54,56,57]. Qualitative themes from this study further suggest that having multiple options to access referral information, such as on a desktop computer's internet browser, in addition to the current mobile app platform, would increase the utilization of referral information by both older adults and clinicians based on individual preferences for using either interface during daily living or work routines. The choice to develop a progressive Web app that is delivered through the Web (which Home Maddirs is) may thus be an attractive option for other mHealth interventions to flexibly allow for dissemination simultaneously on mobile devices and internet browsers accessed on desktop computers.

When performing representative tasks using the mobile app, older adults, on average, perceived tasks to be more difficult, made more errors, encountered more diverse types of errors, and were less accurate and efficient compared with OTs. These observations point to the need for design improvements to better accommodate age-related changes; these include cognitive changes, such as decreased information processing speed and working memory capacity among older adults, and sensory changes, such as decreased near visual acuity and efficiency of visual information processing [58-61]. These results may also be partially explained by the lack of a requirement for participants to self-report comfort or competency with using mobile apps as part of the inclusion criteria for usability testing. The authors chose to embrace an ecological perspective by including older adults with less experience using mobile apps to increase the likelihood of uncovering usability problems that would be encountered in the general population of older adults, who, on average, have less experience using mobile apps compared with younger age groups [62].

Limitations

The limitations of the study included a small sample size and lack of objective health screening that resulted in the recruitment of a nonrepresentative sample of OTs and community-dwelling older adults. Females and individuals with a minimum of a high school education were overrepresented in the sample. Furthermore, older adult participants self-reported no health concerns that would impair their ability to use mobile apps, but this self-report may have been inaccurate, and the results will not generalize to older adults with more significant health or functional impairments. Consequently, results can be used to provide insights to make iterative improvements to the app but should be interpreted with caution, as they are not likely to be reliable and generalizable to the entire population under study.

Other limitations included the use of a single coder to qualitatively code transcripts of audio recordings of usability test sessions. A minimum of two coders is suggested to improve veracity and trustworthiness of themes yielded from content coding analyses [41,43]. The decision to use a single coder was chosen because a primarily objective of this preliminary usability evaluation was to obtain insights to make improvements to the app. Future studies should use two coders to improve the strength of confidence in qualitative findings.

All usability testing sessions were conducted in a naturalistic setting, instead of a standardized laboratory environment. This may have reduced internal validity through the influence of differences in uncontrolled environmental variables within each unique testing environment. We attempted to standardize parts of the testing environment by having participants test the app on the same mobile tablet device running on the same wireless internet hotspot. The choice to conduct usability test sessions in a naturalistic environment was chosen because of the nature of target users groups being busy working clinicians or older adults, the latter of whom may lack reliable transportation or the physical capacity for travel.

Conclusions

Home Maddirs is a promising new mobile directory tool to help increase older adults’ access to OTs who provide home modifications. This study provides preliminary evidence that the mobile app is acceptable and usable to OTs. The results of this study will be used to make improvements to the app, including design changes to accommodate age-related cognitive and sensory changes and to increasingly tailor views of information by audience (ie, consumer vs health care professional). Older adults’ perceptions of acceptability and usability of the mobile app varied considerably. To improve older adults’ access to the mobile directory information, caregivers, health care professionals, and social service coordinators should seek to provide social support, and multiple ways to access information should be made available for older adults who lack experience using mobile apps.

A working prototype of the mobile app is freely available online for public use [63]. Future work will seek to better understand the acceptability and usability of Home Maddirs for key stakeholder groups, including a broader, more representative sample of older adults, caregivers, social service coordinators, and interdisciplinary members of older adults’ health care teams. Future studies are further needed to explore the clinical utility of the mobile app, including comparisons between the use of the mobile app with other methods of accessing this information, optimum integration of its usage into clinical workflows, and evaluation of its impact on timely access to home modifications for older adults.

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Authors' Contributions

AN conducted usability tests, performed data and statistical analyses, and drafted the manuscript. All authors reviewed and approved the final manuscript.

Conflicts of Interest

AN developed the initial prototype of the mobile app under the supervision of the authors ES, ST, MK, and SS.

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Abbreviations

ADL: activity of daily living
HMOTA: Home Modification Occupational Therapy Alliance
Home Maddirs: Home Modifications for Aging and Disability Directory of Referrals
IRB: institutional review board
mHealth: mobile health
OT: occupational therapist
SUS: System Usability Scale

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Original Paper

Effectiveness of a Home-Based Rehabilitation Program After Total Hip Arthroplasty Driven by a Tablet App and Remote Coaching: Nonrandomized Controlled Trial Combining a Single-Arm Intervention Cohort With Historical Controls

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Abstract

Background: Recent technological developments such as wearable sensors and tablets with a mobile internet connection hold promise for providing electronic health home-based programs with remote coaching for patients following total hip arthroplasty. It can be hypothesized that such a home-based rehabilitation program can offer an effective alternative to usual care.

Objective: The aim of this study was to determine the effectiveness of a home-based rehabilitation program driven by a tablet app and remote coaching for patients following total hip arthroplasty.

Methods: Existing data of two studies were combined, in which patients of a single-arm intervention study were matched with historical controls of an observational study. Patients aged 18-65 years who had undergone total hip arthroplasty as a treatment for primary or secondary osteoarthritis were included. The intervention consisted of a 12-week home-based rehabilitation program with video instructions on a tablet and remote coaching (intervention group). Patients were asked to do strengthening and walking exercises at least 5 days a week. Data of the intervention group were compared with those of patients who received usual care (control group). Effectiveness was measured at four moments (preoperatively, and 4 weeks, 12 weeks, and 6 months postoperatively) by means of functional tests (Timed Up & Go test and the Five Times Sit-to Stand Test) and self-reported questionnaires (Hip disability and Osteoarthritis Outcome Score [HOOS] and Short Form 36 [SF-36]). Each patient of the intervention group was matched with two patients of the control group. Patient characteristics were summarized with descriptive statistics. The 1:2 matching situation was analyzed with a conditional logistic regression. Effect sizes were calculated by Cohen *d*.

Results: Overall, 15 patients of the intervention group were included in this study, and 15 and 12 subjects from the control group were matched to the intervention group, respectively. The intervention group performed functional tests significantly faster at 12 weeks and 6 months postoperatively. The intervention group also scored significantly higher on the subscales “function in sport and recreational activities” and “hip-related quality of life” of HOOS, and on the subscale “physical role limitations” of SF-36 at 12 weeks and 6 months postoperatively. Large effect sizes were found on functional tests at 12 weeks and at 6 months (Cohen *d*=0.5-1.2), endorsed by effect sizes on the self-reported outcomes.

Conclusions: Our results clearly demonstrate larger effects in the intervention group compared to the historical controls. These results imply that a home-based rehabilitation program delivered by means of internet technology after total hip arthroplasty can be more effective than usual care.

Trial Registration: ClinicalTrials.gov NCT03846063; https://clinicaltrials.gov/ct2/show/NCT03846063 and German Registry of Clinical Trials DRKS00011345; https://tinyurl.com/yd32gmdo

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KEYWORDS

remote coaching; internet; osteoarthritis; total hip arthroplasty; home-based rehabilitation program; physiotherapy; usual care; tablet app; total hip replacement; rehabilitation

Introduction

With an ageing population and increasing numbers of people with overweight and obesity, the incidence of hip osteoarthritis in the Western world will continue to rise. A further increase in the number of total hip arthroplasties is consequently expected. At present, total hip arthroplasty (THA) is considered one of the most successful clinically and cost-effective surgical treatments available for end-stage osteoarthritis, and a total of 29,937 primary THAs were performed in the Netherlands in 2017 [1]. As in other Western countries, there is an increasing tendency in the Netherlands to perform fast-track surgery, which allows people to 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 covered by Dutch basic health insurance [2]. Patients who want postoperative physiotherapy need additional insurance or have to pay for it themselves, which can lead to suboptimal recovery [3]. To optimize recovery, Bandholm and Kehlet [3] highlighted the need for immediate and intensive postoperative physiotherapy. Austin et al [4] showed that this physiotherapy does not need to take place in a formal setting, and that a home-based program could also be safe and efficacious for a majority of patients undergoing THAs. Additionally, a systematic review by Coulter et al [5] found that physical exercises for patients after THA are similarly effective whether they are performed unsupervised at home or in an outpatient setting.

Recent technological developments such as wearable sensors and tablets with mobile internet access hold promise for providing home-based programs [6]. These developments also allow for more remote coaching options. Remote coaching appears to be a good home-based rehabilitation alternative to supervised physiotherapy in an outpatient setting [6]. A home-based rehabilitation program delivered by means of videos on a tablet could therefore be helpful in the further development of such programs for patients after THA. In a previous study, we proved that such programs are feasible for patients following THA [7]. The results showed good adherence to the program and a positive patient experience; however, the effectiveness has not yet been investigated. Therefore, the aim of this study was to determine the effectiveness of this home-based rehabilitation program by comparing it with usual care. It was hypothesized that a home-based rehabilitation program could be an effective alternative to usual care.

Methods

Study Design

Existing data of two studies were combined in which patients of a single-arm intervention study were matched with historical controls of an observational study. First, a prospective cohort study was conducted applying a home-based rehabilitation program following THA in the Netherlands (tablet study). The study was approved by the medical ethics committee of University Medical Center Groningen (METc2014/399). Next, a transnational prospective observational trial was conducted to compare the effectiveness of the rehabilitation approach following THA in Germany versus the Netherlands (observational study). For this analysis, we used data of the Dutch patients. A protocol of this study has been published and was approved by the medical ethics committee of University Medical Center Groningen (METc2015/483) [8].

Study Population

The tablet study (intervention group) included a total of 30 patients aged 18-75 years who received THA as treatment for primary or secondary osteoarthritis. 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) low proficiency in reading and understanding Dutch. Patients were included between December 2015 and February 2017.

The observational study (control group) included a total of 33 Dutch patients aged 18-65 years who received THA as treatment for primary or secondary osteoarthritis. Patients were waiting for a THA at either Ommelander Hospital Winschoten/Delfzijl or Medical Center Leeuwarden in the Netherlands. Exclusion criteria were: (1) medical conditions that disallow safe participation in a rehabilitation program, (2) cognitive impairment, and (3) insufficient proficiency in reading and understanding Dutch. Patients were included between March 2016 and December 2017.

Intervention

Tablet Study

The home-based rehabilitation program started in the first postoperative week. The program lasted for 12 weeks and has been described in detail elsewhere [7]. Patients performed the exercises independently at home using the tablet for instructions, which were provided by means of a Web-based app [9]. The app also gave participants feedback on their training performance. The program included strengthening and walking exercises based on increasing muscle force, balance, and functionality. Exercises comprised movements that trained the abductors, flexors, and extensors of the affected hip. The content of the program was based on previous research [10,11] and on the most recent guidelines from the American Association of Orthopedic Surgeons and the Royal Dutch Society for Physical Therapy [12] (see Multimedia Appendix 1 for detailed content of the rehabilitation program).

Remote coaching was provided via weekly telephone support from a physiotherapist. During these phone calls, the physiotherapist and patient evaluated the progress and agreed on whether to train at a higher level. The program consisted of 12 levels with the aim of increasing the difficulty level each week. 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 conducted on weeks 4 and 12 postoperatively, and included physical tests and filling out questionnaires.

Observational Study

The Dutch patients in the observational study received only normal usual care with no specific intervention. Both the Dutch Orthopedic Association and the Royal Dutch Society for Physical Therapy recommend continuing physiotherapeutic exercise in an extramural setting after hospital discharge to improve physical functioning [13,14]. However, as reimbursement of treatment costs depends on the insurance situation of the patient, the amount of postoperative physiotherapy applied varies among patients.

Outcome Measures

The measurements in both the tablet study and the observational study were the same. Preoperative demographic data, height, and weight, and perioperative and postoperative complications were recorded. Both objective and self-reported measurements were taken to assess mobility, functional status, and quality of life of the patients. Measurements were taken preoperatively and postoperatively at 4 weeks, 12 weeks, and 6 months at the patients' homes.

Objective Measurement

To assess mobility and functional status objectively, the Timed Up & Go (TUG) test and the Five Times Sit-to Stand Test (FTSST) were performed. TUG is an accepted test to measure mobility, and is considered reliable and practical [15]. During the TUG test, participants were instructed to stand up from the chair, walk 3 meters, turn around, walk back, and sit down on the chair again. Participants were asked to walk at a fast but safe pace. The test was performed three times.

The FTSST is a clinical test to assess lower extremity power and balance, which shows good reliability and validity [16,17]. For the FTSST, participants were asked to stand up and sit down 5 times at a fast speed. The participants were instructed to perform the test with their arms crossed in front of the abdomen when possible.

Self-Reported Measurements

The self-reported Hip disability and Osteoarthritis Outcome Score (HOOS) was used as a disease-specific outcome measure of functional status and quality of life. The HOOS consists of five subscales: pain, other symptoms, function in activities of daily living, function in sport and recreational activities, and hip-related quality of life. Standardized response options are given and each question is scored from 0 to 4 on a 5-point Likert scale. A normalized score ranging from 0 to 100 is subsequently calculated for each subscale (with 0 indicating extreme symptoms and 100 indicating no symptoms). The Dutch version of the HOOS has proven to be valid and reliable [18].

To measure health-related quality of life, the Short Form 36 (SF-36) was used, which is a widely used generic health status questionnaire consisting of 36 questions divided into eight health concepts: physical functioning, role limitations due to physical problems, social functioning, bodily pain, general mental health, role limitations due to emotional problems, vitality, and general health perceptions. Each raw scale score is transformed into a linear 0-100 scale, in which higher scores indicate less disability. In this study, only the subscales physical functioning, role limitations due to physical problems, and general health perceptions were analyzed. The SF-36 has proven to be practical, reliable, and valid for a general and chronic disease population [19].

Data Analysis

Data were analyzed using IBM SPSS Statistics version 23 (IBM Corp, Armonk, NY, USA) and Statistical Analysis System v. 9.4 (SAS Institute, Cary, NC, USA). Patient demographics were analyzed with descriptive statistics using mean and SD or frequency and percentage as appropriate.

This study was designed as a nonrandomized controlled trial combining existing data of two studies. This was achieved by matching each patient in the intervention group to two patients in the control group (ie, 1:2 matching) [20]. Patients in the intervention group were aged 18-75 years, whereas none of the patients in the control group was older than 65 years. Therefore, intervention group patients older than 65 years were excluded from the analysis. The remaining 15 patients in the intervention group were matched based on gender and age to two patients in the control group. Since there were three matches of a woman with a man, these matches were excluded from the analyses. The 1:2 matching situation was analyzed with conditional logistic regression, which is an extension of logistic regression that takes matching into account. A correction for baseline was performed as there were significant differences at baseline between the three groups (intervention group and two matching control groups). Significance was tested at alpha=.05.

Effect sizes were calculated between the intervention group and control groups using Cohen *d*. As one intervention group patient was matched with two control group patients, two effect sizes were calculated per intervention group patient. Cohen *d* of 0-0.19, 0.20-0.49, 0.50-0.79, 0.80-1.29, and >1.3 represents no or a negligible effect, small effect, medium effect, large effect, and very large effect, respectively [21].

Results

Demographic Characteristics

In total, 15 patients of the intervention group and 15 and 12 patients of each control group were included in the analyses. The baseline characteristics of the three groups are presented in Table 1. No significant differences between the groups were found. The intervention group completed approximately 2-9 times more hours of exercise during the 12 weeks of the home-based rehabilitation program compared to that completed by the control groups in the 6 months after surgery.

Baseline characteristics and functional scores on all outcomes of the three groups are presented in Table 1 and Table 2, respectively. Regarding the functional measurements, the intervention group performed the FTSST significantly faster at baseline than the two control groups. For three of the five subscales of the HOOS, the intervention group performed significantly better at baseline than the control groups. Similarly, the intervention group showed higher scores on two subdomains of the SF-36: physical functioning and general health perception (Table 2).

Table 1. Baseline characteristics of the study population (N=42).

Characteristic	Intervention group (n=15)	Control group 1 (n=15)	Control group 2 (n=12)	*P* value
Gender: female, n (%)	10 (67)	10 (67)	7 (58)	.85[a]
Age (years), mean (SD)	59.3 (3.6)	59.3 (3.6)	59.3 (5.3)	>.99[b]
Body mass index (kg/m^2), mean (SD)	26.7 (5.1)	28.0 (4.3)	31.1 (6.5)	.10[b]
Educational level, n (%)				.08[b]
Low	3 (20)	7 (46)	4 (33)	
Medium	6 (40)	5 (33)	8 (67)	
High	6 (40)	3 (20)	0 (0)	
Living situation, n (%)				.58[a]
Alone	4 (27)	2 (13)	1 (8)	
With partner and/or children	11 (73)	13 (87)	11 (92)	
ASA [c] classification, n (%)				.12[a]
I or II	13 (87)	12 (80)	6 (50)	
III	2 (13)	3 (20)	6 (50)	
Exercise hours[d], median (range)	17.9 (13.1-19.9)	6.0 (0.0-48.0)	2.5 (0.0-48.0)	N/A[e]

[a] Fisher exact test.

[b] One-way analysis of variance.

[c] ASA: American Society of Anesthesiologists Physical Status Classification System.

[d] Based on 12 weeks of the program for the intervention group and 6 months postoperative for the control groups.

[e] N/A: not applicable.

Table 2. Functional outcome measures at baseline of the study population (N=42).

