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Walking Foot Insoles for Dynamic Postural Analysis of Patients with Gait Imbalance: A Preliminary Report

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There are different cycles involved in the gait. In order to detect the pathological gait, it is necessary to understand the normal gait. During walk, various parameters were calculated to do analysis for providing further gait training. The aim of this study is to do the investigation and precise identification of deviation in gait pattern. Experimental study is done on thirty-one test subjects suffering from gait impairment. Further, data analysis on subjects is done to measure their gait parameters for usability in their walking aids. Favorable measuring parametric results were obtained and found satisfactory on comparing with standard walking system. The system is capable of determining the standard of care for the assessment and treatment of patients with balance, dizziness and mobility problems.

Keywords: Assessment, Dynamic posture, Gait cycle, Postural stability

Introduction

Walking is a common activity of daily living and at the same times a very complex one. It involves all levels of nervous system and many parts of the musculoskeletal apparatus as well as the cardio respiratory system. Correct posture minimizes the strain on the human body by maintaining balance of the muscles and skeleton.[1] The human gait cycle phase is an important parameter which is used to reflect the characteristics of gait. The gait cycle consists of two phases. Stance phase; it is the duration in which the foot is in the contact with the ground.[2] It includes the phase between the initial contact (heel strike) with the ground and the final contact (toe-off) with the ground. Stance phase ideally constitutes 60 percent of the gait cycle. The other one is swing phase, is the duration in which the foot is not in contact with the ground. It includes the time duration between the toe-off of one foot to the next heel strike of the same foot. Swing phase ideally consists of 40 percent of the gait cycle.[3] After stroke, Hemiplegia is one of the most common impairments which contributes significantly in gait performance reduction. To perform daily activities, many stroke patients do not achieve their independent gait and have difficulty in walking pattern. For gait training, it is required to assess person's walking movement pattern in different environmental situations like in irregular surfaces. For this stated problem, dynamic postural stability assessment system (DPASS) has been developed which is used for assessing the movement pattern and individual's stability control during changes in dynamic situations with real time monitoring. The system provides the unstable surface with different kind of instability to provide less or more difficulty of mobility of board to the user. The total pressure applied can be assumed to be concentrated at a single point known as the center of pressure (COP). The dynamic system does the assessment of the oscillation of the in an anterioposterior direction and right-left, which brings the overall stability of individual posture in any movement.[4] The primary function of the dynamic system evaluation is to assess and quantify how the subject handles instability overall. It is the wearable wireless system with the Force Sensitive Resistors (Interlink FSR-402) placed over the insole of footwear.[5] With this system, various temporal parameters of gait are measured through experimental trials such as number of steps, step time, stride time, stance, swing time, cadence and others. The sensors are sandwiched between the two layers of foot insoles with respect to foot plantar pressure, is the pressure field that acts in between the foot and support surface

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during every day locomotors activities.[6] DPASS system has been designed to identify various temporal parameters of gait with the help of sensors, are used for determining the force variation on foot in different stages of the cycle during walking. For validity test of DPASS system, Zebrismat is used which is suitable for diagnosis of postural deformities and gait analysis.

The aim of this research is to maximize improvement for patient's care, develops and validates a dynamic postural balance measurement system for disease specific which focused on the specific sensory and motor components underlying a patient's functional limitations.

Materials and Methods

Methodology

Dynamic postural stability assessment system consists of shoe insoles for both foot (left and right) in which FSR sensors are placed and acquisition module is carried along with insoles during walking. The detailed block diagram of system development is shown in Fig. 1a. Sensors are fixed over two foot soles at the location of heel and toe as well as metatarsal points. In experimental trial, task is to walk over the Zebrismat with wearable foot soles. The voltage signals corresponding to the magnitude of forces are pulled down from the sensors. These signals are acquired in the data acquisition board sampled at a particular rate for processing.[7] There are six FSR sensors placed in each foot, total of twelve FSR sensors are used for DPASS system development. Bluetooth module HC-05 is used to serially transfer the data to the PC as wireless communication is one of the most important medium of transmission of information from one device to other devices.[8] Vcc is connected to a +5V supply and GND pin is connected to the ground of Bluetooth module. The transmitter pin (Tx) of the Bluetooth module is connected to the receiver pin (Rx) of the Arduino Megacontroller and the Rx pin of the Bluetooth module is connected to the Tx pin of the Arduino board.

