WEIGHT DISTRIBUTION MONITORING SYSTEM FOR PATIENTS WITH PARKINSON’S DISEASE

BACKGROUND
Parkinson’s disease is a neurodegenerative brain disorder that occurs when a patient’s body stops producing dopamine. This chemical is essential in transferring motor commands between the substantia nigra and the corpus striatum which enables smooth, intentional movement in the body. Because this transmission line is degrading, about 68% of the Parkinson’s population reports falling [1].

To assist with these movement disorders and fear of falling, patients use mobility aids. Although mobility aids can play a beneficial role in improving a patient’s day to day life, a recent study challenged the effectiveness of these aids, stating that improper training leads to the aids becoming ineffective [2]. Because patients with Parkinson’s have difficulty receiving feedback on how much weight they are placing on their device, the postural issues tend to increase in severity through bad walker use. Currently, to combat this problem, patients have regular physical therapy sessions where a clinician subjectively watches the patient and relays auditory feedback to that patient to improve the use of their mobility aid [3].

This project sought to address the problem of postural instability and poor walker use through objective sensing and feedback. One current method to solve this problem is a treadmill system that supports the patients to train proper posture [4]. Although, this improves the posture of patients, it isn’t transportable and doesn’t make the patients self-reliant. Another device currently available in the market is the AMTI walker which consists of MCW walker sensors. According to clinician interviews, the high expense of this device places it out of reach of most people who need a walker. A different approach to solving postural instability has been through a smart cane which monitors ambulatory movements and sends feedback [5]. However, it doesn’t indicate the weight applied by the user on the walker, which the clinician on this project argues may be needed to cause postural change.
While some aids are currently available, they do not provide the necessary combination of accuracy, affordability, and portability the clinicians request. Therefore, we have developed a novel, attachable system that detects the percentage of weight a Parkinson’s patient places on a walking aid and delivers said information for improved patient kinesthetic-awareness.

METHODS

Discussions with clinicians identified the need for a low-cost, soft-sensing handle attachment on a walker. The system would detect the load distributed by the user on both handles to assist with rehabilitative sessions during physical therapy.

First, the device had to measure the load with good accuracy and repeatability. Furthermore, it had to be comfortable, durable, and customizable to different types of walker handles. The prototype shown in Fig. 1a consisted of a soft-sensing handle attachment and an electronics box. In order to be effective, the sensor had to meet certain load requirements. Based on a study done by Mcquade et al. [6], the required range of the desired sensor was between 0 to 300 N (30% of the person’s body weight) with a +/- 10% accuracy.

Correct sensor placement on the handle was determined first via consulting a clinician where patients exert the most force on their walker handles. To reconfirm the clinician’s observations, we conducted two different experiments. In the first experiment, we placed clay on the walker handles and had ten test subjects use the walker. We used the palm imprints as an indicator about where forces were most exerted on the handle. This test revealed that the back of the palm is the area where most forces are encountered. This region was further narrowed down by placing two force sensitive resistors (FlexiForce A201, Tekscan Inc., South Boston, MA) in the region and running a second experiment. While these experiments were useful for generally locating where forces were applied by the palm, the sensors proved inaccurate at reading the exact forces applied over a plane.

To read forces applied over a plane, we further developed an air-bladder-based sensor designed by Kong et al. [7]. This sensing unit consisted of a coated, soft-silicone tube connected to an air pressure sensor. The principle behind the sensor operation is described with a single tube in Fig. 2a. Here, the radial deformation due to load $F$ on the tubing, sealed at one end, causes a pressure change between $P_i$ and $P_f$, proportional to the load. Fig. 2b portrays extending the idea of a single tube into a coiled tube to read larger forces ($F_p$) over an area. $P_f$ is then read by an air pressure sensor.

![Figure 2: (a) Step 1: Unpressurized tube. Step 2: Pressurized tube. The difference between pressures $P_i$ and $P_f$ is proportional to force $F$. (b) Increasing the area of the tubing allows $P_f$ to accurately reflect the force of the palm, $F_p$ over an area. $P_f$ is then read by an air pressure sensor.](image)

In the region and running a second experiment. While these experiments were useful for generally locating where forces were applied by the palm, the sensors proved inaccurate at reading the exact forces applied over a plane.

