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Rehabilitation Design Intervention for Older Adult Women through Community-based Co-Design Activities

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This study focused on rehabilitation design intervention for older adult women with low-back pain through community-based co-design activities. The aim was to gain insights from co-design approach to rehabilitation design for older people. A series of collaborative design activities were arranged to organize the design phases and get the data that guide the contents in the subsequent phases by evaluating and adapting initial conditions and design solutions. Firstly, we conducted an exploratory research to analyse the current situation for health conditions and identify major health problems related to older people. In this stage, we found that low-back pain is the major health problem among older adult women from the community of older people in the senior care centre. Secondly, the results of co-design activities were presented, which defined design target and specifications that lead to the early design and development of rehabilitation design intervention. Finally, a confirmatory research was conducted in which the effect of the rehabilitation design intervention on muscle activation level and low-back pain intensity of the older adult women was measured. The results showed that the intervention has positively influenced both muscle activation level and low-back pain intensity. This study can be concluded that the collaboration among multiple stakeholders can enable clear views on the end-user's abilities in design research, which minimize the gap between community members who are central to the study and the design team. The outcomes of such collaborations can contribute to the design of a rehabilitation intervention for affordable healthcare system and also to the portability and ubiquity of the exercise training for older adult women.

Keywords: rehabilitation design intervention; community-based co-design; low-back pain

1 Introduction

Owing to the progressive decline in health and physical fitness of the ageing population, there is an increase in the number of people with chronic pain that result in disability (Pericu, 2017; Blaschke et al., 2009; Groeneveld et al., 2013). The major decline is the rate of spine related disorders that is relatively higher in old age and causing chronic low-back pain (Hayden et al., 2005). The rate of low-back pain is 60–85% during a person's lifespan (Lizier et al., 2012; Andersson, 1999). The pain is itself a common symptom mostly in older adult women (Jaul and Baron, 2017) and 90% of cases are nonspecific because it is not attributed to a recognizable known pathology (Mahel et al., 2017; Balagué et al., 2012).

Due to a number of side effects of the institutionalized care, such as surgery, drug remedies, and non-medical interventions, the importance of rehabilitation through exercise interventions is increased (Piette, 2010; Schreiber et al., 2015; Tones et al., 2006). In old times, rehabilitation was used to recognize the requirements of populations with disabilities. In recent years, the focus has been towards the needs of older people in the community with or without disabilities (Kumar, 2009). Most rehabilitation centres tailor their own objects based on the user's needs and desires. Patients or trainers use universal products as a foundation to design their own personalized objects for healthcare (De Couvreur and Goossens, 2011).

There is an increasing interest in the potential of design approaches towards rehabilitation design by addressing fundamental and yet practical challenges to the healthcare of ageing population. Designers are interested to facilitate co-design activities in the context of healthcare with the aims to positively change the current practices and behaviours (Chamberlain and Partidge, 2017). Co-design is recognized for its benefits in reaching deeper understandings on circumstantial user requirements, and improved value and design process (Steen et al., 2011).

Co-design can generally be applied in situations where subjects are marginalized but experts of their own domain and well-informed about their needs and capabilities that can significantly influence the design process (Ssozi-Mugarura et al., 2017). Older adults with indigenous knowledge (Winschiers Theophilus et al., 2010), deaf people (Blake et al. 2014; Blake et al. 2011), homeless individuals (Southern et al. 2014; Yoo et al. 2013), and children (Bossavit and Parsons 2016; Sanders, 2000) are the key examples of the subjects that form community groups for a deeper understanding of the situations in which implementations can take place over an active engagement and involvement (Dearden, 2008; Ssozi-Mugarura et al., 2017). Community groups are also distinguished by age, gender, and physical capabilities (DiSalvo et al., 2012).

The present study focused on rehabilitation design intervention specifically developed for older adult women suffering from low-back pain. The study was carried out using community-based co-design activities. This approach is developed by Blake et al. (2011) and further studied by Ssozi-Mugarura et al. (2017) to evolve a method that can facilitate collaboration for mutual benefit. It has two parts: co-design and community-based. In a co-design approach, all stakeholders, including designers, researchers, clients, and community groups who will ultimately benefit from the co-designing experience collaborate creatively in the whole design process (Steen et al., 2011; Groeneveld et al., 2013; Sanders and Stappers, 2008). Community-based is endorsed by applying design methods in the context of a community of people (Blake et al., 2011; Groeneveld et al., 2013).