Measurement	Intervention group (n=15)	Control group 1 (n=15)	Control group 2 (n=12)	Odds ratio (95% CI)[a]	*P* value
TUG[b] (seconds), mean (SD)	11.3 (2.6)	12.0 (4.6)	13.2 (5.3)	0.92 (0.77-1.10)	.33
FTSST[c] (seconds), mean (SD)	16.2 (3.0)	20.8 (6.6)	23.8 (11.0)	0.83 (0.70-1.00)	.04
HOOS[d], mean (SD)					
Pain	48.9 (12.8)	35.5 (14.8)	36.3 (18.4)	1.12 (1.03-1.23)	.03
Other symptoms	50.0 (18.2)	29.3 (13.1)	41.7 (19.5)	1.07 (1.01-1.13)	.03
Function in ADL[e]	52.7 (17.5)	34.0 (10.2)	37.1 (19.1)	1.14 (1.03-1.27)	.02
Function in sport and recreational activities	23.3 (13.7)	16.3 (10.0)	20.8 (22.1)	1.04 (0.98-1.11)	.16
Hip-related quality of life	19.2 (10.7)	22.9 (12.9)	24.5 (13.5)	0.98 (0.93-1.03)	.43
SF-36[f], mean (SD)					
Physical functioning	42.7 (14.4)	28.0 (15.2)	24.6 (19.1)	1.07 (1.01-1.13)	.02
Role limitations: physical	33.3 (40.8)	20.0 (36.8)	14.6 (24.9)	1.01 (0.99-1.03)	.16
General health perception	80.9 (12.8)	67.9 (17.4)	51.6 (25.5)	1.08 (1.01-1.16)	.03

[a] Conditional logistic regression.

[b] TUG: Timed Up & Go test.

[c] FTSST: Five Times Sit-to Stand Test.

[d] HOOS: Hip disability and Osteoarthritis Outcome Score; scale of 0-100 (0 = extreme symptoms, 100 = no symptoms).

[e] ADL: activities in daily living.

[f] SF-36: 36-item Short Form Health Survey; scale of 0-100 (higher score = better perceived health or functioning).

Objective Measurements

The outcomes of the objective measurements are shown in Table 3. After baseline correction, significant differences were found in the TUG at 4 weeks, 12 weeks, and 6 months, and on the FTSST at respectively 12 weeks and 6 months. The intervention group performed the two measurements significantly faster than the two control groups.

Self-Reported Measurements

The outcomes of the self-reported measurements are presented in Table 4. The scores of the intervention group were slightly higher on both disease-specific outcome measures of functional status and health-related quality of life, but the differences were not significant. For the HOOS, the intervention group scored significantly better on the subdomain function in sport and recreational activities at 4 weeks, 12 weeks, and 6 months, and also scored significantly higher on the subdomain hip-related quality of life after 6 months. For the SF-36, the intervention group scored significantly better on the subdomain physical role limitations at 12 weeks and 6 months.

Effect Sizes

Effect sizes of the outcome measures at week 12 and at the 6-month follow up are presented in Table 5. The home-based rehabilitation program had a medium to very large effect on the FTSST and TUG test at 12 weeks (range Cohen *d*=0.6-1.5) compared to usual care. These effects were still present at the 6-month follow-up measurement (range Cohen *d*=0.5-1.2). Regarding the self-reported outcomes, the effect sizes at 12 weeks ranged from small to very large. In particular, function in activities of daily living for the HOOS and physical functioning for the SF-36 showed large and very large effect sizes. At the 6-month follow up, a large or very large effect was found on all subdomains of the HOOS and SF-36, except for general health perception of the SF-36.

Table 3. Objective outcome measures of the study population (N=42).

Measurement	Intervention group (n=15)	Control group 1 (n=15)	Control group 2 (n=12)	Odds ratio (95% CI)[a]	*P* value
TUG[b] (seconds), mean (SD)					
T1[c]	10.5 (2.1)	14.8 (4.0)	13.3 (3.9)	0.68 (0.48-0.97)	.04
T2[d]	8.0 (1.0)	10.3 (2.6)	10.0 (3.4)	0.34 (0.14-0.84)	.02
T3[e]	7.5 (1.0)	9.02 (1.9)	8.9 (2.5)	0.33 (0.13-0.86)	.02
FTSST[f] (seconds), mean (SD)					
T1	14.9 (2.9)	21.3 (4.5)	17.7 (3.5)	0.75 (0.56-1.00)	.05
T2	12.6 (1.9)	16.7 (2.4)	14.9 (3.1)	0.49 (0.24-0.99)	.05
T3	11.7 (1.5)	14.7 (2.5)	14.0 (2.4)	0.56 (0.31-0.99)	.05

[a] Results of conditional logistic regression, corrected for baseline.

[b] TUG: Timed Up & Go test.

[c] T1: 4 weeks.

[d] T2: 12 weeks.

[e] T3: 6 months.

[f] FTSST: Five Times Sit-to-Stand Test.

Table 4. Mean (SD) of self-reported outcome measures of the study population (N=42).

Measure	Intervention group (n=15)	Control group 1 (n=15)	Control group 2 (n=12)	Odds ratio (95% CI)[a]	*P* value
HOOS[b]					
Pain					
T1[c]	88.8 (7.6)	71.7 (17.1)	73.5 (15.9)	1.24 (0.93-1.64)	.14
T2[d]	94.0 (3.4)	87.9 (10.7)	78.5 (16.6)	1.19 (0.98-1.45)	.09
T3[e]	98.7 (2.1)	85.1 (12.5)	85.6 (11.3)	1.29 (0.94-1.77)	.12
Other symptoms					
T1	75.3 (13.2)	68.0 (18.9)	62.1 (14.1)	1.03 (0.97-1.09)	.33
T2	82.3 (10.0)	78.7 (15.8)	74.6 (13.1)	1.04 (0.96-1.13)	.37
T3	91.0 (6.0)	76.3 (13.0)	77.5 (17.7)	1.10 (1.00-1.21)	.06
Function in ADL[f]					
T1	76.5 (8.0)	60.6 (17.0)	58.1 (15.3)	1.22 (0.94-1.57)	.13
T2	92.8 (8.5)	79.0 (11.3)	69.7 (14.8)	1.24 (0.99-1.55)	.06
T3	96.8 (3.6)	80.0 (15.6)	79.1 (15.6)	1.25 (0.94-1.67)	.13
Function in sport and recreational activities					
T1	70.0 (18.8)	26.7 (20.1)	29.7 (24.3)	1.10 (1.01-1.20)	.04
T2	76.3 (20.5)	63.8 (26.1)	49.1 (21.6)	1.04 (1.00-1.07)	.04
T3	82.5 (11.6)	59.6 (19.3)	64.9 (24.1)	1.09 (1.01-1.17)	.03
Hip-related quality of life					
T1	50.8 (15.1)	45.8 (18.3)	43.2 (19.5)	1.04 (0.99-1.10)	.11
T2	75.4 (14.8)	71.3 (19.7)	63.0 (21.4)	1.03 (0.99-1.07)	.21
T3	88.8 (8.9)	71.3 (20.2)	69.3 (22.5)	1.09 (1.02-1.17)	.02
SF-36[g]					
Physical functioning					
T1	54.8 (15.9)	41.1 (20.2)	36.3 (20.6)	1.04 (1.00-1.08)	.09
T2	86.0 (6.8)	62.6 (19.2)	538 (18.0)	1.30 (0.89-1.91)	.17
T3	89.0 (7.1)	65.0 (18.9)	59.2 (20.8)	1.26 (0.99-1.60)	.07
Role limitations: physical					
T1	20.0 (34.3)	23.3 (29.1)	6.3 (15.5)	1.01 (0.99-1.04)	.35
T2	70.0 (42.5)	38.3 (42.1)	37.5 (34.5)	1.04 (1.00-1.08)	.04
T3	93.3 (25.8)	56.7 (44.8)	45.8 (39.7)	1.04 (1.00-1.08)	.03
General health perception					
T1	83.1 (15.3)	77.4 (15.9)	66.9 (17.3)	1.00 (0.94-1.07)	.91
T2	86.1 (13.5)	73.9 (20.8)	63.0 (22.2)	1.05 (0.97-1.13)	.26
T3	84.8 (21.5)	72.6 (14.8)	63.4 (31.8)	1.01 (0.97-1.07)	.57

[a] Conditional logistic regression adjusted for baseline for comparison of the two control groups and intervention group.

[b] HOOS: Hip disability and Osteoarthritis Outcome Score; scale of 0-100 (0 = extreme symptoms, 100 = no symptoms).

[c] TI: 4 weeks.

[d] T2: 12 weeks.

[e] T3: 6 months.

[f] ADL: activities in daily living.

[g] SF-36: 36-item Short Form Health Survey; scale of 0-100 (higher score = better perceived health or functioning).

Table 5. Cohen *d* (95% CI) based on mean (SD) functional measure values corrected for baseline.

Measurement	Twelve weeks		Six months	
	Intervention group vs control group 1	Intervention group vs control group 2	Intervention group vs control group 1	Intervention group vs control group 2
TUG[a]	**1.2**[b] (0.4-1.9)	0.7 (–0.1-1.4)	**1.1** (0.3-1.8)	0.6 (–0.2-1.4)
FTSST[c]	**1.5** (0.6-2.2)	0.6 (–0.2-1.3)	**1.2** (0.4-2.0)	0.5 (–0.3-1.3)
HOOS[d]				
Pain	0.6 (–0.2-1.3)	**1.4** (0.5-2.2)	**1.4** (0.6-2.2)	**1.4** (0.5-2.2)
Other symptoms	0.0 (–0.7-0.7)	0.5 (–0.3-1.2)	**0.9** (0.1-1.6)	**0.9** (0.1-1.7)
Function in ADL[e]	**1.2** (0.4-1.9)	**1.9** (1.0-2.8)	**1.3** (0.4-2.0)	**1.3** (0.5-2.1)
Function in sport and recreational activities	0.5 (0.2-1.3)	**1.2** (0.3-1.9)	**1.2** (0.4-1.9)	**0.9** (0.1-1.7)
Hip-related quality of life	0.2 (–0.5-0.9)	0.6 (–0.2-1.4)	**1.0** (0.2-1.7)	**1.2** (0.3-1.9)
SF-36				
Physical functioning	**1.3** (0.5-2.1)	**1.8** (0.8-2.6)	**1.2** (0.4-1.9)	**1.5** (0.6-2.2)
Role limitations: physical	**0.8** (0.1-1.6)	**0.9** (0.0-1.6)	**0.9** (0.1-1.6)	**1.2** (0.3-1.9)
General health perception	0.2 (–0.5-0.9)	0.2 (–0.6-0.9)	0.1 (–0.6-0.8)	–0.1 (–0.8-0.7)

[a] TUG: Timed Up & Go test.

[b] Effect sizes of $d>0.80$ are in bold.

[c] FTSST: Five Times Sit-to-Stand Test.

[d] HOOS: Hip disability and Osteoarthritis Outcome Score.

[e] ADL: activities in daily living.

[f] SF-36: 36-item Short Form Health Survey.

Discussion

The aim of this study was to determine the effectiveness of a home-based rehabilitation program delivered by means of internet technology. To that end, the effectiveness of the program was compared with usual care in the Netherlands. It was hypothesized that a home-based rehabilitation program could be an effective alternative to usual care.

Significant differences were found considering the objective outcomes, and the home-based rehabilitation program also seemed to have had large to very large effects on the TUG test and FTSST at the end of the 12-week program. These large effect sizes in favor of the intervention group were still present at the 6-month follow-up measurement. These results are further supported by the self-reported outcomes. In particular, function in activities of daily living for the HOOS and physical functioning for the SF-36 showed very large effect sizes. At the 6-month follow-up measurement, a large or very large effect was found on all subdomains of the questionnaires, with a medium to large effect found only on the general health perception domain of the SF-36. It can therefore be concluded that compared to usual care, the home-based rehabilitation program has a large to very large effect on disease-specific outcome measures and quality of life.

Austin et al [4] demonstrated that a rehabilitation program does not need to take place in a formal setting to be effective. Our study further shows that recent technological developments can be helpful in providing such a home-based rehabilitation program for patients after THA. Another advantage is that owing to recent technological developments, our program can start immediately after surgery, as advised by Bandholm and Kehlet [3]. Furthermore, earlier research found that physical exercises are similarly effective whether they are performed unsupervised at home or supervised in an outpatient setting [4,5]. Our results show that a home-based rehabilitation program can also be effective when offered with the help of modern technology.

Although the home-based rehabilitation program was performed unsupervised at home, the Web-based app gave participants feedback on their training performance, and remote support was provided through weekly telephone contact with a physiotherapist. A systematic review by Geraedts et al [6] showed that remote coaching in home-based rehabilitation programs is a good alternative to supervised physiotherapy in an outpatient setting. The results of our study are in line with this conclusion. During these phone calls, the physiotherapist and patient evaluated the progress and agreed on whether to train at a higher level. Hoogland et al [7] investigated the feasibility of this home-based rehabilitation program, showing that patients appreciated the weekly telephone-based remote support. The importance of this weekly telephone contact is in line with a previous study of Silveira et al [22] showing that motivation and coaching are important factors for home-based exercise performance and enhanced adherence. Hoogland et al [7] found good adherence to this home-based rehabilitation program and a positive patient experience. This is also in line with other studies indicating that telerehabilitation leads to high levels of patient satisfaction [23,24].

In demonstrating large effects in the intervention group, the results of our study imply that a home-based rehabilitation program after THA can be more effective than usual care. It can therefore be concluded that such a program is an effective alternative to formal physiotherapy. As patients in the Netherlands need additional insurance for physiotherapy or have to pay for it themselves, this could be an option to offer every patient a certain amount of physiotherapy. Although the cost-effectiveness has not yet been determined, a home-based rehabilitation program is likely to be more cost-effective than usual care. A physiotherapist will work for fewer hours, without compromising the effectiveness of the rehabilitation program for patients. In addition, a home-based rehabilitation program can be more suitable than usual care for (1) elderly people who cannot come to the physiotherapy practice by themselves; (2) people living in remote, rural areas who are not always able to travel far; and (3) people who live independently and are not allowed to travel by car the first 6 weeks after surgery.

A limitation of the study is the small number of patients, although this was deliberately chosen as it was a pilot study. However, this small number of patients did not limit finding large effect sizes. In addition, patients who had agreed to participate in the intervention were expected to be able to complete the home-based rehabilitation program, as we wanted to test the intervention for the first time. It is therefore possible that there was selection bias, as patients of the intervention group were probably more motivated than the average patient. Nonetheless, the wide variety in educational level, age, and living situation seems to have provided a representative group. Although there were differences between the intervention group and control groups, these were corrected for in our analyses. Lastly, since patients in the Netherlands need additional insurance for physiotherapy or have to pay for it themselves, there is variability in health care consumption within usual care, resulting in a heterogeneous control group in the current study; some patients received no physiotherapy at all, while others received up to 48 hours of physiotherapy. This variability is representative of the current situation in the Netherlands.

In conclusion, our results clearly demonstrate larger effects in the intervention group, implying that a home-based rehabilitation program after THA can be more effective than usual care. In future research, it would be interesting to conduct a randomized controlled trial with a larger sample size and where at least the outcome assessor is blinded. In addition, it would be worthwhile to investigate whether the home-based rehabilitation program is also effective for people older than 65 and suitable for patients with low preoperative physical functioning. Cost-effectiveness should also be assessed.

Acknowledgments

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Conflicts of Interest

JA is a Philips Research employee. Philips Research provided technical support for the study.

Multimedia Appendix 1
Content of the home-based rehabilitation program.
[DOCX File , 19 KB - rehab_v7i1e14139_app1.docx]

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Abbreviations

FTSST: Five Times Sit-to Stand Test
HOOS: Hip disability and Osteoarthritis Outcome Score
SF-36: 36-item Short Form Health Survey
THA: total hip arthroplasty
TUG: Timed Up & Go test

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Original Paper

Therapist-Guided Telerehabilitation for Adult Cochlear Implant Users: Developmental and Feasibility Study

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Abstract

Background: Cochlear implants can provide auditory perception to many people with hearing impairment who derive insufficient benefits from hearing aid use. For optimal speech perception with a cochlear implant, postoperative auditory training is necessary to adapt the brain to the new sound transmitted by the implant. Currently, this training is usually conducted via face-to-face sessions in rehabilitation centers. With the aging of society, the prevalence of age-related hearing loss and the number of adults with cochlear implants are expected to increase. Therefore, augmenting face-to-face rehabilitation with alternative forms of auditory training may be highly valuable.

Objective: The purpose of this multidisciplinary study was to evaluate the newly developed internet-based teletherapeutic multimodal system Train2hear, which enables adult cochlear implant users to perform well-structured and therapist-guided hearing rehabilitation sessions on their own.

Methods: The study was conducted in 3 phases: (1) we searched databases from January 2005 to October 2018 for auditory training programs suitable for adult cochlear implant users; (2) we developed a prototype of Train2hear based on speech and language development theories; (3) 18 cochlear implant users (mean age 61, SD 15.4 years) and 10 speech and language therapists (mean age 34, SD 10.9 years) assessed the usability and the feasibility of the prototype. This was achieved via questionnaires, including the System Usability Scale (SUS) and a short version of the intrinsic motivation inventory (KIM) questionnaires.

Results: The key components of the Train2hear training program are an initial analysis according to the International Classification of Functioning, Disability and Health; a range of different hierarchically based exercises; and an automatic and dynamic adaptation of the different tasks according to the cochlear implant user's progress. In addition to motivational mechanisms (such as supportive feedback), the cochlear implant user and therapist receive feedback in the form of comprehensive statistical analysis. In general, cochlear implant users enjoyed their training as assessed by KIM scores (mean 19, SD 2.9, maximum 21). In terms of usability (scale 0-100), the majority of users rated the Train2hear program as excellent (mean 88, SD 10.5). Age (P=.007) and sex (P=.01) had a significant impact on the SUS score with regard to usability of the program. The therapists (SUS score mean 93, SD 9.2) provided slightly more positive feedback than the cochlear implant users (mean 85, SD 10.3).

Conclusions: Based on this first evaluation, Train2hear was well accepted by both cochlear implant users and therapists. Computer-based auditory training might be a promising cost-effective option that can provide a highly personalized rehabilitation program suited to individual cochlear implant user characteristics.

