The ALL RISE feedback training system for rehabilitation of sit-to-stand

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Abstract

Introduction

After a traumatic brain injury, rehabilitation is highly pertinent, and the outcome is intensity dependent. Current rehabilitation equipment is very specialised and expensive making it available to very few specialised rehabilitation centres. This is counterproductive as patients admitted for specialised rehabilitation are only admitted for a short period of time.

Objective

The goal of this project is to develop a rehabilitation tool that is highly specialised, but at the same time accessible for patients.

Methods

Four studies have been described. Firstly, a literature review of existing technologies for exercising sit-to-stand and extracting knowledge on how to build the interface. This study will be used to inform the prototype of the equipment. Secondly, a focus group study including experienced physical therapists' (provider) and patients with brain injury (receiver) and examining their beliefs and attitudes in using the prototype rehabilitation equipment. Thirdly, a study testing the prototype on healthy and participants with chronic brain injury. The purpose is to fine tune the prototype and test safety of the equipment. Finally, a literature study to inform the further development of the rehabilitation equipment to make it suitable for patients (physically and financially) to bring home after admission from the hospital, so that exercise can continue at home.

Discussion

Highly specialised equipment may be relevant for patients after brain injury. Patients on the other hand need to exercise and improve their functional capacity much longer than what is offered during admission to a hospital. The increased number of expensive training tools available at the market is still only accessible to very few patients limiting the effectiveness to only a few percentages of the patients.

Keywords: Brain injury; computer interface; sit-to-stand exercise; rehabilitation equipment; research protocol;

Introduction

Severe to moderate traumatic brain injury is a devastating and life changing event requiring longer periods of rehabilitation after the acute phase [1]. It is estimated that about 69 million people worldwide are suffering a traumatic brain injury each year with the highest percentages of people being mainly in the low to middle-income countries. Severe traumatic brain injury corresponds to about 8% of the total affected people with an incidence in Europe of about 1,000 per 100,000 people [2].

After a traumatic brain injury, rehabilitation is highly pertinent, and the outcome is intensity dependent [3, 4]. Current rehabilitation equipment is very specialised and expensive making it available to very few specialised rehabilitation centres. This is counterproductive as patients admitted for specialised rehabilitation are only admitted for a short period of time.

The purpose of this PhD project is to develop a clinically effective rehabilitation equipment for exercising the sit-to-stand movement. The equipment should be based upon general motor learning principals emphasising intensity, repetitions, and challenge the participants as well as motivate them to exercise more and harder through simple gamification [3].

The PhD project consists of four studies:

1. Literature review of existing technologies for exercising sit-to-stand
2. Developing a computer interface integrated with a force platform,
3. Testing the system on healthy and affected participants with chronic brain injury, and
4. Developing a force platform that the participants can bring home for further exercise after discharge from a specialised rehabilitation centre.

Therefore, the end goal of this project is to develop a rehabilitation tool that is highly specialised, but at the same time accessible for patients.

Study 1. Developing an interface for the prototype of the ALL-RISE sit-to-stand exercise equipment

Developing a new interface for rehabilitation equipment requires careful planning. In general, there is a large difference on effectiveness in how augmented feedback is giving for optimising learning [3, 5, 6]. In patients with severe brain injury there is a need for special considerations depending on the cognitive, physical and emotional deficiencies [3, 6]. Motor learning after brain injury is highly inspired by research conducted on healthy individuals [5]. As a rule of thumb exercise need to be intensive, specific, and have an external focus [5, 7], but studies have shown that patients admitted to rehabilitation after a brain injury are largely inactive and sedentary [8, 9].

A few studies have confirmed the importance of high intensity when relearning motor functions after brain injury [10, 11]. Especially, concerning motor relearning of arm function [12, 13] and walking speed and stamina [12]. In these interventions the researchers have tested and used rehabilitation equipment such as arm-robots or electromechanical-assisted gait training for achieving a high intensity of repetitions [12, 14]. Importantly, this equipment incorporates external feedback for specific correction of the intended movements.