In the present study, the collaboration has taken place with 20 older adult women from the community of older people in the senior care centre, a physician, rehabilitation therapist and exercise trainer, a medical student, and the design team with three design researchers. The purpose of the study was to gain insights into the benefit that co-design approach might have on rehabilitation design. For this, we arranged a series of collaborative design activities and organized the design phases to get the data that guide the contents in the subsequent phases by evaluating and adapting initial conditions and design solutions.

We firstly conducted an exploratory research to analyse the current situation for health conditions and identify major health problems related to older adult women. In this stage, low-back pain was identified as a major health problem among the older adult women from the senior care centre. Secondly, the results of co-design activities were presented, which defined design target and specifications that lead to the early design and development of rehabilitation design intervention for older adult women. Finally, we conducted a confirmatory research to assess the effect of the intervention on muscle activation level and low-back pain intensity with older adult women.

2 Research Methods

This study is based on Community-based Co-design process, which includes participatory action research and design approaches, such as contextual inquiry, quantitative and qualitative research designs. The outcome of these approaches can be much more than the design solutions. In the present study, we made initial engagement with older people in the senior care centre through workshops, focus group discussions and observations. The workshops were lasted for five hours in length each day from 2-3 days. Co-design ideas regarding rehabilitation design were expressed in open discussions where each participant shared their experience regarding health problems associated with older people and its possible solutions were highlighted. Older people shared their opinions about the current exercise training programs and its side effects, such as conservative treatments, hard core exercise training with discomfort and tiredness.

According to Ssozi-Mugarura et al. (2017), community-based co-design is achieved through a six cyclical and iterative research process (See Figure 1). In this process, situation analysis is conducted to understand the current conditions. This step identifies the current problem in the present context. This makes ways for collaborative design in which the focus is specifically towards the end-users because their interests are the driving force behind the design process and they are the main stakeholders involved in defining the problems, articulate design criteria and help in design solutions (Groeneveld et al., 2013). In collaborative design, the foundational knowledge of the design situation is gained from other stakeholders on a community level, such as the older people, physician, therapist, exercise trainer and the senior care centre. Moreover, the design phases are organized to get the data that guide the contents in the subsequent phases by evaluating and adapting initial conditions and design solutions. The summary of the process is presented in the following subsections.