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KEYWORDS

telerehabilitation; cochlear implantation; computer-based auditory training; multimodal platform system

Introduction

Hearing impairment is a major public health problem that affects one third of people aged 65 years or older worldwide, and its prevalence is expected to increase in the future in line with global demographic shifts toward an older population [1,2]. The impact of age-related hearing loss is enormous and extends beyond simply not hearing, as people with impaired hearing have a higher risk for cognitive decline, depression, and frailty [3-5]. Hearing restoration via cochlear implant provision has become a well-accepted treatment option for people of all ages with sensorineural hearing loss, enabling many users to achieve open-set spoken word recognition [6,7].

Typically, a cochlear implant is activated and fit to the recipient 4 weeks after implantation. After cochlear implant activation, (re)habilitation begins, including active auditory training as a vital component [8,9]. This step is necessary because the brain must adapt to the new auditory signal, which differs from the auditory signal that it has been accustomed to [10-12]. In general, there are two different auditory training approaches: (1) the analytic bottom-up approach, which is based on the presentation of paired sounds to train specific skills; and (2) the synthetic top-down approach, which uses sentence identification or text comprehension to improve the cochlear implant users' overall communication skills [13,14]. The difficulty level of the training has to be built up in a hierarchical manner starting with the simple detection of sound and the discrimination between different signals, progressing to the identification of a sound and understanding complete sentences, even in the presence of background noise [15].

Rehabilitation sessions are conducted in a face-to-face manner in specialized clinical settings [16]. At present, this arrangement works well; however, it may not be as effective or convenient in the future given the finite availability of clinicians/therapists along with the expected increase in the number of cochlear implant users in line with population aging, longer lifespans, and expanding candidacy criteria [17,18]. Further, cochlear implant users may face several potential obstacles in accessing face-to-face rehabilitation sessions, including inadequate reimbursement of the cost-intensive therapeutic sessions by (public) insurance, problems reaching the clinic due to mobility difficulties or geographic distance, and possible comorbidities [19].

Digital media has now become a part of everyday life [20], and electronic health has been one of the fastest growing economic sectors with potential to improve the accessibility of speech and language pathology services [21]. Furthermore, surveys among people with hearing impairment have clearly demonstrated that the majority of subjects are interested in teletherapeutic listening training because it would enable them to train at any place and time [22].

To date, teletherapeutic approaches have mostly focused on patients with neurogenic disorders, and teletherapy was reported to be as effective as standard face-to-face regimes for people with aphasia [23-26]. However, computer-based auditory rehabilitation for people with a cochlear implant is still at an early stage, especially in the German-speaking world [27,28]. By contrast, several English-language, computer-based auditory training programs exist for adults with hearing loss (hearing aid or cochlear implant users), which are primarily intended to supplement, and not to replace, standard face-to-face therapy [29,30].

Most listening programs are self-directed, such as the well-known Listening and Communication Enhancement (LACE; NeuroTone, Redwood City, CA, USA) structured program with interactive and adaptive tools [31-34]. In addition, Speech Perception Assessment and Training System (SPATS; Communication Disorders Technology Inc, Bloomington, IN, USA) is based on a defined training schedule and includes both analytic and synthetic elements [35]. Computer-Assisted Speech Training (CAST) was developed by the Emily Shannon Fu Foundation with free access via Angel Sound (New York, NY, USA), which incorporates a large variety of speech materials and training protocols, along with various mechanisms concerning audio-visual feedback and adaptivity [36].

A critical factor of home-based training is the user's adherence to the training program [29,37,38]. An important mechanism to encourage people with a chronic illness—who are often driven by external motivation—to persevere with training/rehabilitation is to convert their motivation from external to internal [37]. According to the self-determination theory of Ryan and Deci [39], an individual's experiences of autonomy, competence, and relatedness are the main elements of motivation. Thus, fostering these experiences is integral to the success of a rehabilitation program [37,39]. Furthermore, the cochlear implant user's compliance with the program and the usability of the program, which determines the interaction between person and machine, contributes to the variability in training outcome [31]. In short, the user must be self-motivated and the program must be usable and useful for a successful outcome. For this reason, the end users have to be included in the development process to rule out barriers that might hamper the uptake of the new technology by the health care professionals and the patients, whose attitudes and needs may differ [40,41].

In this regard, the purpose of the present multidisciplinary research project was to develop a highly individualized and structured internet-based teletherapeutic system (Train2hear) for auditory rehabilitation and to evaluate the system's usability and feasibility.

Methods

Search Strategy

To identify the existing German-language computer-based auditory training programs for adult cochlear implant users and to guide our development of Train2hear, we searched various scholarly search databases (MEDLINE, Embase, PubMed, Cochrane, Google Scholar). We were particularly interested in the training modalities, delivery system, and theoretical background of published programs.

Content of the Training

The principle elements of the Train2hear platform were defined according to theoretical auditory rehabilitation concepts, auditory processing models, and the multimodal biopsychosocial concept set forth in the International Classification of Functioning, Disability and Health (ICF) proposed by the World Health Organization [10,42]. A general training schedule was established with different types of exercises that covered various linguistic modalities, which were further split into different tasks. Adaptivity and feedback mechanisms were analyzed and selected. Learning and motivational concepts were evaluated with regard to aural rehabilitation and then adapted to the new training platform.

User Participation

Keeping the user in mind during program development [43], 18 cochlear implant users and 10 experienced speech and language therapists were involved in the entire development process and in this first feasibility study. Once presenting the entire platform to the users, the participants were asked to judge the program after completing two different exercises without guidance of the researcher. The cochlear implant users (13 women, 5 men; mean age 61 years, range 20-84 years) had bilateral deafness and had been using a cochlear implant for a mean of 2.7 years (range 0.5-8 years). The 10 therapists were all women with a mean age of 34 years.

Four questionnaires were used to assess Train2hear: the Bochumer Questionnaire, System Usability Scale (SUS), Short Scale of Intrinsic Motivation (*Kurzskala der intrinsischen Motivation,* KIM), and Therapists' Questionnaire.

The Bochumer Questionnaire was created specifically for this study to assess user experience with Train2hear. This questionnaire contains 33 questions, which all require a “yes” or “no” answer, that cover the following 5 topics: exercise, feedback, statistical features, overall assessment, and relevance. This questionnaire was completed only by the cochlear implant users. For the exercise topic, the users evaluated two exercises, and therefore completed this section twice; for the other sections, the questions were answered once.

The SUS was used to assess the usability of Train2hear [44]. The SUS includes 10 questions requiring responses on a 5-point Likert scale in which the endpoints are “I strongly disagree” and “I strongly agree”. Five statements were associated with an answer of “I strongly agree” to indicate an overall positive assessment of Train2hear. This scoring method was reversed for the other 5 statements in which “I strongly agree” indicated a negative assessment of Train2hear. An answer of “I strongly agree” was worth 4 points and an answer of “I strongly disagree” was worth 0 points; thus, the higher the score, the more positive the assessment. The total score of the SUS is an absolute number based on the answers of all questions given by the total number of participants. A mean score >68 indicates a high level of usability [45]. Furthermore, for each question, an absolute number and percentage is calculated based on the answers of all participants. The SUS was completed by both the cochlear implant users and therapists.

The KIM was used to assess the cochlear implant users’ intrinsic motivation. This questionnaire is the short form of the Intrinsic Motivation Inventory proposed by Wilde et al [46]. The KIM contains 12 questions, which require responses on a 7-point Likert scale in which 1 means “not at all” and 7 means “very true.” The 12 questions are subdivided into 4 sections: interest/enjoyment, perceived competence, perceived choice, and pressure/stress. The maximum score on each subscale is 21. The first 3 sections are positive (ie, the higher the score, the more positive the assessment), and the last section is negative (ie, the lower the score, the more positive the assessment). The KIM was completed by only the cochlear implant users.

The Therapists Questionnaire was created for this study to assess the therapists’ opinion of the quality of the therapeutic concept and the usability of the new hearing platform. This questionnaire contains 29 questions requiring responses on a 5-point Likert scale in which 0 means “not true” and 4 means “very true.” Only the therapists completed this questionnaire.

Statistical Analysis

For the SUS and the KIM, inferential statistics were employed to determine if age (Kendall tau) or sex (exact *U* test) of the cochlear implant users significantly affected their scores. For the SUS, the *U* test was used to compare the scores of cochlear implant users with those of the therapists for each question separately and for the total group mean. For the KIM, which was only completed by the cochlear implant users, the analysis was performed for each question separately and for the mean of the total for each of the 4 subgroups. Scores for the Bochumer Questionnaire and the Therapist Questionnaire were summarized descriptively by the mean and SD. $P<.05$ was regarded as a statistically significant difference.

Ethics

This study was conducted in accordance with the Declaration of Helsinki (from 2018 to 2020) and was approved by the Ethics Committee of Ruhr University of Bochum (18-6423-BR and 18-6423_1-BR).

Results

Aural Rehabilitation Programs

Our literature search revealed a limited number of different computer-based auditory training programs available in German for cochlear implant users. Most of these programs are designed as additional training to consolidate the training progress of standard face-to-face therapy, which are all cochlear implant user–driven and self-administered. See Multimedia Appendix 1 for a summary of these programs.

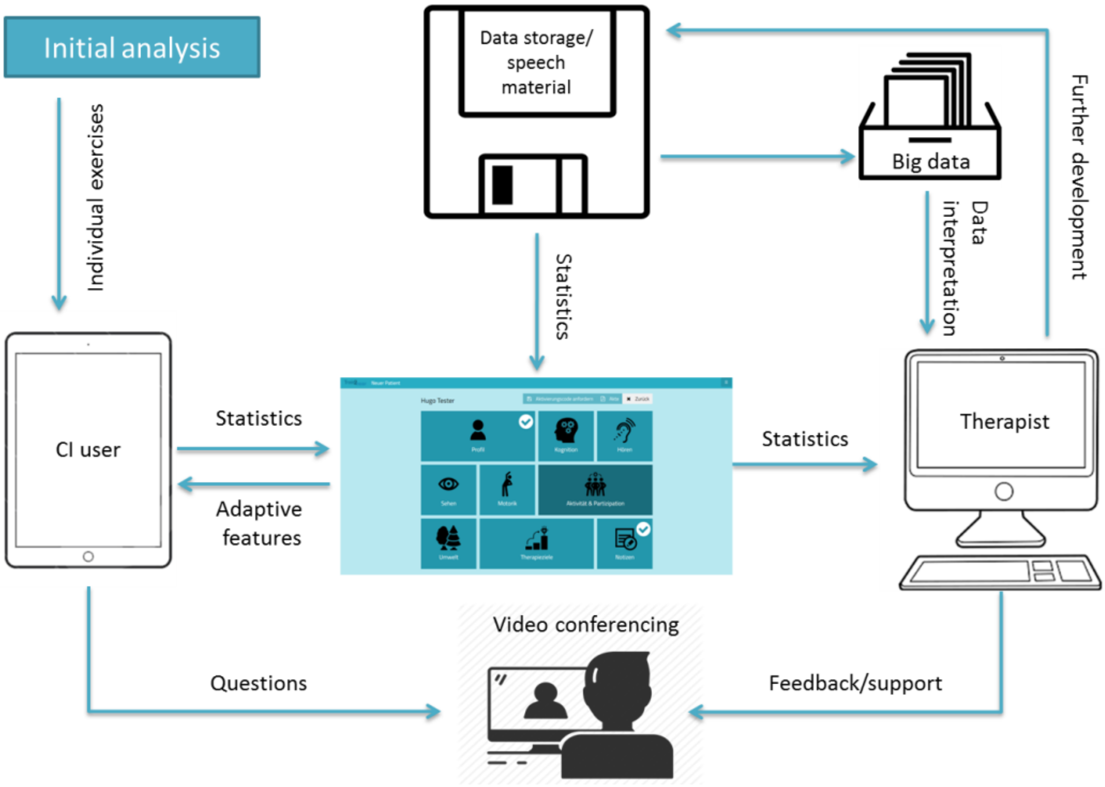
Development of a New Hearing Platform

Background

The features and the key elements of the training program were defined according to the theoretical models of auditory processing and speech understanding proposed by McClelland and Elman [47], Gaskell and Marslen-Wilson [48], Erber [15], and Rönnberg et al [49]. The key elements of the training program are Initial Analysis, Feedback, and Motivation.

The basic components of the hearing platform consist of three different interfaces: one for the cochlear implant user, one for the therapist, and one administrative backend that contains all data and speech material (see Figure 1). To enable personal contact between the cochlear implant user and the therapist, a video conferencing feature was included.

Figure 1. Overview of the concept of the Train2hear hearing platform. CI: cochlear implant.



Initial Analysis

To start the program, the therapist creates an account for the cochlear implant user. The therapist then enters the cochlear implant user's characteristics into the program (Multimedia Appendix 2). Once this step is completed, a login code is sent to the cochlear implant user.

Schedule

The training schedule involves a fictitious trip through Europe, which the cochlear implant user follows in a predetermined order (Figure 2). Each city represents a specific auditory level, in which a defined number of exercises must be completed. The scenarios selected at each city are related to everyday life while traveling, such as checking into a hotel, eating in a restaurant, or taking part in a guided tour (Figure 3). During the journey, the cochlear implant user can choose additional exercises such as games, including memory or crossword puzzles.

Figure 2. Overview of the training schedule during the Train2hear trip.

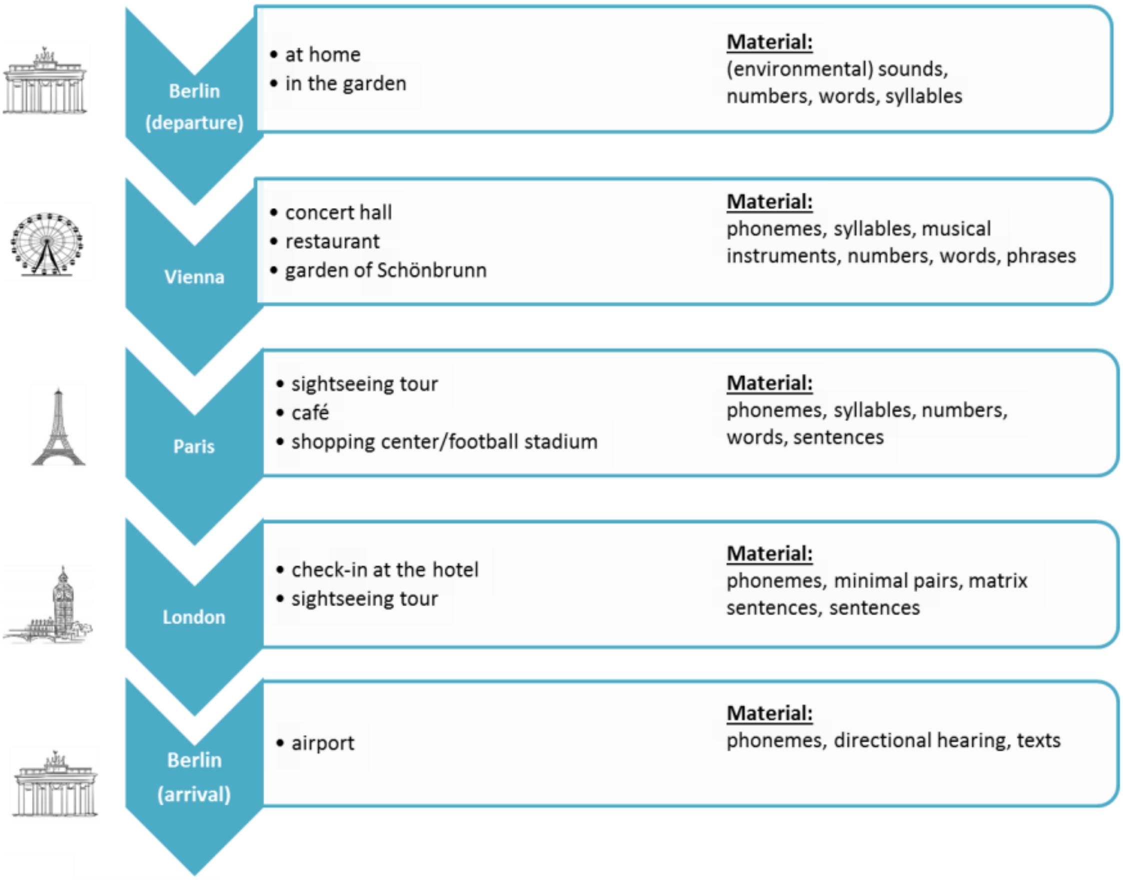
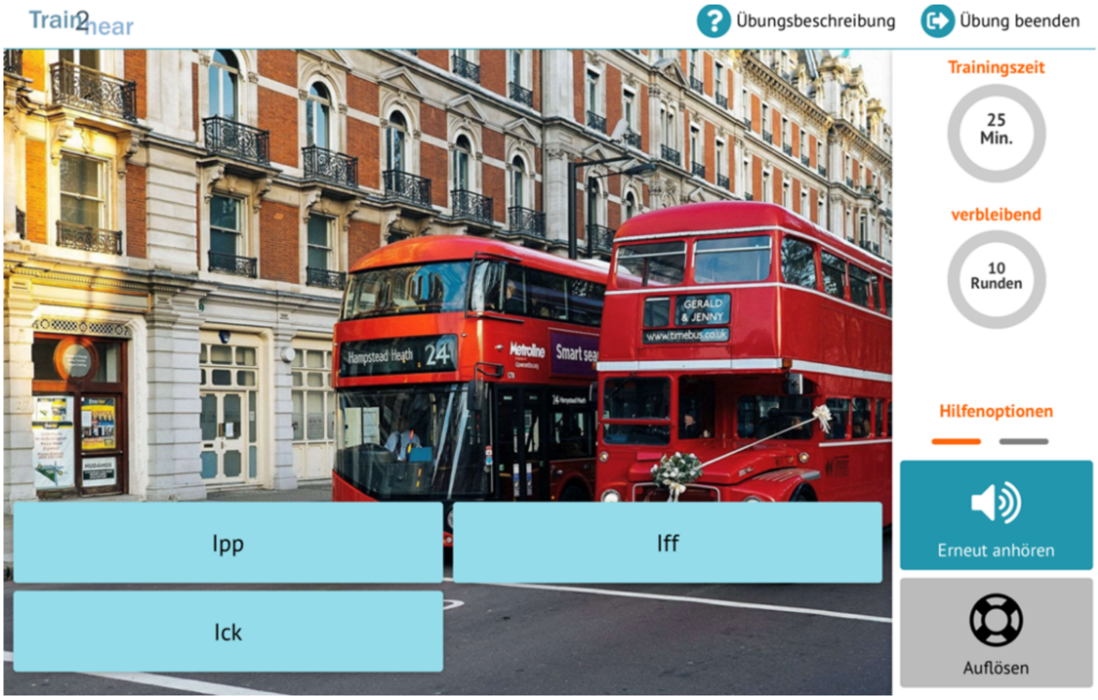


Figure 3. Example of an exercise task (phoneme discrimination).



