Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 147 (2016) 157 – 162
Procedia Engineering
www.elsevier.com/locate/procedia

11th conference of the International Sports Engineering Association, ISEA 2016

Development of a wearable live-feedback system to support partial weight-bearing while recovering from lower extremity injuries

Tkachenko Bril A.[1]*, David V.[1], Scherer M.[1], Jagos H.[2], Kafka P.[1], Sabo A.[1]

[1]*University of Applied Sciences Technikum Wien, Höchstädtplatz 6, 1200 Vienna, Austria*
[2]*Raltec - research group for assisted living technologies, Vienna, Austria*

Abstract

Lower-body physical rehabilitation therapies and technologies are inevitably linked to the sports world. Partial weight-bearing is a common measure that accelerates the healing process following lower-body surgeries or fractures. In order to improve the compliance with this method, a smartphone application was developed. It provides the user with an audible and haptic biofeedback alarm when a predefined threshold is reached by the pressure sensors' data of a pair of instrumented insoles. The preliminary results show that the alarm functionality works in accordance with the stipulations. The biofeedback also appears to have a positive effect on the amount of steps under the target weight.

Peer-review under responsibility of the organizing committee of ISEA 2016
Keywords: "Rehabilitation; lower extremities; live feedback; partial weight-bearing; eSHOE,"

1. Introduction

Partial weight-bearing (PWB) is a commonly employed therapy to rehabilitate patients after certain lower-body injuries [1]. It consists of instructions to bear a certain amount of weight on the operated extremity during ambulation processes [2 - 4]. Studies have shown that this kind of treatment is beneficial for the healing process after certain hip operations, knee surgeries, and fractures in or around the joints of the legs and for amputation patients [5]. Sports-related injuries could be also treated with this method. PWB offers a unique and balanced way, which promotes bone growth and healing while protecting the injury site and surgical constructions around it. This provides the patient with an optimized rehabilitation process that reduces the healing time and allows a quicker re-establishment of normal gait [6]. The loading of the affected limb is restricted based on the concern that excessive weight applied to the injured side could cause the implant to fail, disturbing the fracture's stability and alignment [1]. High strain placed on the affected extremity may lead to deformation or breakage of the surgical construction. However, repetitive loading above a certain level is the main concern regarding implant failure [7].
The need to find a sweet spot that grants an optimized curing course while minimizing the chance of implant failure and complications during the rehabilitation procedure is the justification for the partial weight-bearing method usage. A progressive protocol of weight-bearing as the healing process advances is a common clinical practice, being the most common instructions defined as touch-down weight bearing (around 10kg or 10% - 20% of body weight), partial weight-bearing (35kg or 20-50% of bodyweight) and weight bearing as tolerated, which is regulated by the patient accordingly to the perceived pain [8, 9]. The health care specialist has to evaluate the progress of the patient´s injury and progressively reduce weight-bearing restrictions accordingly by showing the subjects what the objective load feels like [10]. Several techniques have been tried in the pursuit of this goal, verbal instructions and the use of bathroom scales being the most common [2]. Most of these methods have been shown to have a poor outcome in regards to the ability of the patient to reproduce the weight-bearing protocol [11 - 13].
Providing the patient with real-time biofeedback is an approach that has a positive and superior outcome compared to the

* Corresponding author. A. Tkachenko Bril, Tel.: +43-1-3334077-892 ;
E-mail address: tkachenk@technikum-wien.at

1877-7058
Peer-review under responsibility of the organizing committee of ISEA 2016
doi:10.1016/j.proeng.2016.06.206

classical methods in tests performed in clinical conditions or rehabilitation centres. However, the majority of studies determine that a crucial aspect in the success of the limited weight-bearing method is giving the patients a possibility to quantify the asymmetrical loading outside of a clinical environment, since the largest part of the rehabilitation process occurs after discharge from the clinic and patients have been shown to be unable to reproduce the weight-bearing pattern even after short periods of time [11, 14].

Figure 1: (A) eSHOE insoles and embedded electronics. (B) Splash screen of the Android application.

The eSHOE insoles are a mobile gait analysis system based on an instrumented shoe insole that was developed by the Central European Institute of Technology (CEIT RALTEC, Schwechat, Austria) in collaboration with the University of Applied Sciences Technikum Wien [15 - 18]. The system is comprised by two orthopaedic insoles with a built-in embedded system which includes pressure, acceleration forces, angular acceleration sensors and a magnetometer. The relevant pressure sensors of the eSHOE in the scope of this work are the four A401, Tekscan sensitive resistor sensors (FSR) that measure the pressure under the heel, the first and fifth metatarsal heads and the big toe. The device transmits the sensor data via Bluetooth using a KC22.6, KC Wirefree module.

In this work, a solution that supports the PWB therapy and improves the patient’s compliance was developed. Taking all of the previously mentioned factors and considerations into account, an application that could be installed on a smartphone and which would process data wirelessly transmitted from the eSHOE (Figure 1, A and B) insoles’ pressure sensors seemed to cover the needs of providing the patients with a system that generates real time biofeedback on their partial weight-bearing performance, both in- and outside of a clinical environment. The developed system was also preliminary tested with a feasibility study in order to obtain a first impression of its performance.

2. Methods

Structure of the live-feedback system

The system was developed to provide a cheaper and more user-friendly solution for two common problems when prescribing PWB. These are the learning process of the PWB method and the low compliance problem that most of the patients present after discharge from a rehabilitation centre. It consists of the eSHOE instrumented insoles and a smartphone application that provides its users with feedback when a threshold pressure on a lower limb is reached. The measurement software was developed in Java for the Android 3.0 operating system and uses Android Studio [19]. This setting allows it to run on approximately 80% of the Android running smartphones that are available as of May, 2015 as well as all devices that have been produced since December, 2011.
A schematic representation of the signal acquisition, processing and program output of the Android application is shown in Figure 2. The values delivered by the FSR sensors are sent via Bluetooth to an Android device running the application. Upon retrieval, it is analysed in order to determine whether the read data is valid. Then the data is fed into three main functions which analyse and graphically represent the received values, as well as trigger the haptic and sound alarms in case the sum surpasses the selected threshold value. In order to assure high compatibility, the software was tested on three devices that represent two broadly distributed forms of handheld devices: SII and S4 Samsung smartphones and a Nexus 10 tablet, all of which featured different Android versions (SII: 4.1, S4: 5.0, Nexus 10: 5.1).

Feasibility study of PWB with live-feedback

Three young male subjects (S1: 26yo., 1.81m, 83kg, S2: 22yo., 1.84m, 88kg, S3: 21 yo., 1.71m, 70kg) tested the novel live-feedback system. The measurements were carried out with Medilogic (T & T Medilogic Medizintechnik GmbH, Schönefeld, Germany) and eSHOE insoles simultaneously, the first placed over the latter. The subjects wore both systems in their shoes during all trials. The data from the Medilogic insoles was used to quantify the load and the data gathered by the developed application was used to provide live-feedback.

A total of 90 steps were recorded under 3 conditions (30 steps each). Under the first one (C1), the subjects walked with a self-