Virtual rehabilitation of the weigh bearing asymmetry in the sit-to-stand movement

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ABSTRACT

Weight bearing asymmetry is frequently used as a measure of impairment in balance control, and recovering symmetry in weight bearing is considered an imperative objective of rehabilitation. WBA rehabilitation is especially important for the sit-to-stand movement. Transition between sitting and standing, or vice versa, is one of the most mechanically demanding activity undertaken in daily life. In this contribution, we present a Virtual Rehabilitation system specifically designed for the recovery of the symmetry for this movement. The system has been designed with clinical specialists, and it presents very promising features such as the automatic adaptation to the patient. The paper is a work-in-progress that describes the system and presents the validation study that we will follow in a metropolitan hospital. Currently, we are enrolling patients, and the clinical specialists are very encouraged about the potential of the system.

1. INTRODUCTION

A wide variety of clinical population suffers Weight Bearing Asymmetry (WBA), as a consequence of their impairment. This problem especially affects patients with neurological impairments (Pai et al, 1994) and patients who have had lower limb musculoskeletal injuries (Talis et al, 2008). These patients tend to place more weight in the healthy limb, even when they have the capacity to balance more adequately the weight distribution. This asymmetry is frequently associated with loss of postural control, for instance after a stroke (Bohannon, 1988) or due to pain in the injured limb (Hurwitz et al, 1999).

WBA is a potential source of deficit in balance control (Genthon and Rougier, 2005), and affects decisively patients, limiting their movements and increasing their risk of falling. Also, increasing loading in the healthy limb is associated with degenerative joint diseases in this limb. Thus, rehabilitation of WBA is critical to integrate patients in their activities of daily living (ADL).

One of the critical stages of the WBA rehabilitation is the sit-to-stand movement. Transitions between sitting and standing are fundamental for ADL in patients with neurological deficits (Cheng et al, 1998) and in patients with lower limb musculoskeletal injuries (Su et al, 1998).

On the other hand, in recent years there has been increasing research interest in the integration of video game technologies into motor rehabilitation programs. Specifically, different papers demonstrate the validity of Wii Balance Board® (WBB) based systems for rehabilitation and assessment (Gil-Gómez et al, 2011). The WBB is a device originally designed by Nintendo® for the Nintendo Wii® gaming system. It is an inexpensive, widely available wireless device, small size and weight. All these features facilitate their integration in the clinical routine. The WBB has four sensors, one in each corner, that allow to measure the center of pressure (COP) of the user. In (Clark et al, 2010) authors conclude that WBB provides comparable data to a laboratory-grade force platform.

Recently, many authors apply successfully the WBB to the WBA, but they are focused to the assessment of the WBA, not to the rehabilitation. In this way, Clark et al. (2011) demonstrates the reliability of the WBB for recording WBA and COP.
In this contribution we present a work-in-progress of a WBB based system specifically designed for the rehabilitation of the WBA during transitions between sitting and standing. The paper describes the system, that is completely developed, and the clinical trial designed to validate the system as a novel tool for WBA rehabilitation in the sit-to-stand movement. Currently we are selecting the patients for the clinical trial.

2. METHODS

2.1 System

In the design of the system, one of the most important decisions was whether to use one or two force platforms (WBB in our case). In this sense, some authors affirm that it is possible to obtain accurately WBA from a single force platform (Genthon et al., 2008), even for assessment. Other authors, as Clark et al. (2011), support the use of two force platforms to measure the force under each foot, improving the WBA accuracy.

In our case the system is designed for rehabilitation, not for patient evaluation, and then it is also necessary to consider the integration of the system in the daily clinical routine. Furthermore, more accuracy is usually needed in the calculation of the WBA in patient evaluation that in daily patient rehabilitation. Finally we integrate a single WBB in our system, with two footprints marked on it. With this setup we have enough accuracy for daily rehabilitation, and the integration in the daily clinical routine is very easy.

To evaluate the WBA of patients (before and after the validation study), we integrate a simple custom program that uses two WBB, one under each foot. We perform this setup for assessment following the conclusions of Clark et al. (2011), who demonstrate the reliability of a system based in this configuration.

2.1.1 Hardware. One of the advantages of the proposed system is its low cost and the easy integration of the system in the clinical environment. Also, all the hardware components are widely available.

As advanced, the system uses a WBB as the interaction device between patient and system. A conventional computer is also needed–no special high performance features are required–with Bluetooth, and a display device. As display device we recommend a 42”-47” LCD/LED TV, which would allow an easy integration in the environment with good visualization for the user. In our setup we are using a LCD/LED TV trolley floor stand with wheels at the bottom, which permits to move it around easily.

2.1.2 Software. The software of the system is a custom-designed program which utilizes the data sent by the WBB to calculate the WBA, and then it uses this information to perform the interaction. To calculate the WBA, the symmetry index (SI) is used; SI is explained in the Data Analysis section. The design of the software was carried out with the collaboration of clinical specialist in motor rehabilitation, to ensure the correct system approach from the clinical point of view.

Basically, the software is composed of three stages: initially a set of basic parameters is established by the specialist. This is followed by the main stage, which is a game played by the patient. Finally the system shows the main results of the game.