Speech Material

A total of 30 speech tasks were implemented in the training schedule in a hierarchical manner (Figure 2). The speech material used to build up the different tasks covers more than 500 different single words, 600 sentences of different lengths, and about 50 different text messages as well as 500 minimal pairs and 300 syllables spoken by a female and a male speaker. In addition, 50 nonspeech sounds, including musical instruments, were included along with about 25 different background noises with a signal-to-noise ratio ranging from

–20 to 20 dB. To prevent learning effects, the audio files are randomly chosen by the program.

Adaptivity

The cochlear implant users' metrics such as errors, scores, and task completion times are continually captured during the training. This enables the difficulty of the exercises to be automatically and continually adjusted according to the cochlear implant user's performance during the exercises. Different mechanisms concerning the speech material, listening conditions, and level of perception have been defined and included for this purpose (Figure 4). Figure 5 presents an example of this adaptivity. When the cochlear implant user's answers are correct, phonologically similar words are added to make auditory differentiation more challenging; when the performance of the cochlear implant user declines, only words that do not show any phonological similarity are presented.

Figure 4. Dimensions of adaptivity (theoretical framework). CI: cochlear implant.

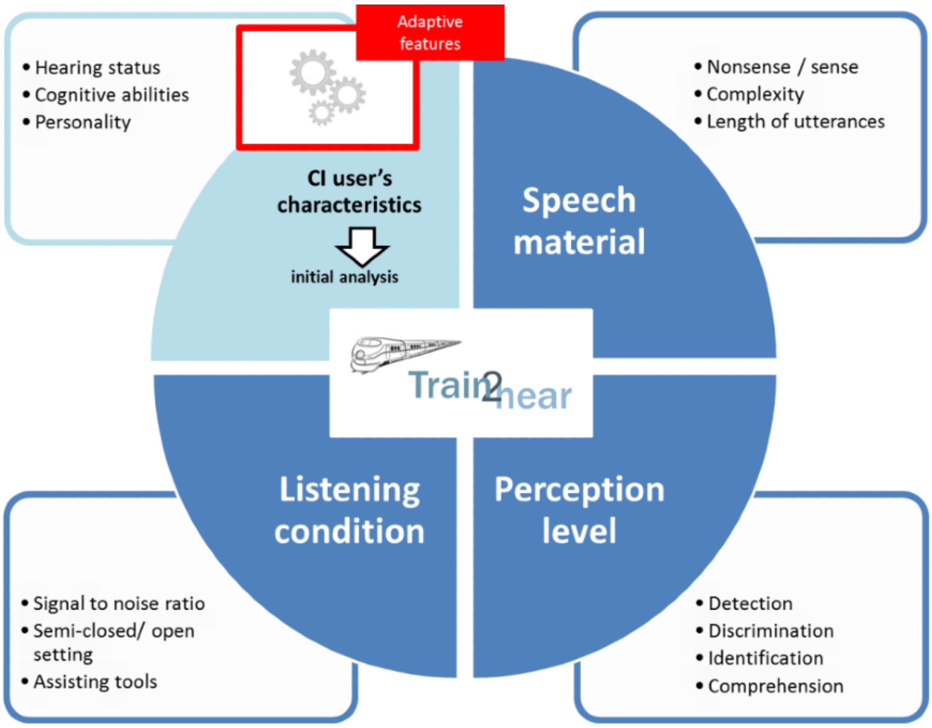
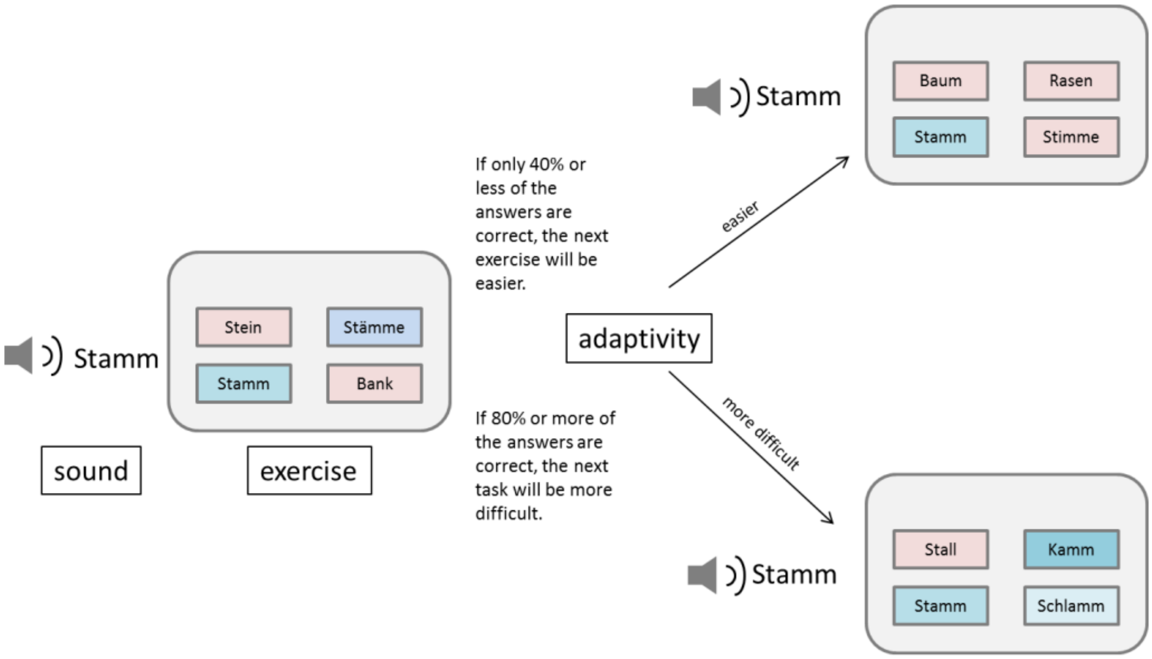


Figure 5. Example of mechanisms of adaptivity.



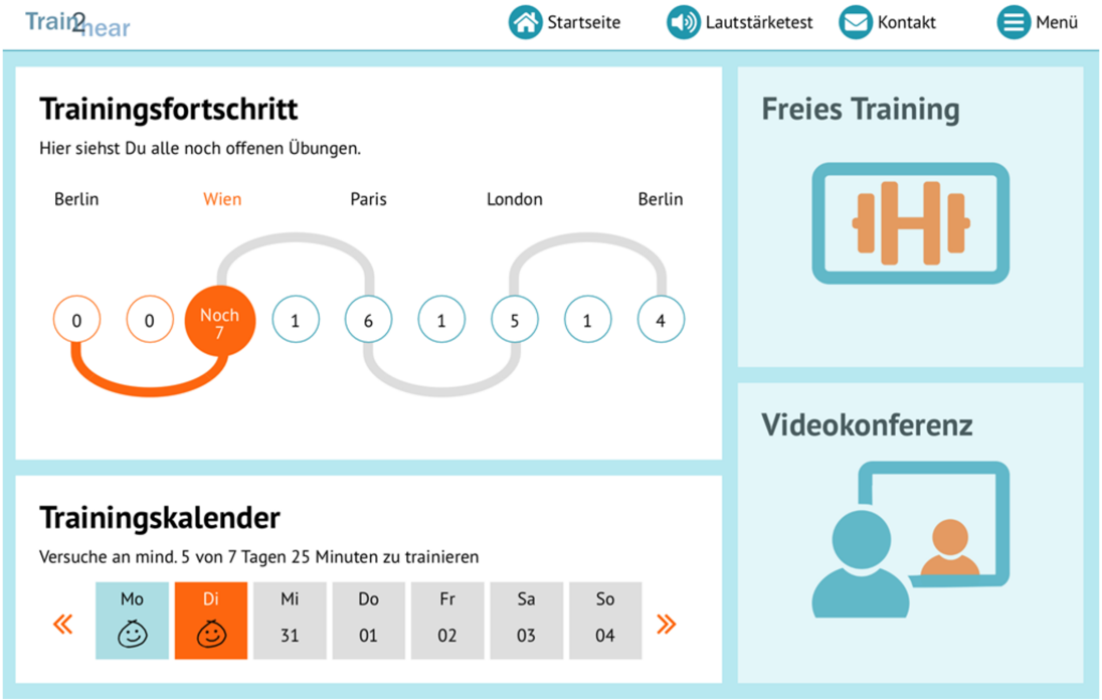
Feedback

Different feedback mechanisms were selected and integrated as supportive elements. Feedback is provided regarding the correctness of the response after completing each exercise. The cochlear implant user's performance is monitored on a statistics page, which is available to both the user and to the therapist at any time during training. Help functions allow the cochlear implant user to repeat an item up to three times or to suppress the background noise.

Motivation

Motivational enhancement techniques were implemented according to the self-determination theory of Ryan and Deci [39], which is based on competence, autonomy, and relatedness. To promote the feeling of competence, an optimal level of difficulty adapted to the individual patient's level and positive feedback after each exercise were implemented. Autonomy was encouraged by allowing the user to perform the training anywhere and at any time. The feeling of relatedness was intended to be achieved by specific verbal information and a detailed statistical analysis provided to the cochlear implant user. Furthermore, a train conductor who serves as an avatar along with a calendar about the time spent in the training were added to the program as additional motivational elements (Figure 6).

Figure 6. Overview of the cochlear implant user's training schedule.



Trainingsfortschritt

Hier siehst Du alle noch offenen Übungen.

Freies Training

Videokonferenz

Trainingskalender

Versuche an mind. 5 von 7 Tagen 25 Minuten zu trainieren

Technical Requirements

Train2hear is a web-based platform designed for a tablet with the mobile operating system iOS and requires access to a wireless network. Passwords are saved in a hashed manner and are indiscernible to outsiders. All data regarding the training are saved for each account separately.

Questionnaires

Bochumer Questionnaire

Overall, the cochlear implant users found that the program met their expectations, that they would recommend it to others, and that they would like to continue using it (items 27-29). Additionally, they reported that the exercises were interesting and relevant to their daily lives (items 30-31).

Multimedia Appendix 3 lists the responses to each item in the questionnaire. A minority of cochlear implant users reported that they had difficulty finding the exercise (item 1) and that they would need more detailed information on their mistakes in order to improve (item 12). Otherwise, the responses were overwhelmingly positive: over 90% of cochlear implant users reported that the exercise was clear (item 2), the function of each button was clear (item 5), images were clear and appealing (items 8 and 9), and feedback was understandable, visually appealing, helpful, motivating, and sufficient (items 11, 13-17). More than 80% of users found the statistical features helpful and clear (items 18-21). A few responses were missing as some cochlear implant users were unsure about the best answer.

SUS

The mean total SUS score was 85.3 (SD 10.32) for cochlear implant users and 93.0 (SD 9.17) for therapists. These scores (and the scores for each question) indicate that both groups found that Train2hear has excellent usability (Multimedia Appendix 4) [45].

No significant difference in total mean SUS scores was found according to group (P=.05). Therapists had significantly higher mean scores on items 7 (P=.04) and 10 (P=.02).

Regarding a possible influence of age on usability among cochlear implant users, increased age negatively correlated with SUS score with respect to the total mean percent (P=.008) and on items 2 (P=.03), 5 (P=.009), 7 (P=.007), and 10 (P=.03).

Regarding a possible influence of sex on usability amongst cochlear implant users, men had significantly higher scores than women on item 7 (P=.01). Some answers were missing because some cochlear implant users and one therapist were unsure about the right answer. See Multimedia Appendix 4 for the full SUS questionnaire items and associated answers.

Intrinsic Motivation

Scores on the interest/enjoyment subsection of the KIM indicated that cochlear impact users found the program interesting and enjoyable. Scores of the pressure/stress subsection (in which, unlike the other subsections, low scores indicate positive feedback) showed that the cochlear implant users did not feel to be under a great deal of pressure while working on the program (Table 1).

Regarding a possible influence of age, increased age negatively correlated with scores on items 7 (P=.004), 10 (P=.007), 11 (P=.02), and 12 (P=.01), and on the total score for the pressure/stress subsection (P<.001). No significant differences were found according to sex. See Table 1 for the full KIM questionnaire and answers. One user did not answer all questions.

Table 1. Intrinsic motivation (KIM[a]) scores for cochlear implant users (N=18).

Item	n (%)	Mean (SD)
Interest/enjoyment		
1. I enjoyed working with the program.	18 (100)	6.50 (0.70)
2. I found working with the program was very interesting.	18 (100)	6.56 (0.71)
3. Working with the program was enjoyable.	18 (100)	6.22 (1.06)
Total	18 (100)	19.28 (2.27)
Perceived competence		
4. I am satisfied with my performance with the program.	18 (100)	5.78 (1.35)
5. I was skillful when working with the program.	18 (100)	5.67 (1.33)
6. I think I was pretty good at using this program.	18 (100)	5.50 (1.38)
Total	18 (100)	16.94 (2.92)
Perceived choice		
7. I was able to manipulate the program myself.	18 (100)	5.22 (1.48)
8. I could choose how to use the program.	17 (94)	4.77 (2.11)
9. I could proceed the way I wanted in the program.	17 (94)	4.77 (2.05)
Total	17 (94)	14.71 (4.87)
Pressure/stress		
10. I felt under pressure while working with the program.	18 (100)	1.39 (1.42)
11. I felt stressed while working with the program.	18 (100)	2.50 (2.01)
12. I was not sure if I could work well with the program.	18 (100)	2.33 (1.94)
Total	18 (100)	6.22 (3.95)

[a] KIM: Kurzskala intrinsischer Motivation; scores are based on a Likert scale in which higher scores indicate more positive answers except for the subsection Pressure/Stress, in which lower scores indicate more positive answers.

Therapist Questionnaire

The therapists found that the program was easy to navigate (items 1-2, 15); had exercises that were clear, relevant, and appealing (items 6-11); and provided feedback that was appealing and motivating for cochlear implant users (items 12-14). Overall, for most therapists, Train2hear met their expectations and they could imagine using it in their therapeutic regimes and recommending it to cochlear implant users (items 22-24). Therapists clearly indicated that the program could enhance regular (face-to-face) training but could not replace it (items 25-27). All therapists thought the program was scientifically sound (item 29).

Although the therapists expressed concern over the clarity of the statistics (items 5, 17), they also indicated that the statistical analysis made it easy for cochlear implant users to understand their own performance (item 18). Some answers were missing as one therapist was unsure of the best answer. See Multimedia Appendix 5 for the full questionnaire items and answers.

Discussion

Principal Findings

A teletherapeutic computer-based training platform named Train2hear was developed, and its feasibility was primarily assessed with cochlear implant users and therapists. This platform allows adult cochlear implant users to train auditory skills on their own.

New therapeutic concepts such as teletherapy have to be considered to meet the growing demand of speech therapy in the future, especially as a method for augmenting standard face-to-face therapy [50]. The advent of helpful and easy-to-use platforms that cochlear implant users can engage with wherever and whenever they like could save therapists' time while also empowering cochlear implant users (and their caregivers) by making it easier for them to participate in and benefit from the rehabilitation process [51]. This concept is in line with Mogler et al [52] who recognized the need to involve cochlear implant users, especially those with a chronic condition or disease, in the rehabilitation process.

Train2hear is a well-structured, therapist-guided program. It combines a standardized protocol and a highly individualized schedule that is tailored to the specific demands of cochlear implant users according to the principle of rehabilitation set forth by the ICF [42].

To promote optimal learning, the exercises are intended to be set at an appropriate level of difficulty; that is, sufficiently challenging to maintain motivation but not so challenging that the cochlear implant user becomes discouraged or frustrated [53]. Computer-assisted programs are an ideal option to permanently and automatically adapt to the user's level during the rehabilitation process [18]. An initial test followed by various mechanisms of adaptivity are therefore core elements of this new auditory training.

As stated by Henshaw et al [37] who analyzed a computerized phoneme discrimination training for individuals with hearing impairment, intrinsic motivation is a key factor with regard to adherence. Thereby, motivational principles to enhance intrinsic motivation have been fully considered in the new training platform [39]. In addition, strong therapeutic guidance is provided to the user by implementing strict instructions, an external control via daily log-in, a videoconferencing tool, and immediate feedback regarding progress during training, as suggested by Humes et al [54].

The results from the questionnaires revealed that both cochlear implant users and therapists viewed Train2hear positively. The cochlear implant users found the training program easy and enjoyable to use, would like to continue using it frequently, and would recommend it to others. Compared to younger users, older users rated usability slightly worse, although their scores still indicated a high level of usability. Older users were also less confident in using the program overall, and claimed to need more technical support. This is in line with previous reports indicating that age is an important variable for computer usage and that gender differences increase with age [55].

Clear introductory videos and technical support via mail, phone, or personal contact should be provided to help older adults cope with a new technology [56]. Moreover, teletherapeutic programs should be tailored to the specific physical or mental barriers faced by older people, such as diminished eyesight or deteriorated motor skills, and factors influencing the acceptance of technology by seniors have to be taken into account in the design [57].

Comparison to Previous Studies

Most computer-based modules that train auditory functions are offered as mobile apps or web-based training options, which are applied as an adjunct modality to consolidate the training progress. The majority of auditory training programs are not therapeutically guided, with the user instead selecting the type and number of exercises they wish to perform [58]. However, learners have been shown to benefit from a well-structured training program that they follow in a defined order [59]. Thus, the Train2hear program clearly defines the type of tasks the user has to perform and the user can only choose the order the tasks are performed within a given level.