Kommenterede [CGR1]: Artikler I Mendeley

Goal setting is considered one of the main drivers in motivating patients to perform more and better [15]. Especially meaningful goals are also considered an important factor. Goals can be set on the quality of the performance or on the quantity. There is still no consensus on whether one is better than the other, but it is assumed that it depends on what the participant want to achieve [6].

Immediately after an exercise session one may experience an improvement, but more importantly is retention of the exercised movements [6]. That is, after a certain amount of time (days) are the person able to recall these improvements and perform on the same level or better? Interestingly, one study found that cardiovascular exercise improved retention at one hour and 7 days after the exercise [16].

Through a systematic review of the literature, all types of feedback technologies that has been developed for improving lower extremity function will be sought. The purpose is to identify key factors for incorporation in the feedback system when exercising sit-to-stand. Through this process, we will produce an exhaustive overview of methods.

Method

This systematic scoping review will adhere to the PRISMA extension for scoping reviews [17].

Through searches in relevant databases (Pubmed, IEEE Xplore, ASCE Library etc.) data on force platforms, force sensors and feedback interface will be sought using terms as “lower extremity”, “feedback”, “system”, “interface”, “retention”, “gamification”, “motivation”, “sit-to-stand” OR “lower-extremity”. We will search grey literature by using the above keywords and searching Google and Google Scholar.

Two independent reviewers will screen title and abstract of eligible records and select these as “relevant”, “maybe relevant” or “not relevant”. The titles that were maybe relevant will afterwards be discussed to reach consensus. If this is not possible a third reviewer will be consulted. Afterwards, the two reviewers will full text screen relevant articles for the final decision of “include” or “reject”. References of included articles will be screened for additional potential articles not found in our initial search.

Inclusion criteria for selecting studies is: 1) equipment tested on any human subject (healthy or any diagnosis); 2) Focus on using the lower extremity; 3) any study design available.

Data from included articles will be extracted by two reviewers. We will extract general information on publication year, author names, country and contact address, specific details about the equipment such as the amount of time the sensor has been available on market, size and weight of equipment etc. Also, specific data on the interface (such as colour, size, sounds etc) and other factors associated with feedback and retention of motor learning will be extracted.

Study 2. Developing a computer interface.

Sufficient and correct feedback is essential to improve the functional outcome in people with brain injury. Attentional or procedural problems due to the brain injury can affect the understanding and interaction with the exercise equipment [18]. It is, therefore, important to develop the interface with only few but simple ways to interact with the participant.

The interface should be adapted in an easy way to the exercise equipment connecting the force platform (AMTI multi-axis force platform system MMS400600-XKSYS) to a TV/Computer screen through an HDMI connection (or similar).

Specifications

The interface should be able to count the number of sit-to-stand exercise that the participant is performing. Along with a goal setting approach, the system should be able to register how many times the participant puts weight through his/her feet as is done when standing, using the connection to the force platform. The quality of the movement is not essential here. If the participant's goal is to reach 100 sit-to-stand, then the interface should be able to count backwards from 100.

Simultaneously, the interface should be able to motivate the participant to do the exercise faster and in pre-specified bouts (5, 10, 15 and so on).

Lastly, a feedback on weight-bearing should be illustrated on the computer/TV screen giving the participant the opportunity to correctly adjust weight-bearing to both feet or to focus more on weightbearing on one foot over the other.

The purpose of this study is to gather expert knowledge from users (receiver and operator) with experience in using other rehabilitation equipment on key components for development of the interface.

Method

This study will be done in three phases for constructive development of the interface. Firstly, a focus group interview with physical therapists and secondly, a focus group interview with patients will establish the most important factors on developing a usable interface. Thirdly, the information will be used to develop the interface.

