Creating a Wearable Device to Help Parkinson's Patients Maintain an Upright Seated Position

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Introduction:

Parkinson’s Disease (PD), affects over 10 million people world wide (MNT Editorial Team, 2016). PD is a progressive nervous system disorder, therefore side effects from the disease get worse as time goes on. The disease is caused by a loss of dopamine neurons in the brain. (Park, J.-H., Kang, Y.-J., & Horak, F.B., 2015). Dopamine plays a role in sending messages to the part of the brain that controls movement and coordination (Brazier & Carteron, 2018). As a result, the most common symptoms displayed by PD patients are tremors, stiffness, slowness (bradykinesia), impaired balance/ falling, shuffling gait (Mandybur 2018) all of which are correlated to movement and control over the body. With the lack of control over one's body, PD causes patients to move uncontrollably and as a result can pose as a threat to themselves in certain situations and result in harm.

There is no found cure for PD, but there are many new devices being created to help alleviate some of the challenges and side effects people have from this disease. Some devices being created are specifically designed for those with PD. Other devices on the market are not made specifically for people with Parkinson's but help with some of the side effects. A device designed specially for people with Parkinsons is the ‘Emma Watch’ (Trotman 2017) this device was designed for comfort and ease. It is worn as a bracelet that counteracts the tremor motion in the hand which then allows the wearer to be able to write clearer. This device is small and can be worn all the time and is very practical for everyday use. Another device specially designed for those with Parkinson's is the ‘Staircase Illusion’ (Soneji M. 2015). This device is for those who have trouble with gait and balance. The ‘Staircase Illusion’ is a mat that has a staircase pattern, it can be put on the floor of one's home. This helps with gait and balance because it allows for a visual aid when walking. The repetition of a staircase also makes it easier for people with PD to remain balanced and have a steady gait. This device is not practical for everyday use because it does not have the ability to be transported wherever the user may need it. Another device that was not designed specially for people with Parkinsons but can help provide support is the 'Aura Powered Flex Suit.' This device was made with the intentions of helping the elderly who have weakening muscles which causes them difficulty when standing up. The Flex Suit is a wearable device that has small vibrators throughout the suit and sends vibrations to the muscles to enhance muscle strength. This device can provide similar aid to people with Parkinson's because as the disease progresses people tend to lose muscle mass which then causes their other symptoms such as gait, balance and tremors, to become worse. The problem with this device is it can be heavy to wear around all the time, especially since the wearers have weaker muscles to begin with. Another device, called the Wolk Airbag (Jayaraman 2018), was created to help stroke survivors but is looking to be implemented to help Parkinson's patients. This device was designed to help stroke survivors who suffer from an imbalanced gait and are susceptible to falling over and potentially hurting themselves. The device can sense when a person if falling over and an airbag will inflate to reduce the load on the hips and protect the body. It is made of a reusable airbag. Although this device is not yet on the market for the public to buy, it is crucial in understanding how to detect when a person is falling and creating a feedback mechanism to counterbalance the force the person is exerting when they are falling. However, the problem with the design of this device is that it only helps people who are standing and walking around. This cannot help people who are sitting in their chair and falling over to the side.

The purpose of this study was to engineer a device specific for those with PD who struggle from a side effect where it is hard to maintain an upright seated position in a chair. This device would have to be lightweight, comfortable, wearable, and easy to use. This device would be able to reduce harm by keeping people upright in their chair. This device will allow people to live a healthier life by allowing one to have better eating habits and talking abilities. When one is slumped over in their chair they cannot eat and are at risk of choking on their food, it also makes it difficult to communicate with others when someone is sliding over in their chair. Therefore, the question posed was, "how can a light-weight, wearable, device improve standard of living by helping Parkinson's patients remain in an upright seated position for an extended period of time?" The hypothesis was that a device that can increase its pressure when it senses a certain acceleration can help those with PD maintain an upright seated position.