To read forces applied over a plane, we further developed an air-bladder-based sensor designed by Kong et al. [7]. This sensing unit consisted of a coated, soft-silicone tube connected to an air pressure sensor. The principle behind the sensor operation is described with a single tube in Fig. 2a. Here, the radial deformation due to load $F$ on the tubing, sealed at one end, causes a pressure change between $P_i$ and $P_f$, proportional to the load. Fig. 2b portrays extending the idea of a single tube into a coiled tube to read larger forces ($F_p$) over an area.

The sensor prototype was attached to the walker handle via the multi-step process shown in Fig. 1b. The process has a don time of less than 3 minutes. The sensor, as seen in step three, was connected to a compact electronics box, composed of a pressure sensor, (HDIM500GUZ8P5, FirstSensor Inc., Mansfield, MA), a microcontroller (Arduino Micro, Arduino LLC, Strambino, Italy), a light-emitting diode (LED) bar graph, and a vibratory motor.

To ensure the accuracy and repeatability of the sensing system, we ran a series of loading-unloading calibration tests to characterize the sensor in terms of repeatability and hysteresis. In the tests, a universal tensile testing machine (Instron 5944, Instron Corp., High Wycombe, United Kingdom) was used to apply and remove forces at a rate of 150 N/s up to a maximum of 250 N. The obtained results enabled us to establish a correlation between the applied force and sensor output. Hysteresis was compensated with the use of the techniques mentioned in Kong et al. [7].

To use the device, a threshold is first set for a particular patient per clinician requirements. The device continually detects the load placed on the walker handles, transmitting force readings back to the clinician in real-time. A light-emitting diode (LED) bar graph is inset in the electronics box. The LEDs allow the clinician to have an indication of the level of forces being detected when away from the monitor where the data is transmitted. Once the patient exceeds the threshold, vibration motors vibrate the handle, alerting the user to the fact that they are placing too much weight on it.

RESULTS

One of the baseline tests for Patient’s with Parkinson’s disease is the Timed, Up and Go (TUG) Test in which a patient is given the task of getting out of a chair, walking 3 m, turning around, and returning to the chair. To evaluate our device one healthy user (clinical collaborator) was asked to simulate a patient with Parkinson’s disease while completing the test.

First, the participant ran a baseline test as a healthy person with proper posture, during which the prototype handle registered negligible force readings. Next, the participant simulated a patient struggling with very poor posture while the handle’s vibratory feedback was turned off. The results of this test can be seen in Fig. 3a. The dotted line represents the set threshold, and the peaks show the participant consistently exerting too much force on the walker resulting in poor, kyphotic posture. Finally, the TUG test was performed one more time by the same participant, but...
with the vibration feedback turned on. The results shown in Fig. 3b show that the sensor registered forces above the threshold much less frequently. In addition, the participant’s kyphotic posture visually decreased. These results provide early support for the hypothesis that reading the forces applied on walker handles, and providing vibratory feedback accordingly, could improve patient posture while using walking aids.

INTERPRETATION

In this paper, we presented a weight distribution monitoring system with the capability of reading forces applied to a walking aid, and providing feedback accordingly. We have created a low-cost, lightweight, and durable device that can be used not only for rehabilitation exercises in clinical settings, but at home as well. In the future, we are looking to further investigate its efficacy with patients that suffer from Parkinson’s disease and to streamline the manufacturing of the sensing system. Furthermore, we will look into adding wireless communication capabilities so that the sensing system can transmit data to a remote monitoring system used by the clinician in real-time. We also plan: 1) to optimize the sensor area placement for more accurate readings, 2) to develop a graphical user interface for the clinician to input threshold values and record rehabilitation sessions, 3) to make the handle Bluetooth compatible for wireless transmission of data, and 4) to develop a mobile application to investigate the real-time weight distribution data and to check the progress of the patients.

REFERENCES