Through semi-structured interviews with themes prepared before initiation of the interviews (e.g. usability, motivation, feed-back, safety), the necessities for the system will be established. The interviews will focus on the vast experience that the therapists have from using technological feedback systems in rehabilitation such as those developed for the Lokomat® or the ARMEO® (Hocoma, Switzerland) that are used regularly at the Department of Neurorehabilitation, Rigshospitalet. Four physical therapists with at least five years of experience within neurorehabilitation and technology will be invited to participate in the study. Afterwards, four patients admitted to the department for rehabilitation after brain injury will be interviewed with the primary focus on factors for improving motivation. These patients should be able to participate in the interviews and, therefore, only have mild speech impairments. During their rehabilitation at the department they need to have had more than six sessions with technological feedback systems.

The work group moving forward will consist primarily of a technical engineer (the Ph.D. student) and two physical therapists from the Department of Neurorehabilitation.

In separate groups, the four therapists and the four patients will be interviewed using a semi-structured approach. Each interview will be video recorded and afterwards, the interviews will be transcripted and divided into relevant themes.

Afterwards, the information will be used to inform the engineer (PhD student) in the development of the interface.

Study 3. Testing the system on healthy participants and participants with chronic brain injury

The interface and the connection to the force platform will be developed during the first phase. In the second phase, the system will undergo evaluation and feedback for potential adjustment from healthy volunteers and end users (people with brain injury). The primary purpose of this study is to test and adjust the interface and the exercise setup, and to monitor clinical safety.

Methods

After developing the interface and the connection to the force platform, a thorough experimental testing and validation of the system is essential. For safety reasons, this testing will firstly be done on 20 healthy participants and afterwards on 20 patients with brain injury. Patients will be recruited from the Department of Neurorehabilitation (early rehabilitation) and from local municipalities (late rehabilitation).

Recruitment of healthy participants will be done through the web-page (www.forsøgsperson.dk) and patients will be recruited through the Department of Neurorehabilitation and through contact to the local rehabilitation centres in the rural area of Copenhagen.

Participants will randomly be assigned to do 150 sit-to-stands as seen in figure 1. Height of the chair will be adjusted to reach 100% of the participants lower leg length.

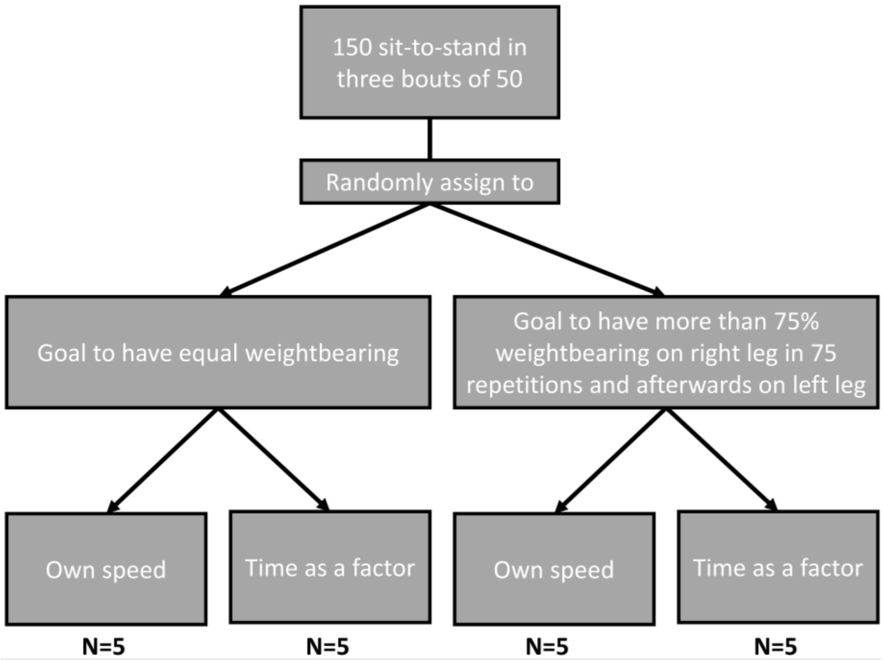

Figure 1. Flow chart

After the participant has completed the exercises, they are asked to rate the interface and provide feedback on a 10-point scale (with 10 being “worked perfectly” and 0 being “did not work at all”) for each of the applied areas of focus (e.g. usability, motivation, safety). The feedback will be used to fine-tune the system. All exercises will be supervised by a physical therapist familiar with this type of exercise.