Although some programs do include different levels of difficulty that the user can choose from, none of the available programs automatically adapts to the user's performance or includes a comprehensive initial evaluation of the user's strengths and weaknesses. Experts' supervision can only be obtained via email, during an in-clinic visit, or by phone. We implemented a video conference element into the new platform, which enables the therapist to perform a simple consultation and to deliver therapeutic sessions.

Limitations

A limiting factor of the present work is the small number of therapists and cochlear implant users included in this first evaluation. Another critical point to mention is the user's adherence to the training [29,37,38]. Interactional and relational processes, which have a great impact on treatment adherence and efficacy of traditional health care, are changed through human-computer interfaces. Given the importance of the user's attitude to telerehabilitation and the availability of a supporting person to the outcome of training [60], professional and nonprofessional users should both be involved in the developmental process as early as possible to increase the acceptance of telepractice. Initial reluctance is not necessarily an obstacle; indeed, Hines et al [61] demonstrated that mixed feelings of therapists toward telepractice might later change to positive awareness [61].

The cochlear implant users themselves were involved from the beginning of the study via an online survey of their needs and expectations. Furthermore, different mechanisms were implemented to encourage cochlear implant users to adhere to the new platform for long-term training. However, evaluation of adherence was not the primary target in the study design.

Outlook

In a future study, we will examine the levels of adherence to Train2hear and its effectiveness as a rehabilitation tool, including more participants for a longer period of evaluation.

Computer-based therapy platforms can record a cochlear implant user's progress in great detail. This external evidence could lead to the creation of better therapeutic interventions and training protocols [17]. Currently, standard face-to-face therapy is mainly based on internal evidence and is highly individualized owing to therapist involvement.

To reduce the time-consuming development of new tasks, future research should focus on automatic creation of items using artificial intelligence.

Conclusions

Teletherapeutic hearing rehabilitation software such as the new Train2hear platform offers a great opportunity for cochlear implant users and therapists. Although there are still several limitations to overcome and various questions to be answered, this preliminary assessment demonstrates that a standardized but highly individualized computer-based auditory training program might have a great and positive impact on hearing rehabilitation in the near future.

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Authors' Contributions

CV wrote the manuscript, with significant contributions from CS, CV, CS, DH, and MR are members of the interdisciplinary team and were involved in the development of the training program. SD and KB initiated the project.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Overview of German computer-based auditory training programs available for cochlear implant users.

[PDF File (Adobe PDF File), 184 KB - rehab_v7i1e15843_app1.pdf]

Multimedia Appendix 2

Components of the initial analysis based on the International Classification of Functioning, Disability, and Health.

[PDF File (Adobe PDF File), 177 KB - rehab_v7i1e15843_app2.pdf]

Multimedia Appendix 3

Bochumer questionnaire for cochlear implant users.

[PDF File (Adobe PDF File), 264 KB - rehab_v7i1e15843_app3.pdf]

Multimedia Appendix 4

System Usability Scale scores for cochlear implant users (N=18) and therapists (N=10).

[PDF File (Adobe PDF File), 220 KB - rehab_v7i1e15843_app4.pdf]

Multimedia Appendix 5

Results for the Therapist Questionnaire (N=10).

[PDF File (Adobe PDF File), 274 KB - rehab_v7i1e15843_app5.pdf]

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Abbreviations

CAST: Computer-Assisted Speech Training
ICF: International Classification auf Functioning Disability and Health
KIM: Kurzskala intrinsischer Motivation
LACE: Listening and Communication Enhancement
SPATS: Speech Perception Assessment and Training System
SUS: System Usability Scale

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Viewpoint

An Internet-Based Consumer Resource for People with Low Back Pain (MyBackPain): Development and Evaluation

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Abstract

People increasingly use the internet to obtain information about health complaints, including low back pain (LBP). LBP is the leading cause of disability internationally, and outcomes are worsening. There is an urgent need for resources that aid improvement of outcomes. There have been calls to engage consumers in the development of resources, but this has rarely been implemented. MyBackPain is a website that was developed with extensive involvement of consumers to ensure that the resource meets their needs for content and presentation. This paper aimed to describe the multistep process undertaken to develop the MyBackPain website and provide an extensive evaluation of its impact. Development of MyBackPain involved 10 steps, many of which have been published in the academic literature. These steps included consultation regarding consumer needs, evaluation of existing internet resources, identification of key messages to be reinforced, identification of frequently asked questions, consensus for content, content development (including development of algorithms to guide tailoring of the user experience), development of consumer-focused evidence-based treatment summaries, development of descriptions of health care providers, and testing. Evaluation included qualitative examination of people's interactions with the website and its effects on their daily lives and an ongoing randomized controlled trial of impact of use of the site on people's LBP-related health literacy, clinical outcomes, and treatment choices. It is hoped that the website can aid in the reduction of the massive burden of LBP and provide a template for the development of resources for other conditions.

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KEYWORDS
back pain; patient education; patient internet portals; evidence-based health care; patient involvement; service user involvement

Introduction

Background

The most recent global burden of disease study confirmed that low back pain (LBP) is the leading cause of disability worldwide [1], with enormous individual and economic burden. LBP accounts for 30% of all chronic pain [2] and affects up to 80% of individuals at least once in their life [3]. Unnecessary and ineffective assessments and/or treatments and poor quality management contribute to much of this burden [4]. Although negative messages and beliefs can lead to worse outcomes [5], beliefs about LBP can be positively affected by evidence-based information [6,7]. Furthermore, empowering patients to make informed choices can assist them to engage successfully with health advice and reduce care needs [8]. Early education and access to the most effective treatments could reduce the excessive burden of LBP. This understanding provides a foundation for a resource for people with LBP to provide accurate information about their condition, to empower them to actively participate in managing it, to navigate treatments, and to understand the roles of different health care providers.

Despite clear clinical guidelines, research of primary care physicians indicates that most individuals with LBP do not receive evidence-based care [4] and best possible outcomes are not being achieved [4]. For instance, contrary to guideline recommendations, more than 25% of patients are referred for imaging [4] and less than approximately 20% of patients with new LBP receive advice and education, although this is universally recommended in guidelines [4]. Of particular concern is the fact that 20% of patients with LBP are inappropriately prescribed opioids [4]. This research strongly suggests a gap in translating identified best practice and disseminating evidence-based LBP information.

People increasingly use the internet to obtain information related to health conditions [9,10]. The capacity of the internet to provide tailored information in varied formats at a time and place of the user's choosing makes it an ideal platform to educate and engage people with LBP in the management of their condition. Notably, people with LBP consistently express a desire for trustworthy information about their condition [11-14]. Internet-based resources could enable patients to become better informed about their condition and treatment options [15-18] to improve outcomes and guide appropriate use of health resources [16,19,20]. Enhanced health literacy as a consequence of access to high-quality internet resources could also lead to efficient use of clinical consultation time [17,19], enhance relationships between patients and clinicians [16], and shared decision making [19].

Unfortunately, most websites about LBP provide inaccurate information [21] and are consistently rated as *poor* in overall quality when evaluated against criteria developed from relevant guidelines and research [22-24]. Furthermore, the criteria used to evaluate websites have largely been based on perspectives of researchers or clinicians [24-26], with a foundation in traditional literature [22,27] or clinical practice guidelines [22,23], and have not considered patient perspectives [28]. There is increasing emphasis placed on consideration of perspectives and preferences of people with a condition [29]. Furthermore, the relevance and accessibility of material are improved by involvement of consumers in the development of health information resources [30]. Despite repeated recommendations for consumer involvement in the preparation of educational resources [31], there has been limited attention to consumers' views regarding content and presentation [15,26,32-34].

Objectives

This paper describes the process undertaken to develop a consumer-focused internet-based resource for individuals with LBP and the evaluation of its impact. Here, we describe the multistep process undertaken to develop the resource, with specific emphasis on the engagement of consumers, clinicians, and experts at each step, and the plan and preliminary outcomes from analysis of impact.

Methods and Results

Overview of Website Development

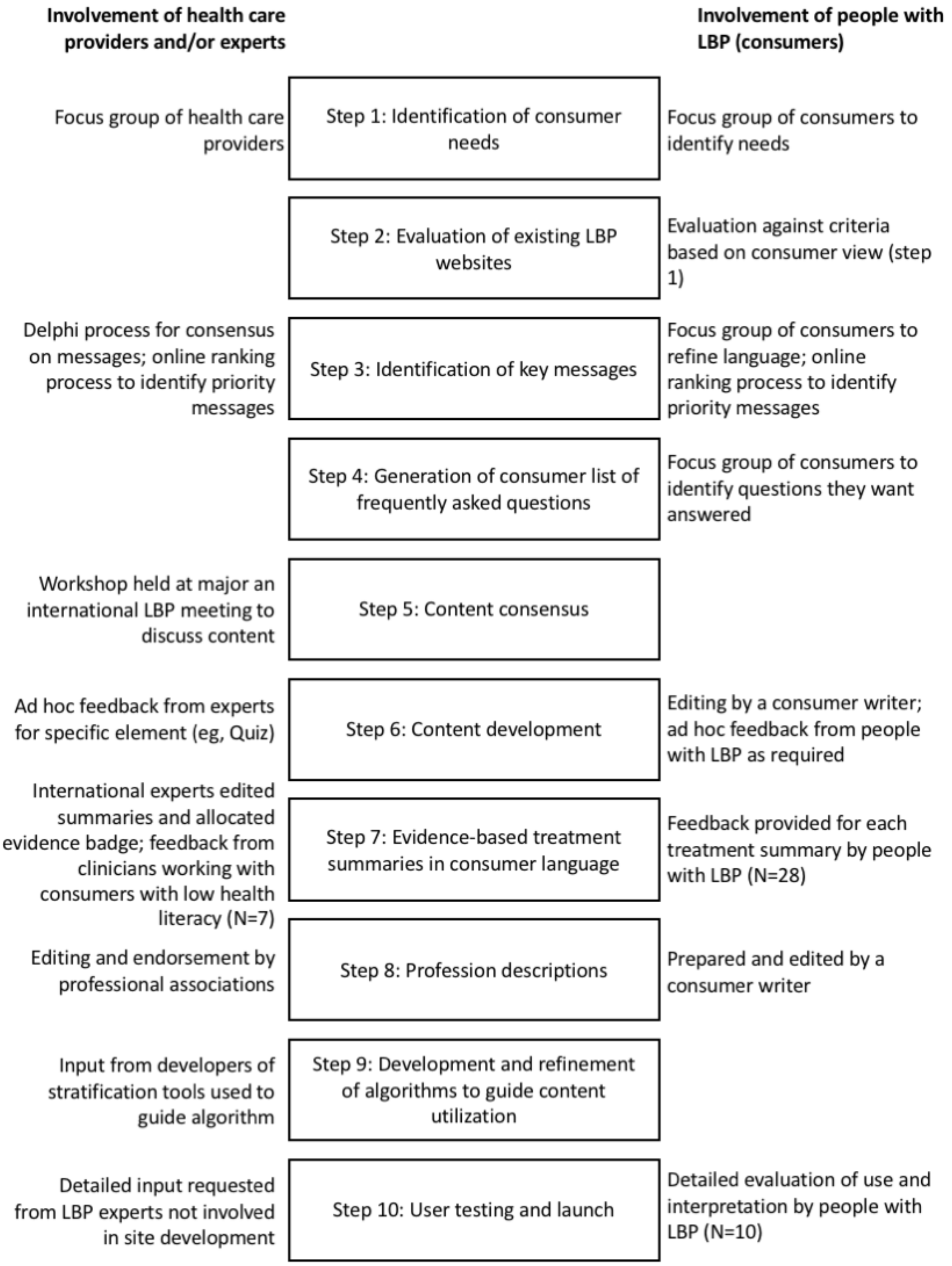
The overall objective of the development of the internet resource for individuals with LBP was to provide high-quality, evidence-based resources that would meet the needs of consumers in terms of content and presentation. The overarching strategy was devised a priori and was planned to involve input from people with the condition (experts by experience), clinicians, experts from multiple disciplines, and professional societies at multiple time points (Figure 1). A series of research studies with qualitative and quantitative components were undertaken to inform the development and ensure the resource met the objectives.

Development of an Internet Resource for People With Low Back Pain

Step 1. Identification of Consumer Needs—Website Content and Presentation

The first step in the development of the website was to undertake 2 qualitative studies to identify the needs of people with LBP in terms of content and presentation. These studies involved focus groups and interviews with people with LBP [35] and health care providers from multiple disciplines [36]. Data were analyzed thematically and used to generate a list of 12 content areas and 4 presentation preferences (an adapted version from Nielsen et al. [35] is presented in Textbox 1). Although people with LBP and health care providers agreed in most content areas, there were some differences. For instance, consumers wanted more specific explanation of diagnoses and treatments than the health care providers deemed possible or comfortable to provide on a website. Consumers also wanted capacity for consumer-to-consumer interaction in online forums, whereas health care providers express concerns that patient experiences may reinforce inappropriate messages. We deemed it too early to implement an online support group, and we have recently undertaken a systematic review (Maclachlan L, Mills K, Lawford BJ, Egerton T, Setchell J, Hall LM, Plinsinga ML, Besomi M, Teo PL, Eyles J, Mellor R, Hodges P, Hunter DJ, Vicenzino B, Bennell K, unpublished data, November 2019) and survey of views of individuals with musculoskeletal conditions [37] regarding online support groups as preliminary steps toward developing this component.

Figure 1. Steps undertaken for the development of the MyBackPain website. Involvement of consumers, health care providers, and experts is identified for relevant steps. LBP: low back pain.



Textbox 1. Consumer preferences for website content and presentation.

Desirable content:

1. Physiology/neurophysiology of low back pain—anatomy and explanation of pain
2. Different diagnoses
3. Treatment and management options (including alternatives)
4. Treatment outcomes (including side effects)
5. Roles of different medical and allied health professionals
6. Ways to improve function in daily life, eg, perform household tasks
7. The psychological and social impact of chronic low back pain
8. Ways to verify the quality of the information
9. Locally available health care resources/community groups
10. Product information
11. Questions to ask your health care practitioner
12. Information for partners and family members

Desirable presentation methods:

1. Mixture of presentation methods, including written information, videos, graphics, and animation
2. Interactivity
3. Lay person stories
4. Different levels of information—“drill down” if interested

Step 2. Evaluation of Existing Low Back Pain Websites

To determine the need for the potential resource, a review was undertaken to determine whether current websites already met consumer needs for content and presentation [38]. This review was undertaken at 3 different time points (2010, 2015, and 2019; to determine whether resources were changing over time) and involved virtual searches using Internet Protocol addresses from different countries (Australia, the United Kingdom, and the United States; to determine whether alignment of website content and presentation was better in some locations than others). All websites were evaluated against a 16-item checklist (12 content items and 4 presentation items) developed from the consumer preferences identified in step 1 [38]. The review identified that existing websites were poorly aligned with patient preferences, that this was not improving (or was even getting worse) over time, and did not differ between locations of the internet search. In 2010, no website was scored as *excellent*, and 58% scored as *poor* or *fair*. Key areas in which websites did not meet consumer needs were as follows: less than 50% of websites included information on treatment outcomes or information on psychological and social impact of chronic pain, less than 20% of websites included information regarding health care provider roles or questions to ask health care practitioners, and none of the websites included information for family and friends. On the basis of this review, it was deemed necessary to begin building a consumer-focused internet resource for people with LBP.

Step 3. Identification of Key Messages

In step 1, consumers and health care providers had expressed a clear preference for access to evidence-based information about multiple aspects of LBP. Although evidence for treatments and diagnostic procedures are frequently the subject of systematic reviews and meta-analysis, other aspects of advice and education are infrequently considered in this robust manner. As a result, we sought to identify and reach expert consensus on a list of evidence-based messages that should be reinforced frequently and consistently in various formats (eg, patient narratives and information sheets) in a website [39]. For this step, evidence-based messages were first identified from the literature (clinical practice guidelines and systematic reviews, eg, the study by Koes et al [40]), which produced a provisional list of 44 messages. Second, a multidisciplinary panel of experts and patients with LBP were consulted using a Delphi process to review, to add to, and to refine the key messages. Third, using consumer focus groups and a consumer writer, messages were refined and language was optimized to ensure messages were understandable and nonambiguous to people with LBP. This process resulted in a final list of 30 key messages that were categorized into 6 major thematic areas: principles of management, reassurance, staying active, unnecessary interventions, red flags, and disease knowledge (Table 1).

Table 1. Key messages identified for reinforcement throughout the website.

Thematic area and key message	Expert rank	Patient rank
Stay active		
Bed rest for more than a day or two is not good	14	22
Do not take back pain lying down	19	25
Staying active helps prevent long-term back problems	5	8
When you have back pain, carry on with normal activities as far as possible	2	24
When you have back pain, staying active is important. You need to pace yourself to return to your usual activities	1	5
Unnecessary investigations		
Blood tests are usually not needed in the majority of cases of LBP[a]	29	28
CT[b] scans have little use in diagnosing back problems, and caution should be exercised because of the large amount of radiation involved with their use	22	30
Imaging (eg, x-ray, CT scan, or magnetic resonance imaging) is usually not needed in the majority of cases of LBP, particularly when your pain has been present for less than 6 weeks. Talk to your doctor about this	10	21
X-rays will not highlight the cause of pain in most cases, unless a fracture is suspected	12	27
Principles Mx[c]		
Health practitioners can assist in screening for causes of back pain	30	15
If you have any further questions to ask your health practitioner, write them down and discuss them at your next visit	28	9
Persistent LBP is influenced by a number of factors—physical, emotional, and environmental; it is important to address each of these areas	18	6
Staying positive is important. Help is available	21	13
Take ownership of your own well-being	20	20
Work toward returning to your usual activities, with guidance from your health practitioner	16	7
Work with your health practitioner to address your concerns	26	10
Work with your health practitioners to manage your back pain	27	11
Work with your health care team to set goals	25	16
Disease knowledge		
In around 95% of cases, it is not possible to pinpoint the cause of back pain	23	29
LBP may happen again over time	24	19
Reassurance		
In most cases of recent onset back pain, the pain will get better in several weeks; however, this varies from person to person	7	14
It is normal to worry about the cause of your back pain and the impact it may have on you	17	12
It is not necessary to know the specific cause of your back pain to manage the pain effectively	13	23
It is rare for LBP to be caused by a more serious health problem	9	26
Most people find that their back pain settles down over a short period of time. If your back pain persists and is worrying you, consult a health professional	6	4
Most people have pain in their low back at some stage in their lives	11	18
Your pain may not necessarily be related to the extent of damage in your back. Hurt does not necessarily mean harm	3	17
Red flag		
You should see a health practitioner if you have back pain and any of the following: pain that spreads down 1 or both legs: a fever, recent invasive procedure (eg, surgery), recent significant trauma, unexplained weight loss, and history of cancer	8	3
You should see a health practitioner urgently if you have back pain and either of the following: bladder and/or bowel disturbance or significant leg muscle weakness	4	1

Thematic area and key message	Expert rank	Patient rank
You should see your health practitioner if your back pain is severe and it is worrying you, if you are having difficulty managing your back pain, or if your pain is getting worse	15	2

[a] LBP: low back pain.