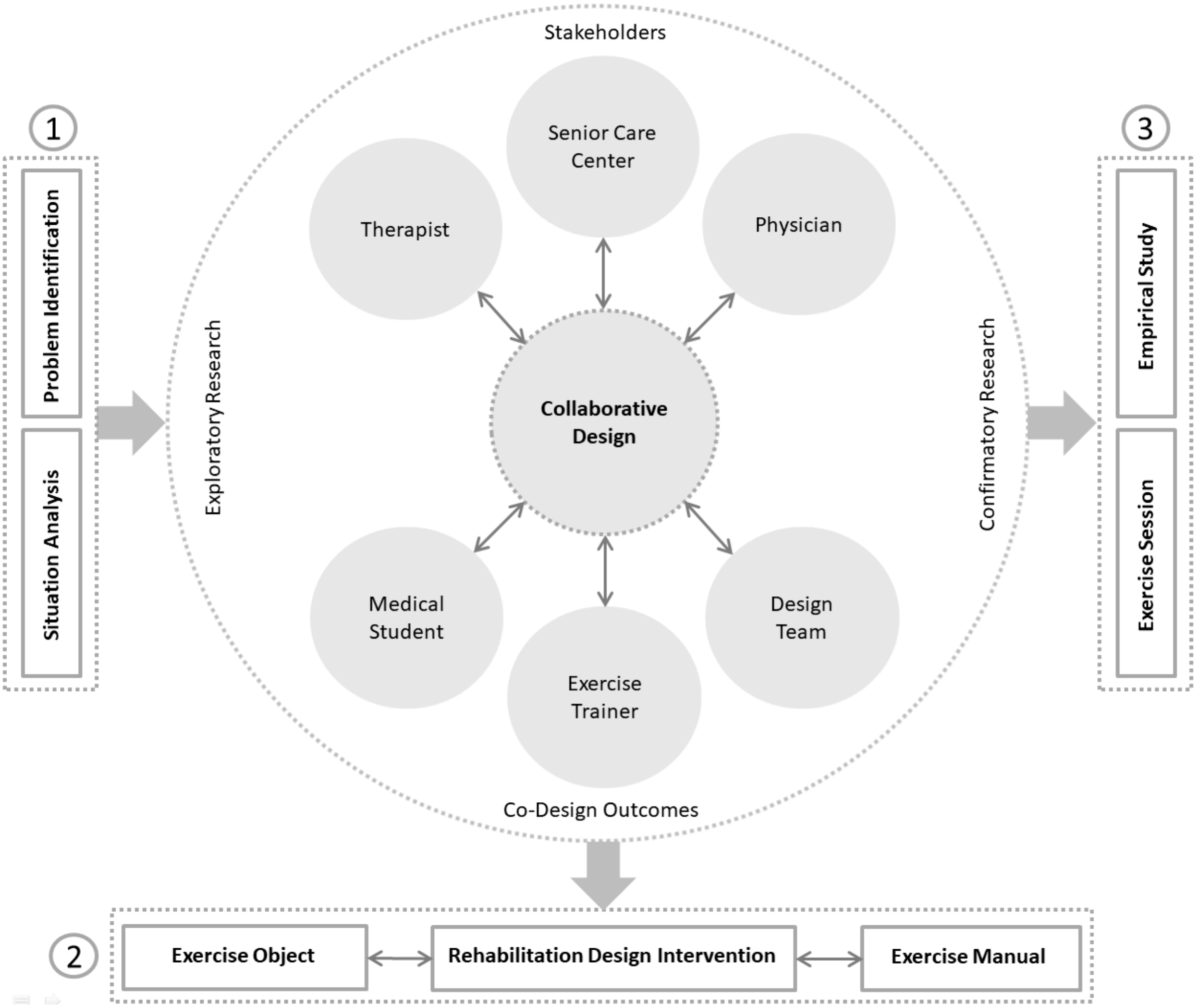

Figure 1. Iterative community based co-design research process for Rehabilitation Design

2.1 Exploratory Research

We thoroughly discussed with the physician, therapist and the exercise trainer about the spine abnormalities that cause low-back pain, and its possible solutions in the rehabilitation design settings. This was a discussion session in which the partners shared their past experiences to construct a view on the context of spine related disorders. The therapist and the trainer had trained several patients who had spine abnormalities in the local training centre. During the session, they also shared their training manuals and customized objects. The physicians discussed muscle anatomy and shared some cases in which the patients were treated with the same abnormalities. This session determined three factors that contribute to low-back pain: *spine abnormalities*, *poor posture stability*, and the *back muscles stiffness*.

We arranged several meetings with the senior care centre in Ulsan City in South Korea regarding the arrangement of collaborative study by presenting our study protocols, objectives and the outcomes. The centre's officials were agreed to collaborate with us, and thus they announced it to the older people in the care centre and around one hundred older people were agreed to participate in this study.

We arranged a workshop in the senior care centre in which we listened to the voices of the older people and their experiences with low-back pain (See Figure 2 as an example). Most of the older people were suffering from spine related disorders and some of them had spine surgeries due to which they had low-back pain.

Figure 2. Senior care centre, exercise training centre and workshop settings

Based on the informed consent, a total of 30 older adult women were exposed to a medical check-up and a radiographic examination using X-ray imaging in a local clinic with the physician. 20 older adult women were found to have low-back pain. They also had major and minor spine deformation based on the medical reports. We arranged another workshop with these patients along with the therapist and the trainer to discuss the pain management. During the workshop, the therapist and trainer showed their training manual and exercise object and trained some patients for a while. They used a customized training object with an inclined slope with 20°, which was made by the training centre for muscle stretching exercise and asked their opinions regarding the training. We collected answers like, “intensive exercise training cause discomfort and tiredness”, “the exercise is helpful for muscle stretching and better than conservative treatments” and “I felt some muscle fatigue due to muscle stiffness”. This activity helped us to address the areas in the body where the patients felt fatigue during the training. These areas were traced by applying the existing methods those from Lehman et al. (2004), and Vera-Garcia et al. (2010) to find appropriate muscles for which a specific training can be designed. These muscles were Latissimus Dorsi (LD), and Lumbar Erector Spinae (LES).

Firstly, we studied the anatomy of the muscles specified in the previous stage by the physician and the therapist and conducted literature review on the training exercises for muscles around the spine. We arranged several discussion sessions with the therapist, trainer, physician and the patients and discussed a concise literature study on the muscle stiffness and its specific training. The rationale was to design a training that can manipulate the back muscles (LD and LES) to keep the spine within the normal curvature, thus the conforming symptoms of low-back pain can be prevented. This session was very informative, which inspired us to further the study. Based on several exercise trials with the patients, consulting previous studies, such as Rainoldi et al. (2004), Nam et al. (2017), Ginn and Halaki (2015), and Lovell et al. (2012), we designed a 15-step training manual with the customized training object based on 20° inclined slope surface. The customized object is presented in Figure 3 as an example.