Afterwards, 20 participants with chronic brain injury and different degree of impairments will go through the same exercises. Depending on their level of impairments, a number of subjective (subject-wise) adjustments will be incorporated to fit a realistic goal for each participant. We aim to target participants who have some difficulties in doing sit-to-stand exercises and should, therefore, have a score of 30 seconds or above on the five-repetitions sit-to-stand test [19].

During the exercises we will monitor heart rate in healthy and participants with brain injury. Measurements will be done using the ePatch system (bioTel, Philips) which measures continuously three lead electrocardiography. Also, the Borg scale for monitoring perceived exertion from exercise will be used during each bout of sit-to-stand exercises.

Each participant should be able to reach at least 150 repetitions of sit-to-stand exercises in total. It is possible to divide the number of repetitions in three bouts of 50. If the participants cannot reach this number of exercises in one session, they are allowed to rest in between and will continue the exercises afterwards. We will then continue to measure heart rate.

After completion of these exercises, the participants will be interviewed and asked to rate the quality (their beliefs) of the exercises on a 10-point scale in regards to how exhausted they were from the exercises, if they would recommend this to others and if they believe that exercises of this type would benefit them in the future.

All adverse reactions during the exercise sessions will be registered. The day after completing the exercises, the participant will be contacted and asked if they have experienced any discomforts. Here, general muscle soreness would be expected, but special focus on not being able to complete daily activities and routines will be registered. This will be done over telephone using a structured interview guide ensuring that the same questions are answered by each participant.

Data analysis

All qualitative data will be analysed by the primary investigator and divided into separate themes. These data will be used to do adjustments to the interface and exercise setup. All ratings on the quality of the exercises (e.g. usability, motivation, safety) and the monitored heart rate will be presented as means with standard deviations or medians and interquartile range depending on their distribution.

Study 4. Developing a force platform that the participants can bring home for further exercise

Kommenterede [CGR2]: Indsætte artikel fra Sada

People with brain injury need exercises at a high intensity and for a longer period than what can be accomplished during their hospitalisation. Focussing on applying qualified and intensified exercise out of the regular therapy sessions are, therefore, an important focus. Traditionally, in the Municipality, the doses of exercises are delivered two to three times per week for 30 minutes. Studies have highlighted that for improving functional outcome, the number of repetitions would have to be markedly increased [4]. This is not possible as physical rehabilitation efforts in the municipality are not logistically prepared for this.

Kommenterede [CGR3]: Afsnit om større behov og mindre personale

One solution would be to develop exercise equipment that the participants easily could set up at home.

As the prototype consists of a heavy force platform (28.64 Kg) with a height of 4 cm, the applicability for the participants to bring this home for further exercise is very low. Hence, the purpose of this project is to develop a force plate that is as thin as possible and easy to carry.

Through a systematic review of the literature, all types of technologies that uses force sensors will be sought. The purpose is to identify lightweight systems and sensors that can be easily adapted to a force-plate system for further development of the ALL-RISE rehabilitation system.

Method

Through searches in relevant databases (Pubmed, IEEE Xplore, ASCE Library etc.) data on force platforms and force sensors will be sought using terms as (“Sensor”, “force plate”, “pressure”).

Two independent reviewers will screen title and abstract of eligible records and select these as “relevant”, “maybe relevant” or “not relevant”. The titles that were maybe relevant will afterwards be discussed to reach consensus. If this is not possible a third reviewer will be consulted. Afterwards, the two reviewers will full text screen relevant articles for the final decision of “include” or “reject”.

Data from included articles will be extracted by two reviewers. We will extract general data on publication year, first author, time sensors have been available on market etc. Also, specific data on weight, durability and applicability to other systems will be extracted and compared.

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