<u>Methodology:</u>

Overview of the Device:

This study focused on creating the mechanism to measure the acceleration as a person falls over in their seat to be able to gather data to find the threshold at which a person accelerates and the device needs to recognize that it must inflate to prop the person back to an upright seated position. The purpose of this is to find that threshold so it can be implemented into a future device. The eventual suit will be able to recognize that a person is falling over in their chair based on the acceleration and inflate a bag on the sides of the device located on the upper part of the hip.

Components of Device:

For the design of the future device there were many components that has to be analyzed. The main tool that would be used to be able to allow the device to work together is the sensors. The main question is how many sensors need to be used and where the sensors should be placed? It is believed that one sensor would measures the pressure inside the bag, one to also ensure that the bag does not over inflate and one to detect the speed at which the person falls to the side in their chair. The sensor chosen was an IMU sensor because it has a gyro sensor to sense movement along the X,Y, Z axes. Other sensors were analyzed such as ultrasonic sensor as well as a strain gauge but were ultimately not chosen based on the fact that they would have been hard to orientate on a moving body.

A programmable chip that would measure the inputs is necessary in being able to create the mechanism that could function together cohesively. The chip would be part of a circuit board that would need to be inserted in the suit as part of the sensor unit. But adding this to the device adds weight and we do not want to make the suit overly bulky. The circuit board would need to be connected to a compressor which would need a quick release time to catch the person from falling but also be sensitive and not propel the person in the other direction. The circuit board would also need electricity, it would either need to be plugged in to a wall or it could employ a lithium polymer battery pump. Plugging the device into the wall would be easier to have the constant source of electricity but keeping the device plugged into the wall would limit mobility. Thus finding a mechanism to keep the person mobile and not have to be plugged in is ideal for this device.

In order for the device to be able to catch the person when it inflates the source for what will be used in the bag is crucial. The potential substances that could be used are some sort of liquid (ie water), carbon dioxide or air. A liquid would be too heavy and add lots of weight which would hinder the practicality of the device. Small carbon dioxide canisters are lightweight but are hard to refill and the tank would need to be changed after all usages. The compressed air canisters are lighter weight, more accurate, lasted longer, and were easier to control.

Testing to Determine the Threshold:

<u>Creating the Acceleration Device:</u>

The purpose of this device is to be able to measure the acceleration as people fall over in their chairs and then be able to program the device to recognize that speed and inflate to reduce harm and push the person back upright.

To create this mechanism the materials needed were an Arduino UNO board, a MakerFocus MPU-6050 GY-521 Module IMU sensor, dupont cables and a USB cable. The component that would measure the acceleration is the MPU-6050 sensor. The sensor is an

Inertial Measurement Unit (IMU) which measures and reports orientation, velocity, and gravitational forces through the use of accelerometers and gyroscopes (Sparton 2015). To create the mechanism the MPU-6050 had to be interfaced to the Arduino board in order to properly communicate with one another and be able to read the desired accelerations. The MPU-6050 was sautered so the sensor and arduino board could be interfaced with the use of male-female dupont cables. Once interfaced, a code was downloaded onto the Arduino board. Finally the mechanism was connected to a computer via a USB cable so the program could be officially downloaded to the Arduino board and the readings could be displayed on the computer when testing the device.

Code:

The code used to measure the accelerations was attained from github.com. The code entitled "I2C device class (I2Cdev) demonstration Arduino sketch for MPU6050 class using DMP (MotionApps v2.0)" (Rowberg, 2012) was created to measure euler angles, yaw/pitch/roll, real acceleration and world acceleration. In this study, the code was adjusted to just output world acceleration because it has gravity removed, and is adjusted for the world frame of reference. This will allow the data to be read in a real frame of reference and be already oriented for how a person moves. This will allow for more accurate data to be attained.

Experiment Setup:

Participants consisted of healthy (non PD patients), children and adults ranging from ages 14-47 and all genders. Participants were asked to fill out a sheet with their age, weight and height. As well as all participants were given an informed consent sheet and if they were under

18 they had to get a guardian signature prior to any experimentation. Participants were also given a number to maintain confidentiality.