Figure 3. Inclined sloped training object used for training

2.2 Confirmatory research

During the co-design activities, we noticed that the patients were excited about the exercise training. Thus, we decided to conduct an empirical study with the patients for a period of five weeks. Although this period was not enough for the completion of the training but our intention was to observe some effects of the training on the patients. Generally, a longitudinal study required an adequate amount of time to achieve the study objective; however the patients had different time schedules and daily life routines and some were not available. As such, we could not extend the training period. Based on the consent of the patients, we conducted the training sessions with eight patients from Monday to Friday and Saturday and Sunday was set for resting. We conducted two measures: Self-report low-back pain intensity (LBPI) using Post Wong-Baker Pain Rating Scale[1] with anchors (0 = “No Pain”, 10 = “Worst Pain”), and muscle activation level (MAL) using electromyographic (EMG) activity. The rationale behind these measures was to observe the effects of the design intervention on the patients’ muscles and pain intensity. Figure 4 shows the EMG activity as an example.

Figure 4. EMG activity

The EMG data was collected simultaneously from LD and LES muscles using surface bipolar electrodes from eight older adult women. For this purpose, a 4-channel EMG device (sEMG-4, PolyG-A, Laxtha, Ulsan, Korea) was used. The electrodes were placed on the specified muscle bellies at standardised sites (Lehman et al., 2004; Vera-Garcia et al., 2010). After cleaning the skin with ethanol, disposable Ag/AgCl surface electrodes disks with a

1For Wong-Baker Faces Pain Rating Scale: http://wongbakerfaces.org/

diameter of 11.4 mm were placed on the sites. The sampling rate was 256 Hz and the signal was amplified with an overall gain of 210.084 and filtered to produce a bandwidth of 4–120 Hz using band pass. Besides, Notch filters were used at 60 Hz. The data was recorded and digitize using Laxtha Telescan 2.89 software. We developed a program in Matlab for EMG signal normalization for further analysis.

The self-report LBPI measurement was conducted after each day exercise training while the MAL measurement was arranged on every Friday for a period of five weeks. To obtain MAL for each muscle, we firstly collected the maximum voluntary contraction (MVC) of the specified muscles (MVC Value) for five seconds. Subjects were asked to ramp up to maximum power over the first two or three seconds, retaining full effort for the remaining time. MVC is a standardized method for measuring the strength of muscles. We then recorded the muscle activation level (Raw EMG Value) during the exercise training. The normalized EMG data was obtained by dividing the raw EMG values by MVC values and multiplied by hundred (Sousa et al., 2012).

3 Results

3.1.1 Workshop results

During the co-design process, all patients were directly involved in the training and the subsequent discussions on each exercise step. The report of workshop activities showed that the participants had concerns about some of the steps in the exercise training because of the discomfort and fatigue caused by the training. The report revealed that these steps required much time to complete the whole training while the target users were the older population who is a vulnerable group of the society. In any case, they might be felt fatigue and lost stability and because of their worsening of fine motor skills (Tufail and Kim, 2017), they might be dropped or slipped from the training objects. Therefore, the design intervention was made by eliminating eight steps that contributed to discomfort (See Table 1). In addition, the slope angle of the exercise object was reduced to 15 degree slope inclination.

Table 1 The 7-step training manual along with the specified muscles and location

	Training Step	Muscle	Location	Body Position
1	Standing position (Normal standing)			Standing on feet
2	Maintain standing posture and breathe long			Use inclined plane with 15° slope
3	Standing with hands up	LD and LES	Lateral trunk around the spine	Lateral Bending
4	Bending towards right and left side			Right bend
5	Making an S shape with the body			Left bend
				Forward bend
6	Expanding hands forward			Flexion
7	Bend Forward and Downward			Forward bend
				Downward bend

3.1.2 Empirical results

The rehabilitation design intervention was evaluated by using empirical analysis. For this purpose, we used repeated measure ANOVA design. The dependent variables were LBPI measured through post subjective self-report responses, and MAL for LD, LES, AM, and GM muscles based on objective measures of the normalized EMG data collected for a period of five weeks. The independent variable was the rehabilitation design intervention with five levels (Week 1 to Week 5) of the within subject factors. Follow-up post-hoc comparison using LSD test was conducted to explore a significant main effect of the design intervention with the five levels on LBPI. The same procedure was applied to examine the effect of the design intervention on MAL for each muscle.