![Figure 1. Main stage of the game with patient standing up.](image)

As advanced, the main stage is a game, because one of the most important advantages of the virtual rehabilitation is the possibility of providing more entertaining rehabilitation. In this way we follow a game scheme, to motivate further the patient, increasing their adherence to the rehabilitation process. In the game, the patient controls a balloon that can move around the screen, see Fig. 1. When the patient rises from the chair, the balloon goes up until the top of the screen, and when the patient sits the balloon descends until the
bottom of the screen. In this vertical movement the globe is flanked by two sides with thorns. The balloon can also be moved laterally depending on the patient's SI, and then if the asymmetry is too high the balloon will touch one of the sides with thorns and it will explode. The patient does not see directly a SI score; he get SI feedback through the horizontal position of the balloon: the more balanced SI is, the balloon appears more centered between the two sides with thorns. The asymmetry tolerance of the system (the SI range in which the balloon does not explode) can be configured by the specialist or even can be adapted automatically by the system according to the patient.

In order to make the patient to stand or to sit, sharp elements appear during the game (darts, wasps, daggers, …) that move horizontally toward the balloon. These elements may emerge in two predetermined positions, up or down, coinciding with the vertical position of the balloon when the patient is standing or sitting. If one of the sharp elements touches the balloon it explodes.

All in all, the aim of the game is to keep the balloon intact as long as possible. During the game, the SI of the patient is registered in real time. The different events and parameters of the game are also registered, providing specialists data to analyze the evolution of the patient in their rehabilitation. It is necessary to emphasize that this data is very important, because this is information about the WBA patient during the sit-to-stand movement. Furthermore it is objective, non-dependent on the particular appreciation of a specialist.

Previously to the main stage, the specialist sets a number of parameters to customize the rehabilitation session. These parameters define variables such as session time, the speed of sharp elements and SI level allowed. This last parameter is very interesting, because it has the possibility of establishing an adaptive level: if the patient bursts the balloon quickly the system is progressively more permissive with the level of asymmetry of the patient; if the patient preserves the balloon for a long period, the system would became less permissive with the asymmetry of the patient. The aim of this adaptive level is to avoid the frustration of patients maintaining their motivation.

In the third and last stage, the system displays the result to the patient-the average survival time of each balloon-. With the results, the system provides visual and auditory reinforcement (confetti, applause, …).

### 2.2 Validation Study

As advanced in the introduction, this paper describes a work-in-progress. In this section we describe the criteria that we are following for the selection of the patients and other features that we consider for the validation study of the system.

#### 2.2.1 Participants.

We plan to validate the system with a minimum of forty patients, divided in two groups: control group and experimental group.

The inclusion criteria are: the ages of patients between 8 and 75 years old; patients can walk 10 meters indoors with or without technical orthopedic aids; Patients have WBA problems due to lower limb surgery and / or neurological deficits -SI over 20%, following Cheng et al. (1998) conclusions-.  

The exclusion criteria are: patients whose visual or hearing impairment does not allow an appropriate interaction with the system; patients unable to follow instructions; patients with severe dementia; patients with cognitive impairment –Mini-Mental State Examination (Folstein1975) score under 24-; patients with unilateral neglect, aphasia, ataxia or any other cerebellar symptom. All patients will sign written informed consent prior to enrollment in the study.

#### 2.2.2 Intervention.

Patients will complete a total of thirty sessions: three sessions every week in a period of ten weeks. The control group will follow the traditional rehabilitation program during all the period. The experimental group will replace the corresponding time of the traditional rehabilitation with the proposed system. Every session will last for thirty minutes, including all the stages of the system. Depending on the patient and his condition at the time of the intervention, the specialist will divide a session in different sub-sessions, separating every sub-session by short breaks (from one to five minutes).

#### 2.2.3 Data Analysis.

For the data analysis we evaluate each patient twice: before the beginning of the validation study and immediately after. In each evaluation we obtain many different values, but we base our analysis especially in four values: SI during sit-to-stand movement, SI during stand-to-sit movement, time needed to stand up and time needed to sit down. The two last values are in seconds. The SI values are a percentage: the difference of weight bearing between both legs as a percentage of total body weight.

To obtain the SI in each evaluation we have developed a very simple application based on two WBB. In this case we use two WBB because we want to assess the WBA, and this setup is validated for this purpose (Clark et al, 2011). This application only requires the repetition of the sit-stand-sit transition as many times as defined. In our case, following the study of Christiansen et al. (2010) we use a total of five repetitions for
each patient. The final SI is the average of the SI of the five repetitions. For every patient we will measure their SI before the intervention period and after the intervention period.

3. CONCLUSIONS

Standing up and sitting down are among the most common activities in daily life. Thus the rehabilitation of the WBA in these movements is critical to prevent falls and enable the integration of patients in their ADL as soon as possible.

In this paper we present a system designed to rehabilitate these movements. The system has many potential advantages over the traditional rehabilitation methods. Once the parameters have been initially set up (a brief stage that last less than one minute for the specialist), the system can guide directly the patient in their rehabilitation session, without requiring specialist intervention. Moreover, the system is able to automatically adapt the difficulty of the task according to the characteristics of each patient. Due to the ludic approach proposed, the system increases the motivation of the patient, allowing the increase of the adherence to the rehabilitation process. The system records, automatically and in real time, the progression of patients, providing to the specialist objective feedback to evaluate their evolution.

We also present the validation study that we will follow for this system. This validation study will be conducted in a specialized service of a hospital. Currently, we are enrolling patients for the study.

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4. REFERENCES


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