[b] CT: computerized tomography.

[c] Mx: management.

Once developed, the list of key messages was subjected to 2 additional analyses. First, 2 groups (people with LBP and multidisciplinary international LBP experts) were asked to rank the messages in terms of their perceived priority or importance using an online process. This process highlighted some similarities in order of importance expressed by these 2 groups (eg, both groups prioritized messages related to identification of *red flags* to recommend the seeking of advice from a health care provider) but also some major differences. For instance, people with LBP prioritized messages about management strategies and ranked advice to avoid unnecessary investigations very low, whereas health care providers prioritized advice to stay active and reassurance. Contrasting views of experts and consumers were not unexpected but highlighted that care would be required to ensure patients were engaged with the website (eg, access to the information they wanted), and they were also guided to advice that may be contrary to their desires/beliefs (eg, patients continue to demand investigations despite evidence that they are only indicated in a small proportion of cases and evidence that early imaging can increase disability and duration of LBP [41]).

Second, developers of clinical practice guidelines that were published after the preparation of the list of key messages were surveyed using a Delphi method to ascertain whether messages remained consistent with newly developed guidelines. All messages were endorsed using this process.

Step 4. Generation of Consumer List of Frequently Asked Questions

In parallel with the development of a list of evidence-based key messages, a qualitative study with focus groups of people with LBP was undertaken to identify a provisional list of questions that consumers would like to have answered with an education resource (Nielsen M, Hodges PW, unpublished data January 2017). Thematic analysis of the focus groups provided an initial list of “frequently asked questions” (FAQs) to serve as a starting point for FAQs to be added to the site during development.

Step 5. Content Consensus

After establishing the needs of consumers and confirmation that a new resource was needed to meet these needs (described above), we held a workshop at the 13th International Back and Neck Pain Research Forum in Campos do Jordao, Brazil, to generate expert consensus on the plans for content of the website. At the workshop, participants endorsed the findings of the prior steps, and it was agreed that the website should aim to improve health outcomes for individuals with LBP by (1) enhancing the confidence of individuals with LBP to manage their condition and make evidence-based treatment choices and to avoid ineffective, unnecessary, and potentially harmful investigations and treatments; (2) demedicalizing and normalizing LBP with messages in multiple formats that reinforce that LBP is a natural part of life for many and in most cases can be managed with early return to activity; (3) providing tools for individuals to identify whether further investigation and/or management may be required; and (4) engaging patients in healthy behaviors and attitudes about LBP. These objectives of the website were used to underpin the development of the content in step 6.

Step 6. Content Development

Using the outcomes from steps 1 to 5 as a starting point, an extensive process of content development was undertaken with leadership by a postdoctoral research fellow (background in physiotherapy and psychology), an international multidisciplinary steering committee, and a consumer writer. A partnership was developed with Arthritis Australia, which is a charitable, not-for-profit organization and the peak arthritis consumer body in Australia, to host the site and aid in the development of specific areas of content (eg, preparation of videos).

Table 2 presents the final list of content areas and the intended purpose of each. Content was developed using varying methods and consultations according to nine key principles: (1) written in consumer language, (2) evidence based, (3) bio-psycho-social underpinning, (4) aligned with key messages, (5) no commercial goal, (6) no single professional affiliation/bias, (7) focus on empowerment of patient to take control of their LBP, (8) focus on reassurance and informed choices, and (9) using a design that would be engaging for users (contemporary, interactive, and intuitive). Content presentation methods were aligned with the preferences of consumers identified in step 1. Development of content for several areas required a more detailed process and are described separately in steps 7 to 9.

Table 2. Final content developed for MyBackPain website.

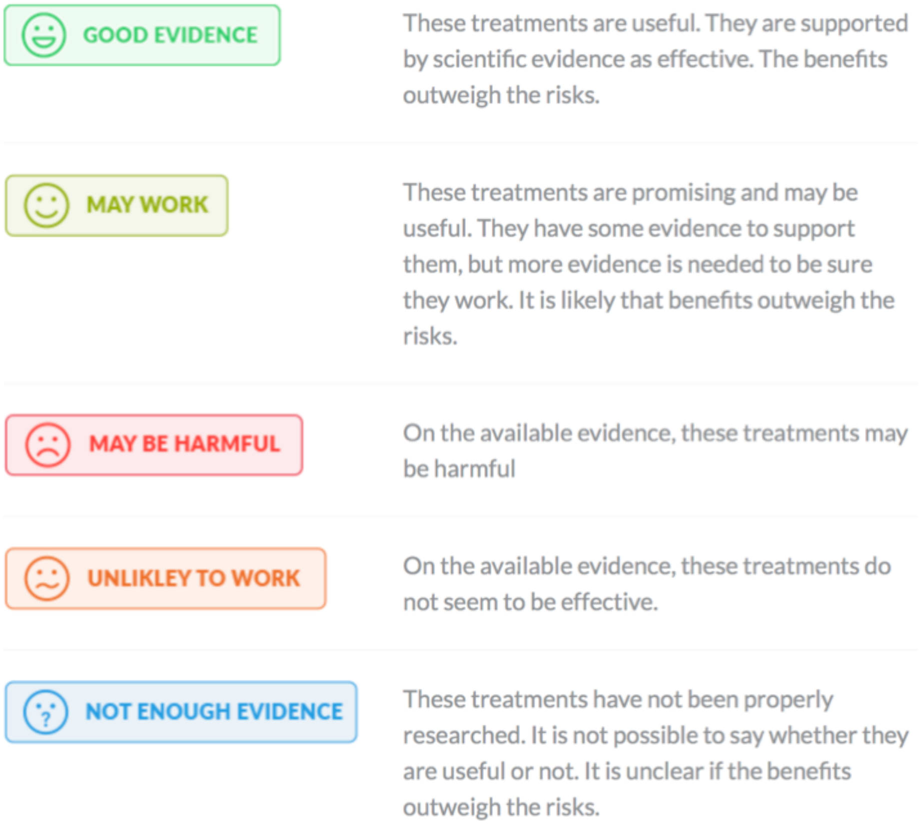
Content area	Purpose
Guide me	Provide tailored guidance regarding prognosis and recommended resources based on responses to questions based on 2 evidence-based prognostic tools
Back pain information	
About back pain	General information regarding back pain with emphasis on reassurance and bio-psycho-social model of pain
Do it yourself	Summary of useful tips to help people with LBP[a] to do the things they want/need to do. Also link to other online self-help tools (eg, *Paintrainer* program to learn pain coping skills)
Treatments	Evidence-based summaries of 80 common treatments for LBP in consumer-friendly language. Evidence badges to provide quick reference of efficacy of intervention. Information of how to prepare for a consultation with a health care professional and questions to ask
Health care professionals	Description of health care professionals who commonly manage LBP and how to find them
Test your knowledge	Quiz to test knowledge about LBP that addresses main key messages and common myths about LBP
For family and friends	Guide to information for family and friends to understand LBP and provide support
Videos	
Back pain information	Library of videos designed to provide narratives that reinforce key messages
Living well with back pain—people's stories	Stories of people who are living with LBP
Frequently asked questions	Key questions identified by consumers as issues they want to understand better
What can I do to help my LBP?	Response to questions related to self-management
Back pain causes	Responses to questions related to back pain causes
What is going to happen?	Responses to questions regarding prognosis and other requests
Seeking help	Responses to general questions regarding health professionals
About us	Information regarding the developers and funders of the MyBackPain website
Other features	
Daily/weekly healthy messages by email	Messages sent to users, based on key messages, sent at a frequency indicated by the user

[a] LBP: low back pain.

Step 7. Evidence-Based Treatment Summaries in Consumer Language

Orthodox and complimentary treatments commonly used by people with LBP were identified by the expert steering committee with consumer input. The committee agreed upon a final list of 80 treatments grouped into 16 broad areas (Table 2). An independent expert group (International Centre for Allied Health Evidence, University of South Australia, Adelaide, Australia) was contracted to develop a draft description of each treatment, and a synthesis of research evidence was prepared from the best available evidence (systematic reviews, clinical trials, and clinical practice guidelines). Draft descriptions were edited for language by a consumer writer. For each treatment, information was provided regarding (1) basic description (what is it?, how does it work?, and is it effective for treating back pain?), (2) detailed treatment information, (3) points to consider (defined as "pluses" and "minuses"), (4) FAQs, and (5) key references. A series of "evidence grade badges" was developed by the expert steering committee with consultation with external experts in evidence-based practice and a consumer writer (Figure 2). Evidence grades aimed to enable quick identification of evidence levels for treatments or the potential for harm and were also designed not to overemphasize scientific evidence (or lack of) as the only source of information that might be of value to consumers. International experts in each type of treatment (including a senior and early career researcher where possible) were identified by the expert steering committee to review each treatment summary and allocate an "evidence grade badge." All summaries and evidence grades were reviewed for consistency by the steering committee and 3 additional experts over a series of teleconferences. After completion of the 80 treatment summaries, 28 individuals with LBP were recruited to provide detailed review of 2 to 3 treatment summaries each to provide feedback of content and language. We also garnered feedback from 7 clinicians working with people likely to have low health literacy.

Figure 2. Evidence grading badges developed to enable identification of evidence levels for treatments or the potential for harm.



GOOD EVIDENCE	These treatments are useful. They are supported by scientific evidence as effective. The benefits outweigh the risks.
MAY WORK	These treatments are promising and may be useful. They have some evidence to support them, but more evidence is needed to be sure they work. It is likely that benefits outweigh the risks.
MAY BE HARMFUL	On the available evidence, these treatments may be harmful
UNLIKLEY TO WORK	On the available evidence, these treatments do not seem to be effective.
NOT ENOUGH EVIDENCE	These treatments have not been properly researched. It is not possible to say whether they are useful or not. It is unclear if the benefits outweigh the risks.

Step 8. Profession Descriptions

In step 1, consumers had indicated confusion regarding the role of different health care providers. Descriptions were prepared for health care providers who manage back pain that have a registration board in Australia. Descriptions were prepared by the expert steering committee and consumer writer. These were refined and then approved by the professional associations that represent each discipline.

Step 9. Development/Refinement of Algorithms to Guide Content Utilization

A total of 2 algorithms were developed on the basis of existing stratification/prognostic tools to guide users of the website toward information that is tailored to their individual needs. The STarT Back tool [42] and Pick-up tool [43] were adapted to guide the user experience for individuals with LBP of greater than or less than 3 months duration, respectively. The STarT Back tool stratifies individuals with low, medium, and high risk for poor prognosis based on responses to 9 questions. The Pick-up tool calculates probability of good outcome based on responses to 5 questions. The tools were used to evaluate possible risk of poorer outcome and tailoring information regarding advice, particularly with respect to providing reassurance, and recommendations for access to psychologically informed resources were necessary. The “guide me” algorithm also included identification of *red flags* (eg, change in bladder and bowel function and perineal numbness) to trigger advice to seek medical consultation.

Step 10. User Testing and Launch

A full beta version of the website was constructed and extensively reviewed by consumers and experts. In-depth consumer input user testing was conducted with 10 individuals with LBP of different presentations and durations. Each consumer was observed as they interacted with the website and asked to voice what they were thinking as they moved through the site. This testing focused on both site content and functionality. A summary of feedback was recorded. Four experts who were not involved in development of the site were asked to provide detailed review of the website and written feedback. All feedback from the consumers and experts was discussed by the expert steering committee and postdoctoral fellow and addressed if appropriate. The site was launched on the July 30, 2019 [44]. The launch date was 12 months after the website was completed to ensure that the primary end point for a randomized controlled trial (RCT) of the impact of use of the website (see below) was not affected by control group participants inadvertently accessing the site. Figure 3 shows the landing page of the website. Multimedia Appendix 1 is a brief video that was prepared for people with LBP and clinicians who treat LBP to outline the purpose and content of the website.

Figure 3. Screenshot of landing page for MyBackPain, an internet resource designed for people with low back pain to obtain information about their condition and guidance for managing/living with low back pain.

Got back pain?
Learn how to manage it here.

First time, or ongoing back pain?

This website provides trustworthy and up-to-date information on low back pain. Developed by expert researchers, health professionals and people with back pain, we aim to get your back on track.

Understand & manage your back pain

Evaluation of MyBackPain

Evaluation 1: Randomized Controlled Trial of Impact of MyBackPain

Before the launch of MyBackPain, an RCT was undertaken to investigate the effectiveness of the website in improving spinal health literacy, treatment preferences, and clinical outcomes for people with LBP, in comparison with other online resources. MyBackPain was made available by username/password access only during this period. The pragmatic trial was conducted online. Participants were 440 people with nonspecific LBP of any duration, stratified to those with LBP for a duration of greater than or less than 12 weeks. Participants, research staff, and the biostatistician were blinded to treatment allocation. Data were collected at baseline and 1, 3 (primary end point), 6, and 12 months via online surveys and questionnaires. The primary outcome measure was spinal health literacy measured using dimensions 2 and 3 ("having sufficient information to manage my health" and "actively managing my health") of the Health Literacy Questionnaire [45]. Participants are asked to consider their LBP when answering the survey. Secondary outcomes include the quality of treatment preferences (whether patients choose treatments that are supported by evidence) and LBP clinical outcomes (pain, disability, and quality of life). The trial has been prospectively registered (ACTRN12617001292369; registered on September 7, 2017). Long-term outcomes will be finalized in May 2020, with trial results available soon thereafter.

Evaluation 2: Interdisciplinary, Postqualitative Evaluation of MyBackPain

Although health websites provide information in a convenient format, they can be reductionist in their capacity to accommodate the complexities of human life, health, evidence, and the diverging philosophies underpinning different forms of health care. A postqualitative analysis of MyBackPain was undertaken by a team with backgrounds in public health, sociology, physiotherapy, psychology, and occupational therapy and an *expert consumer* with LBP (Setchell J, Olson R, Turpin M, Costa N, Barlott T, O'Halloran K, Wigginton B, Hodges P, unpublished data, February 2019). The analysis aimed to evaluate the success of the website at providing health information that was simultaneously *scientifically rigorous* and avoidant of associated pitfalls such as reduced consideration of complexity of the condition. The analysis was guided by Ahmed's theory [46] of the socioculturality of emotions and was designed to reflect on experiences as the team individually navigated the website, followed by team discussion. Through this postqualitative inquiry process, it was recognized that some forms of communication used in the website had the potential to marginalize some users (eg, although images showed individuals of diverse background, all were happy and undertaking productive activities, which may marginalize users who do not identify with those images, and *evidence* for treatment was limited to RCTs—although this is conventionally used in most evaluations of treatment efficacy, other forms of evidence [eg, qualitative interpretations] can contribute and can be desired by users) but liberated possibilities of others (eg, videos presented real stories by real people). Caution was identified regarding the assumption that consumer education and *choice* enhance consumer health and the potential unintended negative effects of the focus on changing individual behaviors, particularly *lifestyle* factors such as activity and exercise, which can lead to feelings of guilt when this cannot be achieved and shame that they are somehow responsible for their LBP. Each of these issues can be addressed though refinement of website messaging and explicit recognition within the website to acknowledge the issues.

Evaluation 3: Qualitative Analysis of People's Interactions With the Website and Its Effects in Their Daily Lives

A qualitative study was undertaken using methods adapted from discourse analysis to identify potential *tensions* in the website content (Setchell J, Turpin M, Costa N, Hodges P, unpublished data October 2019). Participants with LBP were observed while interacting with the website and asked to discuss their responses. For 1 month before a follow-up interview, these participants took photographs of what was happening in their lives when they thought of the website. Photographs were used to prompt discussion. A postcritical discourse analysis approach identified 4 areas of *tension* in the presentation of material on the website: (1) the website focused on reducing LBP, with little discussion of living with LBP, which may be the goal or the reality for some individuals; (2) the website tended toward discussion of keeping active and not resting, potentially leading to feelings of guilt if activity targets could not be met; (3) there was tension between educating people with LBP to make their own choice vs providing explicit guidance, with the desired balance between these depending on the individual user; and (4) although the treatment summaries intend to inform users of evidence-based treatments to guide choices, this information had an unintended negative impact on some participants who had used disproven or potentially harmful treatments. These tensions were unanticipated in the design of the website and will be addressed by explicit recognition and discussion of these *tensions* in multiple formats (eg, videos and pop-up boxes at appropriate locations of the site where tensions arise).

Plan for Review and Revision of MyBackPain

As information regarding LBP (particularly treatments) evolves with future research, there will be a need to review and update the content of the website. A governance structure has been established to overview regular review and revision of the content. The website uses a content management system with concurrent possibilities for updating much of the content. Critically, the content of the treatment summaries will be updated at least biannually with the guidance of the international advisors who contributed to their development (and others, as appropriate). New content is planned and contingent upon future funding.