The results indicated that the LBPI score statistically differed across each level of the rehabilitation design intervention: $F (4, 28) = 15.65$, $p < 0.05$, $\eta p2 = 0.691$ (See Table 2).

Table 2 LBPI score across the design intervention levels

	Mean	**S.D**
Week 1	6.25	0.98
Week 2	5.83	1.22
Week 3	4.45	0.46
Week 4	4	0.94
Week 5	3.62	0.33

As shown in Table 2 above, the mean LBPI score at week 1 and week 2 was higher than that of week 3, week 4 and week 5. It indicates that participants perceived certain decrease in the pain intensity when the exercise was continued in the later weeks. As shown in Figure 5, the score of LBPI was lower at week 5, which indicated that when the exercise is continued the pain intensity is decreased. These findings clearly indicate that the rehabilitation design intervention can positively influence the pain intensity with the ongoing exercise training using the intervention (See Figure 5).

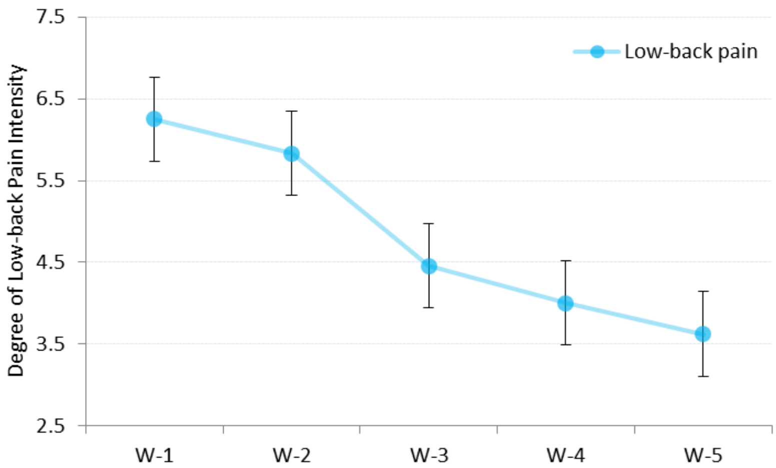

Figure 5. Low-back pain intensity with five weeks training

We performed repeated measure ANOVA tests to measure the effect of the design intervention with five levels on MAL of LD and LES muscles.

The results showed that MAL for LD muscle differed significantly between the intervention levels: $F (2.03, 12.23) = 5.37$, $p < 0.05$, $\eta p2 = 0.472$ on a greenhouse-Geisser correction (See Table 3). However, this difference is against our assumptions that the muscle activity level gets higher when the muscle is effectively trained with the exercise. There was no statistical difference between the mean LD at week 1, week 3 and week 5, indicating that the rehabilitation design intervention retains the muscle activation level of LD muscle in the later weeks.

The results showed that MAL for LES muscle differed significantly between the intervention levels: $F(2.14, 12.85) = 22.13$, $p < 0.05$, $\eta p2 = 0.787$ on a greenhouse-Geisser correction. It indicates that the rehabilitation design intervention significantly influenced the muscle activation level of LES muscle.

Table 3 Muscle activation levels of LD and LES

	Muscle	Mean	S.D
Week 1	LD	29.61	7.57
	LES	18.39	4.21
Week 2	LD	20.69	8.94
	LES	34.48	10.91
Week 3	LD	28.96	8.10
	LES	39.36	8.70
Week 4	LD	23.74	7.75
	LES	38.17	8.57
Week 5	LD	27.99	13.64
	LES	36.29	12.33

As shown in Table 2 above, the mean LES muscle at week 1 was lower than the mean LES muscle at week 2, week 3, week 4, and week 5. It indicates that the intervention design increased the MAL for LES and maintained the muscle strength in the later weeks (See Figure 6).