There are only two connection wires in this system which connects the data acquisition board to the sensors of each of the foot. The power source is tied with the data acquisition module, thus powering the FSRs and the Arduino board. The common +5V is fed to one leg each of the FSRs and the other ends of the FSRs are connected to the analog pins of the Arduino from A0 to A11. The Bluetooth module is paired with the Bluetooth of the computer after initiating the developed system. The subject is made to stand straight for a few seconds after establishing the Bluetooth connection between the data acquisition module and the computer. The sensor values are recorded in a computer through developed user interface in Laboratory Virtual Instruments Engineering Workbench (LabVIEW) platform as shown in Fig. 1b.[9] This enables interface to fetch the data serially transferred to the port by the data acquisition module. The interface shows real time information of each foot sensors data in form of voltage and left-right foot pressure distribution. After the completion of task, the data is saved in the location set in the program and was later fetched in MATLAB[10] for detection of different events. The experimental trials are taken in synchronization with the Zebrismat. Zebrismat and DPASS both recorded the walking pattern simultaneously. The results of both the systems are compared to evolve the validity of DPASS system.

Subject preparation and experimental protocol

Total of thirty-one subjects/patients were recruited for the experimental trials, 5 female and 26 males, and their ages ranged between 13–70 years (average 50) who

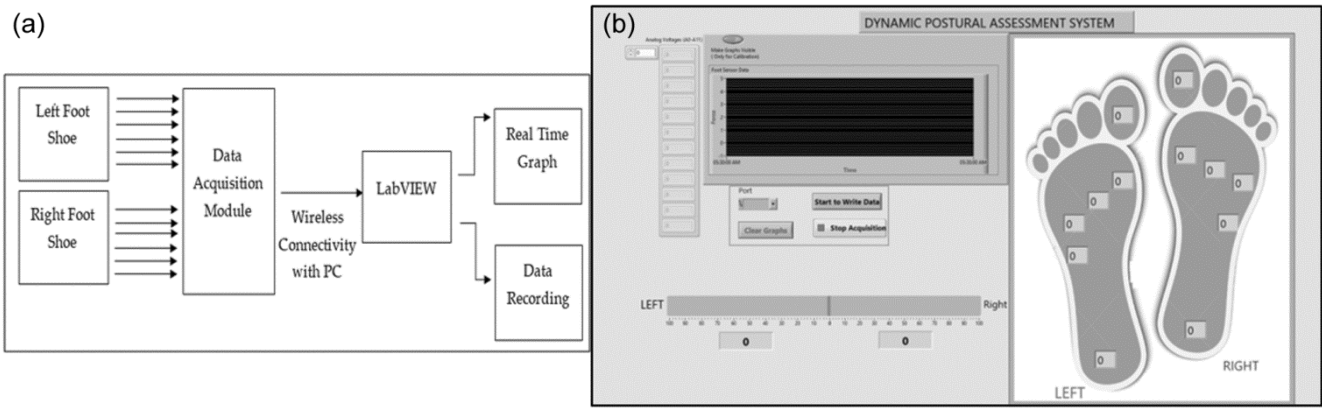

Fig. 1a — Block diagram of developed foot insoles system; 1b — developed user interface for foot insoles

had difficulty in walking such as left hemiplegic (LH) and right hemiplegic (RH) for at least six months out of which only five subjects (P1 to P5) gait data for five trials repeatedly with a four weeks follow up was analyzed. All subjects who were unable to walk independently or not willing to participate are excluded in the study. Protocol for experimental trials data acquisition was done in two steps i) subject has to wear insoles as shown in Fig. 2a and walk independently over the Zebris mat in three steps and ii) repeat the first step four times. Three-foot zone analysis method is adapted in Zebris mat which is suitable for diagnosis of postural deformities and gait analysis. The same method is used in foot insoles for gait analysis of developed DPASS system.

Fig. 2a — Dynamic postural stability assessment system; 2b — patientwearing foot insoles during trial

The experimental trials on the subjects have been accomplished in the Gait Lab in the department of Physical and Rehabilitation Medicine (PRM), PGIMER, Chandigarh and analysis is done by calculating gait parameters as shown in Fig. 2b.

Results and Discussion

Disease specific assessment is done in dynamic postural stability assessment system on patients suffering from gait impairment. It is the standard of care for the assessment and treatment of patients with balance, dizziness and mobility problems. DPASS includes various gait parameters such as step time, stance time, swing time (for both left & right foot) and cadence.