Discussion

This paper describes the multistep process undertaken to develop a website for people with LBP to meet their expressed needs for content and presentation. The rigorous process used to develop this resource is rare, and we hope that outlining the iterative steps we undertook might help others to develop resources for consumers. A major component of the process was extensive involvement of consumers in defining the content, providing feedback on the content, and evaluating the final website. A multidisciplinary group of international experts were recruited to guide development of the website and provide input/review of content at many steps. Most steps involved in the development of the website were undertaken in a formal manner with publication and presentation of the results in academic literature.

MyBackPain was designed to address the issue that most available resources do not meet the expressed needs of people with LBP [38] and use language that is not optimized for users to understand [23]. It has also been identified that websites for LBP generally provide inaccurate information and do not consider the spectrum of presentations of LBP [21], another key objective of the development of MyBackPain.

It is hoped that MyBackPain will provide a useful resource for people with LBP and their friends and families. We also hope that health care providers will derive benefit from referring patients to the website for reinforcement of key messages and to generate a partnership in decision making for treatment. Ultimately, the intention of the website is to contribute to reducing the massive burden of LBP. The extensive process of development and consumer/expert engagement that we have undertaken could also provide a template for the development of resources for other conditions.

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Conflicts of Interest

None declared.

Multimedia Appendix 1
Explanatory video for MyBackPain: introduction to purpose and features of the website.
[MP4 File (MP4 Video), 189910 KB - rehab_v7i1e16101_app1.mp4]

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Abbreviations

FAQs: frequently asked questions
LBP: low back pain
RCT: randomized controlled trial

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Original Paper

Web-Based Consumer Health Education About Back Pain: Findings of Potential Tensions From a Photo-Elicitation and Observational Study

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Abstract

Background: Low back pain (LBP) is a leading cause of disability worldwide, with huge social and economic impact. There is extensive extant literature investigating the efficacy of various management approaches ranging from surgery to psychological interventions to exercise. However, this work has focused almost entirely on efficacy in terms of pain reduction, functional improvement, and psychological changes. This focus has meant that unanticipated social or socio-cultural effects of back pain health care have received little attention.

Objective: This study aimed to scrutinize some of the conceptual tensions inherent in contemporary LBP health care approaches and to highlight their material effects.

Methods: We used a qualitative research design adapted from discourse analysis, which was able to consider key discursive *tensions* underpinning a LBP website. Data collection involved observing the interaction between adult participants with LBP and the website in the following two ways: (1) observational interview, where participants were observed interacting with the website for the first time and asked to discuss their responses to it as they moved through the website and (2) photo-elicitation, where for a month after their first use of the website, people took photographs of what was happening in their lives when they thought of the website and discussed them in a follow-up interview. We used a postcritical discourse analysis approach to examine data produced from these methods.

Results: Our postcritical discourse analysis identified key discursive tensions, including between living with *and* reducing LBP, keeping active *and* resting, and patient choice *and* giving guidance.

Conclusions: Our analysis suggests ways for considering less dominant perspectives without having to discard the benefits of dominant ones. Although the focus of LBP discourses has changed (less biomedical and less about cure), they still hold on to some of the problematic dominant paradigmatic concepts such as biomedicine and individualism. The tensions we highlight are likely to be highly useful for teaching and implementing LBP care across multiple health care settings.

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KEYWORDS

low back pain; lumbar; discourse analysis; qualitative methods; public health

Introduction

Background

This paper discusses the use of an adapted discourse analysis approach to consider key nuances and tensions in contemporary approaches to the management of low back pain (LBP). We use the term *postcritical* to delimit a poststructuralist move that blurs boundaries between categories [1-3]. In doing so, we move beyond the discursive dichotomies of *dominant* and *silenced* discourses often constructed in discourse analysis [4]. This blurring allows consideration of how even seemingly contradictory discourses might be fruitfully employed in health care toward beneficial outcomes. We highlight how a postcritical analysis can help to tease out nuances, complexity, and tensions between ideas and approaches to health care management, without needing to dismiss any perspective. For the purposes of this paper, we have used one health care example as a case study: an LBP website that is considered exemplary in its use of both contemporary understanding of pain and the evidence base regarding LBP management.

LBP is widely reported to be the leading cause of disability worldwide [5] and is considered a major global public health problem [6]. Research reports the *burden* of LBP to include considerable direct and indirect costs [7], individual impact [8,9], and wider economic costs [10]. Unnecessary assessments and indiscriminate use of ineffective and potentially harmful treatments have led to the misuse of health care resources [11]. As patient education has been found to be effective for prevention [12] and improvement of LBP [13], access to evidence-based information could potentially lessen the impact of this common condition.

LBP education can be delivered in many ways, such as via health professionals and via public health messaging. People with LBP do not always have access to health education through health care professionals (as they may not deliver it [14]). For this and other reasons, individuals often self-manage their symptoms based on information sourced elsewhere [15,16]. Likewise, service users report a desire for information about their LBP even after consultations with service providers [17]. The internet is a popular and important source of health education for people who experience LBP because of its convenience and high accessibility.

Despite the massive potential of the internet to provide tailored and valuable information, LBP websites are often rated as poor [18], including when evaluated against criteria developed from international guidelines [19,20], and do not meet consumer needs [21]. Given this lack of *trustworthy* information about LBP, a consumer-focused LBP web-based resource was created. The website *MyBackPain* was developed as a research translation output by 2 of the authors (JS and PH) in collaboration with a leading international LBP research organization, key industry bodies, individuals with LBP, and clinicians [22]. The development of the website involved an extensive process of research translation of LBP research, including evidence-based information about 80 types of LBP treatments and contemporary understanding of musculoskeletal pain [22]. The website reflects a postpositivist approach and focuses on the following key messages: (1) enhancement of consumer confidence in self-management and treatment choices, (2) encouragement of engagement in behaviors and attitudes to reduce the burden of symptoms, and (3) reassurance and demedicalization of LBP.

Although the website content is supported by the current LBP literature and its messages reflect an up-to-date understanding of LBP, it is important to consider that MyBackPain may have unintended effects on individuals who experience LBP. For instance, it has been found that emphasis on behavior change, such as engaging in physical activity, can be problematic and might lead to increased shame, guilt, and stigma, which can result in avoidance of healthy behaviors [23,24]. A strong focus on *patient empowerment* can also be problematic and shift the responsibility from society to individuals [25]. Another important issue is that attempts to lessen fear and anxiety can be perceived as devalidating or patronizing by individuals with LBP [26]. It is challenging to present complex information in ways that will benefit the variety of individuals who access sites seeking information about LBP.

Objectives

The primary aim of this study was to determine how key messages of contemporary LBP health education and their underlying assumptions are taken up by individuals with LBP and consider any potential unintended effects of the messages on the users of the website.

Methods

Study Design

We employed a qualitative study design derived from a discourse analysis. We used a combination of 2 data collection techniques: an observational *interview* and photo-elicitation. Data were analyzed using an adapted discourse analysis approach to investigate the (multiple) effects of interactions with the website in the lives of individuals with LBP and how the website's *key* messages were integrated into consumers' lives, paying particular attention to any unintended effects of the messages.

Participant Selection

Participants were recruited through consumer support organizations for people with chronic pain, advertisements in local community centers, contacting participants from previous studies, social media, and word-of-mouth. Inclusion criteria were: (1) self-identification as having (or having had) LBP; (2) English language proficiency; (3) currently living in Australia; (4) aged 18 years and above; and (5) sufficient technological literacy to use a website, learn to use a digital camera, and communicate via conferencing software if required. There were no exclusions based on LBP duration or comorbidities. Efforts were made to ensure inclusion across genders, ages, and representation from both rural and urban participants. We assessed these factors iteratively during data collection: after the first 10 interviews and then again after the next 5 interviews. Recruitment was ceased when a satisfactory level of participant diversity (there were similar numbers of men and women, and there were at least two rural participants, and there were at least two participants in each decade who were aged between 20 and 60 years) and iterative analysis showed few new concepts relating to study aims. The Institutional Medical Research Ethics Committee approved this study.

Data Collection and Procedure

Participant consent was obtained using a 2-step process. First, all participants were sent the study information via email, and initial written consent was obtained by return email. Second, consent was reconfirmed verbally before the first interview. Data generation consisted of 2 methods:

1. *Observational interview*: For approximately 1 hour, a researcher observed each participant as they interacted with the website for the first time. The researcher asked probing questions during the observation to encourage participants to share their understanding of, and reactions to, the website (eg, "Can you describe to me what you see in front of you?" or "How does what you are looking at make you feel?"). Leading and topic-defined questions were avoided. Interviews were conducted either in person, if participants lived close to the university, or via conferencing software using screen sharing. For the small number of interviews that utilized conferencing software, we used additional prompting questions (in addition to observing which page of the website the participant was on) to ensure we could gain insights into the participants' interactions. For example, "Can you describe what you are reading or looking at now?" or "Which part of the page were you looking at when you thought that?"
2. *Photo-elicitation*: During the 1-month period following the observational interview, participants were asked to use a digital camera to document moments in which they recalled messaging on the website. A simple digital camera was offered to all participants if they did not already have one. However, all participants elected to use cameras embedded in their mobile phones for convenience. Reminders were sent via text or email twice weekly to prompt participants to take at least one photograph per day (if relevant). Photographs were shared with the researchers and uploaded to a secure location. This methodology allowed the participants to share representations of their lives and experiences through visual content, making the *invisible visible* [27]. The photographs were discussed in an approximately 45-min long interview. Interview questions were semistructured and designed to discuss each photograph to consider how the interaction with the website related to their lives and left room for additional information about participants' experiences (eg, "Can you discuss why you chose to take this photo?" or "How did you feel when you took that photo?").

Both sets of interviews were audio-recorded and subsequently transcribed by a professional transcription service. Field notes were written after each interview. Interviewers were all physiotherapists who were trained in interviewing and observational techniques: 2 were females (NC and JS) and 1 was male and external to the research team. JS has a PhD in qualitative research, and NC and the external researcher are PhD students. All data were anonymized during transcription, and photographs and other electronic data were handled securely according to institutional guidelines.

Methodology and Theoretical Implications

The project was underpinned by an adapted discourse analysis methodology. Discourse analysis considers the way in which language, text, images, or objects produce (or reproduce) certain *realities* or *truths* in relation to power, social, or political inequities [28]. Commonly, critical questions drive the analysis [28]. Our questions were as follows: (1) What messages or *truths* (discourses) were implicitly or explicitly present in the interactions between people with LBP and the website? and (2) What are the material and social implications of these discourses in the broader context of LBP health care?

We intentionally employed data collection methods that produced data on the *interaction* between the website, people with LBP, and their lives. This relational approach is consistent with the new materialist and affective philosophical turn away from purely textual analysis toward consideration of material as well as social effects and understanding of the interrelationship between technology and humans [1,29]. Observation and photo-elicitation added a visual element to the data, expanding sensory awareness and, therefore, induced feelings and thoughts that increase the reflexive process [30] to produce data that were meaningful in the context of people's lives [31]. Our analysis did not attempt to quantify *how many* or *to what extent* messages were taken up by participants. Rather, our analysis was designed to examine *how* key messages were taken up by participants, consider their underlying assumptions, and any potential unintended material and discursive effects on people's lives as a result of their interactions with the website.

Rather than highlighting discrete *dominant* or *silenced* discourses (a common approach to critical discourse analysis) in the participant uptake of the website messaging, we conceptualized the discourses on a continuum and in tension. As discussed in the Data Analysis section below, this conceptualization of *tensions* was not a preexisting approach but was produced during our analysis as a way to make sense of our data. This poststructuralist relational conceptualization of a continuum of discourses and *tensions* among this continuum allowed us to move beyond binaries to consider that dominant and silenced discourses might be able to coexist and interact in helpful ways. The dynamic nature of this approach also provided the possibility of considering emphasizing or deemphasizing particular *competing* discourses. In this way, we were able to trace and examine, and not necessarily try to erase (but possibly rework), paradoxes, complexities, and contradictions that are a frequent and perhaps unavoidable part of living with and managing LBP.

Data Analyses

Analyses were conducted iteratively and concurrently with data collection to allow investigation of new information as the study proceeded. The research team conducted formal analyses of the interview transcript data using a combination of individual and team analysis techniques as follows. First, each team member (all authors) individually reviewed the incoming transcripts to identify concepts relating to the research aims. The subsequent step included team analyses of emergent data in 3 team meetings to refine concepts into key discourses and defining conceptual patterns where *points of tension* between interacting or potentially competing discourses were evident in these data. We developed the concept of *points of tension* during our analysis (ie, it was not a concept we preimposed on the data). Our analysis did not produce any discourses that did not sit among these tensions. The 2 analytic steps were completed 3 times with iterative summative notes made by JS after each cycle and shared with the other authors. These multiple analytical cycles were used to facilitate the identification of patterns and conceptual congruence. Any discrepancies between researchers are included in the reporting of results. Study rigor was guided by Tracy [32], who outlined 8 key markers of qualitative research quality including worthy topic, rich rigor, sincerity, credibility, resonance, significant contribution, ethics, and meaningful coherence. All relevant markers were addressed. Reporting rigor followed the consolidated criteria for reporting of qualitative research [33] with all 28 relevant criteria addressed.

Results

Overview

We recruited 15 participants for this study. Participants' ages ranged from 25 to 68 years, with a mean of 39.5 years. A total of 7 participants were identified as female and 8 as male. All participants were currently employed, except 1 who was studying at a university. Table 1 gives details of the participants' demographic information. All were interviewed at least once and most were interviewed twice; however, 2 were not available for the second interview (both because of difficulty scheduling the follow-up interview). We included all data gathered from all participants regardless of whether they completed the second interview.

Table 1. Demographic characteristics of the study participants.

Demographics	Values
Age (years)	
Mean (SD)	39 (12)
Range	25-68
Gender, n (%)	
Female	7 (46)
Male	8 (54)
Length of time with low back pain (years)	
Mean (SD)	14.2 (14.1)
Range	0.2-33 years
Current pain level (out of 10)	
Mean (SD)	3.1 (2.5)
Range	0-8

Our analyses identified implicit or explicit discourses in the participants' engagement with the website and identified key points of interaction and potential tension between these discourses that were pertinent to our research aims of determining how key messages embedded in the website were taken up by participants, and the potential unintended material and social implications for individuals with LBP. Textbox 1 presents an overview of these tension points. We discuss each point of tension below using key quotes from the data to illustrate. Participants were distinguished by pseudonyms. As is common in qualitative research, much of the discussion of our findings is included below within this Results section.

Textbox 1. Analysis identified five key tensions between discourses.

- Reducing lower back pain…living with low back pain
- Providing information…providing guidance
- Keeping active…rest
- Providing information about harmful treatments…feeling okay about choices
- *Human* elements…biomedicine

Tension 1: Reducing Lower Back Pain...Living With Lower Back Pain

Our analyses highlighted an interaction between 2 different discourses related to managing LBP. These discourses highlighted different *truths* about how to manage LBP. The first discourse was *reducing LBP*—this *truth* could be framed as imperative to work toward reducing, easing, or curing LBP. The second *truth*, *living with LBP*, seemingly conflicts with the first discourse, as it suggests that the focus could be shifted from trying to reduce LBP toward considering how to coexist or thrive while living with LBP. *Reducing LBP* was a prevalent discourse in the data, whereas *living with LBP* was less common. In this section, we first discuss the presence of these discourses in the data and then consider how they interacted and might interact differently.

The research team discussed that these discourses were evident in various ways in the participants' discussions of the website in the context of their daily lives. The *reducingLBP* discourse was particularly apparent when participants were looking at, or remembering, the treatments page of the website. This page presents a list of treatments with descriptions of how much evidence there is to support their efficacy. For example, Jordan, who had only had LBP for 2 months, described that he was looking at this page "to see whether you can relieve my pain immediately" by looking through different management approaches (medication, mind-body exercise, pain thoughts and beliefs, rest and activity, acupuncture, and muscle energy technique). *Reducing LBP* was also evident in that many participants (regardless of the length of time with LBP) took pictures of different management strategies when thinking of the website: for example, Barbara (chiropractic clinic), John (ibuprofen and massage), Martin (2 types of medication), and Sharon (float tank, yoga, chiropractor, osteopathy, and massage). One month later, several of the participants clearly demonstrated that they had remembered elements of what they had read on this page of the website:

> *It mentioned that paracetamol is not hugely effective. It said Ibuprofen is probably one of the better ones because it is an anti-inflammatory.* [John]

These data suggest that this discourse is pervasive regardless of the chronicity of LBP.

The *reducing LBP* discourse also arose in more implicit ways. For example, in the following discussion, Dani, who had lived with LBP for more than 10 years, clearly expressed a decision to focus on reducing LBP when discussing her plan to eschew her holiday in favor of focusing on health care:

> *So I'm going to be spending all this money on Pilates to fix my back and that's going to be taken out of the holiday fund. But I just realised this morning [smirks], there's no point going on holiday if I don't fix my back, because it's not going to be enjoyable.*

The second discourse, *living with LBP*, was less frequently evident in these data and was most often implicitly discussed. As the name suggests, *living with LBP* is different from the first discourse in that the focus now is not on trying to change the LBP but rather working out how to live with it. This could involve approaches toward acceptance, coexistence, or learning to thrive with the condition. For example, Barbara, who also had long-term back pain (>20 years), said in her second interview that she had recently read an article on the Australian national broadcaster's website (ABC Radio), which reminded her of the messages on the MyBackPain website. She said that the discussion focused on *moving through the pain* and *not restricting your life around the pain*. Albert (with a shorter 2-year history of LBP) also mentioned the website's messaging to avoid getting scans (such as x-rays and Magnetic Resonance Imagings). The website explains that scans are often not helpful because serious pathology is rarely the cause of LBP and that scans rarely help with diagnosis. Albert suggested that this messaging might make him "feel a little bit more relaxed" about his back pain and that, as a result, he might "face it differently, with a more positive view." Interestingly, although this message was clear to Albert, he quite strongly disagreed with it and continued to argue that a diagnosis was needed so that the "correct" treatment approach could be taken. The variability in participant responses adds to other research that suggests that accepting less than perfect health states is certainly something that people do, but that levels of acceptance vary with age (increases with age) and severity (decreases with increasing severity) [34]. Although our study was not designed to compare across participant characteristics, our analysis suggests that chronicity might be another factor. Overall, the *living with LBP* discourse appeared to be more contested (and contestable) than the *reducing LBP* discourse, perhaps both in relation to the website and in discursive understandings of LBP more broadly.