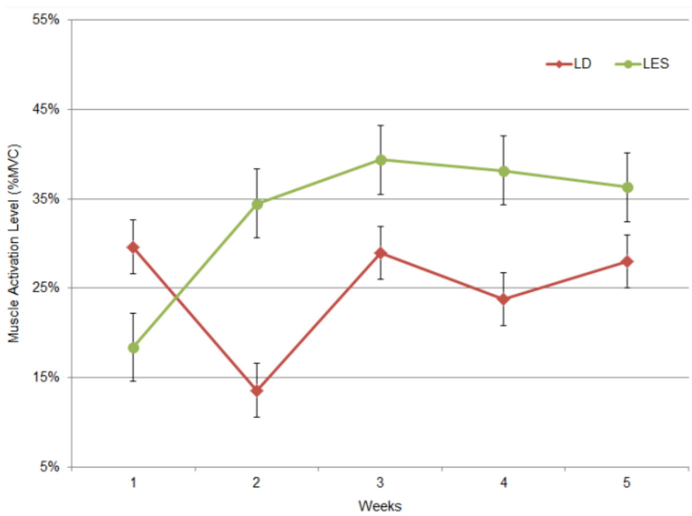

Figure 6. Muscle activation level for LD and LES muscles with five weeks training

The above results showed that the rehabilitation design intervention positively influenced both muscle activation level and low-back pain intensity. The muscle activation level can be increased by training the muscles that can ultimately decrease the low-back pain intensity. However, the effect of the intervention design on the low-back pain and muscle activation level is lower because the specified duration of the exercise training is not enough due to which some participants reported additional time period for muscle training.

3.1.3 Interview results

Overall, the patients expressed positive views about the exercise training in the subsequent interviews. A summary of the interviews are presented below.

- All patients were grateful that the training helps decrease the pain, some patients believed that the training also decreased their leg pain
- The exercise object with 15 degree slope angle benefits muscle relaxation and posture correction
- Patients requested to take the training object to their homes to keep the training continue
- Patients believed that the training helps them on their knees, shoulders and waist exercise
- Some patients mentioned to suggest the training to their friends and families

As the patients were active partners in the co-design process, thus we valued their opinions and desires, which they expressed throughout the study. As per their request, we provided them the exercise manual along with the training object so that they can continue the training in their homes. Once they trained their muscles successfully with the intervention design, they will contact us again to further the design and development process. Overall, we noticed considerable improvements in the patients' health condition based on the current findings.

4 Discussion and Conclusions

This study presents rehabilitation design intervention using community-based co-design activities. A sequence of methods was used to define a design target based on low-back pain caused by spine related disorders experienced by older adult women. Community-based co-design has provided significant results. A design solution was conceptualized and iteratively developed in discussion with various partners in the co-design activities. The solution provided in this study has the potential to reduce low-back pain intensity by inducing muscle stretching exercise and posture correction training. Studies have shown that poor posture and inadequate body movements reportedly increase spine deformations that ultimately cause low-back pain though age factor, fitness, stress and physical and occupational overload also contribute to the pain (Searle et al., 2015). Low-back pain is a backache associated with muscle stiffness located under the last rib and above the lower gluteal muscle folds with or without leg pain (Chou et al., 2007). We found that the low-back pain intensity was decreased in the last week training comparing with the training on week 1. Similarly, we found that the muscle activation level was increased in the last week training when compared with the first week training. This shows that low-back pain intensity is associated with the muscle activation level. Although the results of the training were significantly effective but there were a number of issues that needed to be address in order to use the exercise object for household training purposes. This issue was raised when the patients showed their interest to continue the exercise training after the duration of the five weeks study. The object was made of wooden boards that needs significant changes in its shape and structure. It has a poor mechanism for angle adjustment, stable angle fixation and folding function for portability, which made the use of the object challenging because the target users were a vulnerable group of the society. Thus, future work should be conducted to design the object that meets the above issues. The internal and external properties of the exercise object involved system level design that assembles the product properties and components from the concept development, determine the combination among the components, and demonstrate the detail design for design verification, testing, and refinement should be studied (Lee et al., 2017). Moreover, the shape of the human body, various angle adjustment and stable angle fixation mechanism should also be considered.

The rehabilitation design intervention may contribute both to the affordability of the healthcare and also to the portability and ubiquity of the exercise training based on its ease of use. The intervention is especially design for the ageing population; they can perform the training at anyplace as the exercise object is lightweight and small in size. The participants are currently using the rehabilitation design intervention in their homes, which is a commitment to a long-term collaboration beyond the initial design for experiment and remains an important aspect of the community-based co-design process. This study concludes that the collaboration among multiple stakeholders enable clear views on the end-user's abilities in design research, which minimize the gap between community members who are central to the study and the design team who are external researchers. Further study will be carried out into the application and adaptation of the approach in following development phases of the current rehabilitation design intervention by contacting the patients to understand the long-term effect of the exercise training.

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