Patient's Gait Analysis Report

Study is done on human walk to compute and evaluate few important parameters of gait for two phases; stance and swing using DPASS.[11] Further, evaluated parameters such as left and right foot swing, stance, step time, stride time and cadence are compared with standardized system (Zebris mat) parameters for

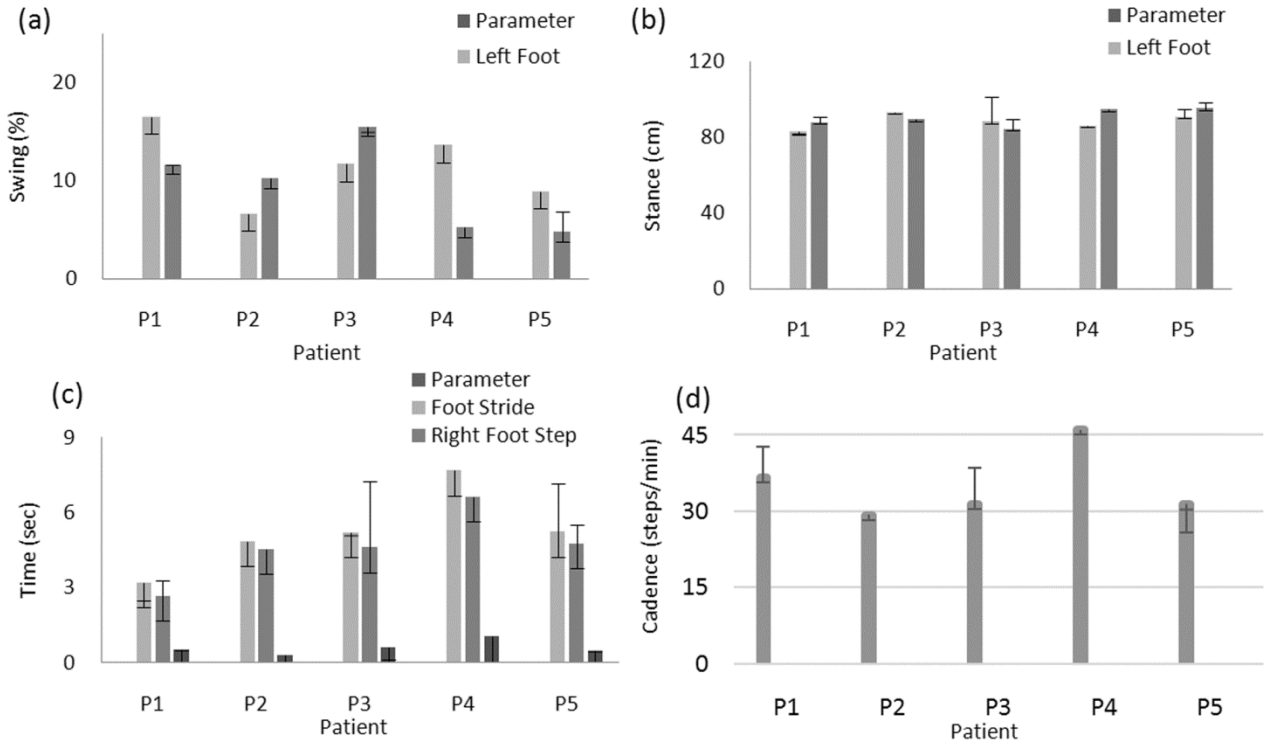

Fig. 3 — Error plot between DPASS and Zebris mat of parameter: (a) left and right foot swing; (b) left and right foot stance; (c) left and right foot step & stride time; (d) cadence

validation of developed foot insoles. Fig. 3 shows the error plot graph between DPASS system and Zebris mat data which indicates an approximate error of 5%, an acceptable range. It has been identified that the developed system can be used for further assessment and training for patients with gait imbalance.

Conclusions

In this paper, the developed foot insole based dynamic postural assessment system was analyzed on patients suffering from gait impairment. The system is validated against the standard system (i.e. Zebris mat). There is an error of 5% approximately which is in an acceptable range. Thirty-one patients are recruited for the trials. Out of which follow up of five patients is done for four weeks. The preliminary result shows that the system is able to assess the balance profile during dynamic condition and the individual pressure at the metatarsal points and heel. The system has an advantage over other static system that it can be used in different environmental conditions like on stairs, walking on slippery or irregular surfaces. In future, various alternate sensors can be installed in the developed system to provide it a better reliability. The algorithm can be improved using machine learning skills so that it may prevent false alarms of various gait events and developed gaming environment for therapy.

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