There were other times when the 2 discourses were held in considerable tension in the participants' lives. Returning to Dani's discussion of whether or not to spend money on Pilates to "fix her back" or to go on holidays, in response to the information on the website, Dani's discussion put the 2 discourses into competition—she decided that she could not go on holiday (living with LBP) until she fixed her back (reducing LBP). In participants' responses to the website, there was little attention to concepts such as acceptance of LBP or other forms of the *living with LBP* discourse. Interestingly, in the second interview, it appears that Dani *had* decided to go on holiday. The discourse underpinning her discussion then changed. For example, Dani had taken a picture of a framed photograph she saw in a shop:

> *I remember the website said that back pain is just one part of your life. It doesn't have to be your life, and is this whole other life around it. Unfortunately, you tend to fall into the trap of, "Oh, my back hurts. I can't do anything." So when I saw picture of the cow [in a field], it just reminded me of my holiday, and it made me realize that there's a whole bunch of stuff I can do besides just work on my back to reach my goals...just doing things that I used to enjoy doing and getting back to what used to make me happy.*

Here, Dani moves away from a focus on changing her LBP (reducing LBP discourse) and refers to different messages on the website than those that were mentioned by people when discussing reducing LBP. She reframes to say that having back pain is acceptable if it is not the only focus of your life. It is not the pain that needs to be fixed or reduced but rather the focus of her life (living with LBP discourse).

At first glance, these discourses appear to be contradictory—one argues for work to reduce LBP and the other argues against a focus on reduction. We suggest, however, that this is not necessarily the case. In fact, it has been argued that it is this very ability to hold 2 apparently contradictory concepts and approach them in a nonlinear way, which is key to being able to adopt the kind of complex thinking that helps to manage health conditions (particularly persistent ones) [35]. We can see a number of practical ways in which this could happen. For example, a person may dedicate some of their time and energy to reducing their LBP—for example, doing things they think help to reduce it (eg, doing exercises or seeking new treatments), and spend some of their time and energy working on living with their LBP (eg, engaging in activities they enjoy or adapting their home environment to make it more comfortable to live with their LBP). This type of *tinkering* with their self-care has been discussed in other research on people's self-care practices, for example, research on how people living with type 1 diabetes use multiple approaches to manage the complexities of their condition [36,37]. Rather than being problematically contradictory, having both discourses present in health messaging might thus be beneficial to assist patients in managing potential complexities. Clarifying and speaking to this *tension* in a health information resource, such as the MyBackPain website, could help people make more conscious decisions about these potentially competing *truths* and perhaps reduce some of the internal conflict that balancing these truths might bring to the surface.

Tension 2: Providing Information...Providing Guidance

Another source of complexity in the data was about whether it is the *expert* (in this case, the health resource website—MyBackPain) or the health *consumer* who has the responsibility/choice to decide which approach to LBP management to follow. The tension here was between providing information (ie, presenting choice) and providing guidance as to how to weigh up choices. The complexity of this issue has been discussed in other studies. For example, Pluut [25] highlighted similar discourses in an analytic review of the literature that attempts to define *patient-centered care*. Key discourses identified in that study were *caring for patients*, where it is primarily the *expert* health professional that decides the course of action, and *empowering patients*, where patients are encouraged to make their own choices and decisions [25]. Both approaches have potential pitfalls: if a health resource is too prescriptive, it is a top-down approach that does not allow space for adaptation, individualization, or contextualization. On the other hand, if everything is left up to consumers to decide, this can be an abdication of responsibility, and at worst, neglectful [37]. Similar to Pluut's findings, our analysis highlights a tension in how the website was taken up by consumers between prescribing *best* courses of action (discourse=*providing guidance*) and leaving choices up to consumers by presenting various options (discourse=*enabling choice*).

One of the participants, Barbara, explicitly discussed the website as placing responsibility for action and decisions on the individuals with LBP rather than on the health professionals (or the website). She expressed this *enabling choice* discourse as positive:

> *It seems to be a self-help managing pain rather than just a directory of professionals or therapists or people to see. It's more about self-care which interests me... It doesn't give you an impression of being a quick fix or having all the answers.*

Similarly, when John first viewed the website he said:

> *It's very upbeat and sort of: "You can take back your life." "You don't have to stop doing things." "You just need to manage your lifestyle a bit better."*

Although some of the participants' responses are positive, this sense of responsibility endowed on the individual can be problematic. It fits with what Foucault [38] would call a *neoliberal agenda*, where control and responsibility are decentralized from traditional forms of power, and instead, people control themselves (or, as Foucault would say *self-disciplining*). One of the reasons why this form of control can be so successful is that responsibility and guilt are closely linked—if something goes wrong, it is then the fault of the individual.

Being responsible for choice can be a burden for some, perhaps particularly those with lower health literacy—people may not have the time or resources to choose well [37]. In some participants' reactions to the website, there was a sense of disempowerment evident when they were presented with a lot of options with little guidance as to how to understand what they meant. There does not need to be low health literacy for this to be the case, for example, the sense of disempowerment was clear in Jordan's interview (Jordan has considerable university-level health training); when he was looking through a list of almost 80 treatments, he said with an overwhelmed tone of voice:

> *There are so many treatments here!*

Many treatment types were described, and the level of evidence for each one was given; however, there was little guidance to highlight what *evidence* means (eg, *not enough evidence* was often misconstrued as *does not work*). Expressing the feeling of disempowerment differently, John, who had a positive response when first viewing the website, discussed a photograph he took of a historic jail for the study. When asked why he took that picture, he said:

> *Having an issue like lower back pain is a bit like being in prison. Because there's a lot of things you can't do. There's a lot of rules you have to abide by. You know, if you really want to take care of yourself, you have to watch what you eat and all that sort of thing.*

As explored in other literature [39,40], the burden of responsibility for self-management can be large.

It is important to note that it is inevitably problematic to dichotomize patient choice and guidance as manifesting separately—even when a health resource presents choices, how they are framed, the detail provided about each, the order in which they are presented, and guides people how to act [37]. For example, participant Thomas said he suspected there was a hierarchy in the order in which the treatment options were presented on the website, with the most supported treatment approaches listed higher up in the list. How options are expressed directs people in one way or another—there is inevitably some sense of valence or directionality. It is perhaps unavoidable that a health resource provides some guidance, choices, and education. However, our research suggests that it is important to include in the design of the health resource an explicit consideration of how to balance these options, provision of clear options for guidance or choice, and making it explicit to consumers what is being done.

Tension 3: Keeping Active...Rest

Another key message that was apparent in the interview data, and was a critical point of tension, was that it is important to keep active (*keeping active* discourse). However, resting was less discussed (*rest* discourse). Like many other participants, Franco said that the main message he took from the website was:

> *Try to be active, try to be active, try to be active, try to be active. I think that was the first message that I got. I was trying to find guidance, and that's the first message. The second is that, it's related to the first one, is to saying that the pain doesn't necessarily mean that it is damaging more. If not too painful to try to [keep active]. Even if it seems bad, try to do something about it.*

Keeping active was seen as a core message by many of the participants. This message is easily recognizable as it is a common contemporary discourse that repeats throughout Western society and health care [40]. Barbara explicitly mentioned this prevalence in her discussion of the website in the context of something she had heard on the radio (mentioned briefly above):

> *Yeah and exercise and movement... I was actually just reading an article on the ABC website this evening that was talking exactly about this study you're doing, talking about how moving through the pain, when you have back pain. It's very much the topic at the moment.*

In her first interview, Barbara had added some nuance to the discussion when she first looked through the website:

> *Personally, I find bed rest difficult because I'm a person who likes doing things and I don't like to be restricted in that way. I do find laying down, especially on the floor, helps my back a lot.*

Here, Barbara expressed that some forms of rest are helpful for her. However, overall, rest was rarely highlighted as important to consider/incorporate.

The tension between how much to keep active, in what ways, to what intensity, and how much to rest was little explored in the website. This is a common issue across health care messaging—ignoring the importance of rest is one of the problems that has been highlighted as an unintended outcome of the current focus on *exercise as medicine* [40], which is reproduced in this website. The lack of attention to rest (no one can be active all the time) seemed to contribute to a sense of a lack of clarity for participants as they tried to incorporate messages to remain active into their lives (J Setchell et al, unpublished data, 2020). When people are unable to achieve what is recommended, guilt and shame can be associated with a perceived pressure to keep active [24,41]. For example, in response to reading the following advice on the website, "Research strongly supports returning to normal activities as soon as possible as one of the best ways to recover from back pain. This trains your body's protection system to not be so sensitive and let you do the things you want to do, without restriction by muscle spasm or pain," 25-year-old John gave a big sigh and said:

> *I feel like this is a catch-22. The best way to stop my lower back pain from changing is to stop activities that might set it off. It depends on what the activities are.*

Although most participants seemed to incorporate the *keeping active* discourse into their lives, and few incorporated the *rest* discourse, a small number of participants took on a more balanced perspective between the 2 discourses. For example, in her second interview, Megan discussed a photo that she took of a message from a mindfulness app on her smartphone:

> *Interviewer: ...it says, "Wanting things in the mind to be different is exhausting. Whereas being at ease is a little more peaceful." Can you explain to me why you took this photo?*
>
> *Megan: Yeah. It reminded me that there has to be a yin and a yang. You can't constantly be worried or wanting a difference and you need to rest. You need to rest your mind, and you need to rest your body.*

Tension 4: Providing Information About Harmful Treatments...Feeling Okay About Choices

The analysis highlighted a further tension. The website presented information about management strategies that are likely to be harmful or ineffective. The intention of providing this content was to better inform people about the risks of LBP treatments that have strong evidence that they are potentially harmful and/or ineffective (eg, surgery for back rather than leg pain and long-term use of opioid medications). Although alerting people to the risks (side effects, risk of adverse events, and financial cost) of some treatments has obvious positive benefits in terms of warning people about risky or unnecessary treatments, our analysis also highlighted some unintended potential negative effects. The issue seemed to arise when someone had already tried one of the treatments that were said to be harmful/ineffective. For example, in Tiffany's second interview, she discussed her use of prolotherapy (an expensive and painful treatment that involves multiple injections into ligaments and other tissues around the spine). In her second interview, Tiffany recalled the website's negative messaging about prolotherapy's effectiveness (ie, "High quality research suggests that prolotherapy is not helpful for leg or back pain. It is not recommended as a treatment for back pain."). She explained how she felt when she was at her doctor's office waiting to receive another course of prolotherapy:

> *I was disappointed that the website said that prolotherapy wasn't helpful, even though it was what I was there to have with my specialist...On the website, some of the references to articles were dated. I've had back pain for thirty-three years, I want the latest information.*

Here, Tiffany discussed her disappointment and, understandably, felt the need to both justify her use of the controversial treatment and discredit the website's perspective by critiquing the references used. She also discusses the instability of prevailing discourses around LBP:

> *Like all the things that I learnt about my back thirty-three years ago, they're telling me the opposite now. I used to treat my pain by trying to ignore it and use distractions, whereas the latest in psychology says you've got to accept it and make it part of you. Thirty years ago when I had a spinal fusion, that was the way it was done. But now we've moved on and that would be not the way to treat my pain now.*

Although this sense of feeling judged or conflicted about previous or current choices after looking at the website was not often apparent in the data, we considered it important. To our knowledge, there is no literature on this topic; however, it is likely that frustration, lack of trust, guilt, and shame can result if people have made these choices in the past/present or when they do in the future. It raised questions such as can we help people manage understandable responses like Tiffany's to shifting treatment recommendations over time? Is there a way to further invite people to consider the suggestions given on the website in light of the fact that what is believed to be an effective treatment, including what the evidence supports, changes over time?

It was encouraging that 1 participant read the website differently—showing that in some people's interpretation, there was a good balance between showing that "some treatments are harmful" and "feeling ok about choices." Barbara said:

> *I would say that it doesn't discredit any treatment or approach that you want to use. If a treatment or path isn't effective, it's saying that there's not enough evidence, it doesn't just discredit it. It still leaves an opening for people who have tried things and find that they do work. So if they're comfortable continuing to use a certain treatment that works for them, it's not saying "don't do it, you're being ridiculous" or whatever. So I think that's important. I just saw the way that it guides and validates what people have experienced.*

If this type of response had been more frequent among participants, this would have been a successful outcome. Ideally, we believe it is unlikely to be helpful to tell people they are wrong to choose treatments that work for them in a health resource or to make them feel bad for using ineffective or harmful treatments, as shame and guilt have long been recognized to be associated with negative health outcomes [42]. Rather, we suggest it is important to be open to a variety of approaches and possibilities that evidence to support or reject particular approaches to management can change [35]. However, at the same time, we want to be clear about the evidence (or lack of) and potential harms/costs of treatments.

Tension 5: Human Elements...Biomedicine

The final tension was between presentation of biomedical information as well as more *human* aspects of living with LBP. By *human* we mean the nonbiological or biomechanical dimensions of LBP, such as the psychological, social, interpersonal, cultural, or ethical aspects of living with, and managing, health conditions [43], in this case LBP. As a complex and multifaceted approach to LBP is now widely advocated in research to include more than just biomedical elements [6,44], the website presented both biomedical and human aspects of LBP.

Perhaps because of their different perspectives on the relative relevance of the biomedical and human aspects of LBP, participants seemed to be quite divided on whether the website presented a helpful balance of these perspectives. For example, Tiffany spoke about the focus of management strategies presented on the website:

> *I think the bias is a medical perspective rather than a health and wellness perspective...From what I've explored of your website, it didn't look like it was very favourable to non-medical treatments.*

Similarly, when looking through the list of practioners who work with people with LBP provided by the website, Charlotte noted that there seemed to be more practitioners focused on biomedical/mechanical elements than those who attended the *human* aspects of LBP. She added that the professionals listed tended to take an individualistic approach that lacks attention to the broader social/systemic context in which a person with LBP is situated:

> *I would be more likely to want to see a social worker or a psychologist who can take a systems view [towards LBP management] because I have to manage a lot of different people and medical appointments and so to have someone you can work closely with who draws those people together and draws me into a case management plan. ...They don't have good communication skills. They are lovely people but they don't have the training in micro core communication skills that social workers have so they don't really understand proper empathy and proper communication that patients often need.*

To John, even the design of the website felt medical:

> *it's designed by someone who also does websites for hospitals. It's very much got that feel in the sort of palate and layout.*

On the other hand, a small number of participants thought differently. For example, Barbara said she thought the content of the website was "very expansive" and explained the benefits of this by adding:

> *Instead of having to go through different avenues, through like the scientific, the clinical, the western medicine aspect of things, versus the alternative route. The website seems to include everything.*

Overall, it seemed as though most participants experienced the website as attending to more of the biomedical dimensions of living with LBP. Preferably, a more multifactorial approach would better suit current understandings of how to manage persistent conditions such as LBP that affect many aspects of a person's life.

Discussion

This study aimed to examine how key messages in a health resource were taken up by participants, to consider their underlying assumptions, and any consider potential unintended effects on people’s lives as a result of interacting with the resource. Our key finding was that there were numerous points of tension that contributed to how participants with LBP were likely to integrate the website messaging into their lives. Our focus on potential unintended negative consequences of this messaging determined that the key points of tension for participants were between (1) *living with LBP* and *reducing LBP*, (2) *keeping active* and *resting*, (3) *providing information* and *providing guidance*, (4) *providing information about harmful treatments* and helping people *feel okay about choices*, and (5) *human* elements and *biomedical* elements. We have highlighted these tensions not only to evaluate this one resource but also to highlight tensions that are likely to be common across management approaches in the field of LBP. Arguably, many of these tensions exist in some form across many aspects of health care, including those beyond LBP. We also believe that, although we focused on health information in the form of a website, the discursive tensions would also be present across different mediums, including face-to-face health care interactions.

This study investigated tensions between different discourses produced in the interaction between a website and the people who use it. Our assumption was that this interaction with websites is not neutral. That is, people do not conduct a neutral examination of the site; they come in with preexisting ideas and experiences that interact strongly with how they navigate the site (eg, what parts of the site they choose to access, what they give the most attention to, and what information they accept or dismiss) and what they learn from the site. People bring their own knowledge and experiences, which interact with the website information in complex ways. Thus, our findings do not attempt to determine the extent to which the website messages are taken up, as they are as much about the individuals who were our participants (and the broader context they live within) as about the health information resource. We, therefore, suggest that readers consider that this study was conducted in Australia, with most participants experiencing LBP over a long period and all participants being employed at the time of the study (1 participant was a student). This would affect the transferability of results across contexts. We acknowledge that the participants might have recalled the website more frequently, or in a different way, because they were knowingly part of a study that included, for example, receiving twice-weekly reminders to make a photographic note of when they recalled the website. Although we did not attempt to examine the amount/extent of website recall, this study context might have affected the emphasis of the tensions we describe.

We suggest that our results can be most useful if the tensions or interactions are not considered as continuums with a beginning and end but rather as a milieu (a middle) where it is not possible to dismiss either aspects of these tensions but acknowledge them explicitly and mix them, perhaps in an amount that is titratable to the individual. That is, it is possible to have a message that speaks to both the concepts to greater or lesser extents. Furthermore, it is also possible that both points can coexist (ie, not necessarily mutually exclusive or antonymic). For example, perhaps it is possible to include evidence about harmful treatments but at the same time discuss potential limitations to evidence, and that it is understandable that at times people choose treatments with little evidence. Indeed, the way forward might be to *include both messages* at once, where possible, as well as making the tensions between them more explicit. Sharing information with that kind of complexity is often easier in formats that allow for more nuances and that engage a human-centered design approach (eg, collaboratively designed videos, artwork, and personal narratives) [45]: messaging that can convey contradictions, emotional content, and contingencies.

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Conflicts of Interest

None declared.

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Abbreviations

LBP: low back pain

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