To conduct the experiment, participants wore the vest. Participants sat on a chez lounge bed which is flat but had cushion on all sides which would protect the participants as they fall over. There was also a chair with no legs that was placed on top of the chez lounge to simulate how a person would actually be wearing a device in real world situations.

<u>Testing the Acceleration Device:</u>

Figure 1 The Vest: This is the vest participants wore, arduino board is in the pocket with the USB cable coming out of a small hole in the pocket. Attached is the MPU-6050 to the chest using fabric to hold the sensor in place. As well a tight belt on the upper stomach region to ensure the vest does not move around and is tight to the body.

To test this mechanism, participants wore the vest. The vest was made with a similar design as the eventual suit is intended to look like. The vest consisted of the IMU sensor mounted onto the vest using a piece of fabric sewn on to the vest with a small slit in the middle so the sensor could be put into the pocket and the wires wouldn't get in the way. This also provided security so the sensor’s was tight on the person's chest so the sensor would only be affected by the person's movement. The arduino board was placed in the right pocket of the vest so that the wires would not be stretched too far and the mechanism could all move with the participant and not restrict any of their movement.

To gather the data on the speed as one falls over in their chair participants wore the vest and then be asked to fall over 5 times to the left and 5 times to the right. All participants were shown a “model fall” conducted by the researchers in order to standardize the fall. This was also used as a safety precaution to ensure that everyone understood the way in which they were supposed to fall over. Once the participants understood the way they were supposed to fall, the trials were started. When the person was falling over in the trial the time it took for the participant to start their fall and end their fall was measured. With the code all the numbers the numbers that were obtained for all the axes was displayed through the monitor on the computer. For all the data that was obtained a time stamp was correlated to each data point. Since there were so many data points as the person fell, the time that was measured for the length of the fall was used to isolate the data for the specific time at which they fell. This data was then organized into charts by trial and participant. The average was taken for the accelerations for each participant and both the right and left sides. Finding the averages of the accelerations of the fall created a threshold at which a person will acceleration. This threshold will be able to indicate that when a person is falling at the speed in the threshold to then be able to inflate.

Results / Data:

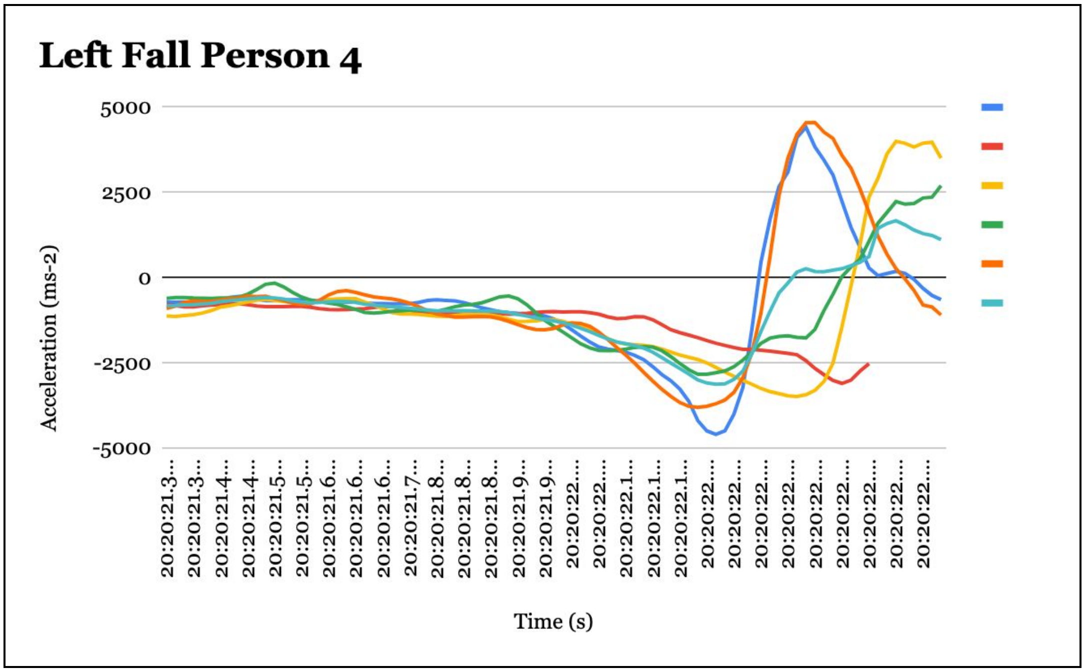

Figure 2 Example Graph Left Side:

Graph depicts the acceleration measured given over a time interval for all 5 trials conducted and the average for the left side of participant 4.

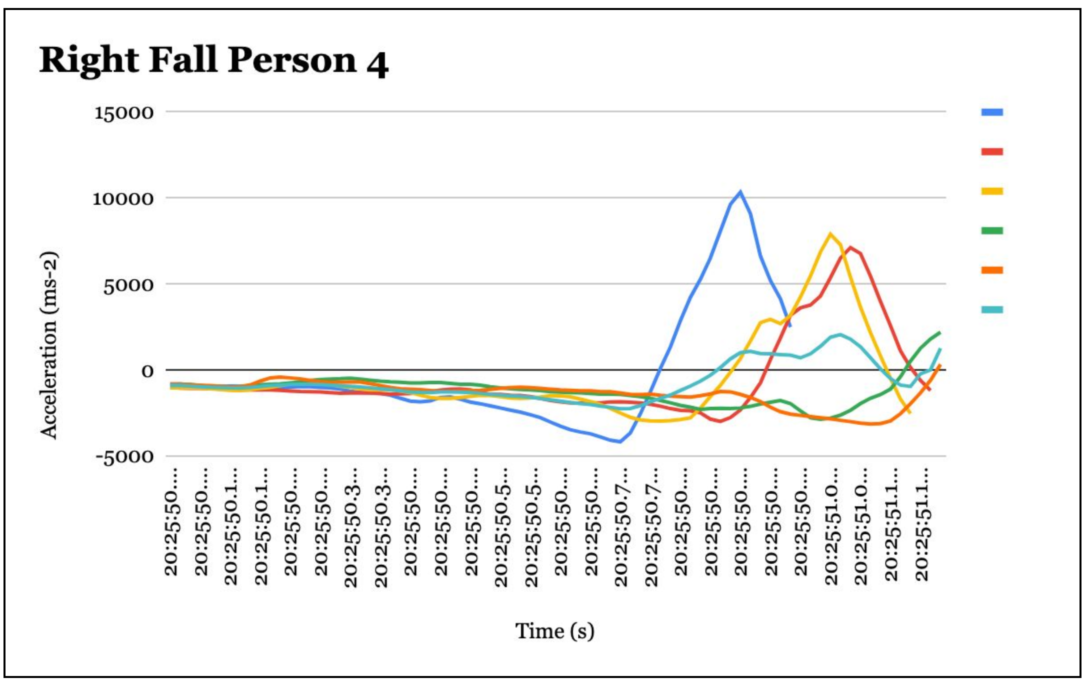

Figure 3 Example Graph Right Side:

Graph depicts the acceleration measured given over a time interval for all 5 trials conducted and the average for the right side of participant 4.

Left Side Average Accelerations (ms^{-2})	Right Side Average Accelerations (ms^{-2})
-3039.2	-3527
-2082	-2363.2
-1274.6	-1895.8
-3178	-2995.8
-2052.8	-1818.8
-4438.6	-2232
-3682.6	-2489.6
-2019.4	-1895
-2887.6	-2870
-3178	-2995.8

Figure 4 Average Accelerations: Numbers were averaged from all 5 trials in their respective sides from the number found and the bottom peak of each line on the graphs

From the data collected the graphs were created and in the graphs there is a clear bottom peak prior to rapidly increasing, this demonstrates the times at which the fall starts prior to the body being in free fall as it is going towards the chair. Furthermore from these graphs all the bottom peak numbers were attained and averages for each participant in order to create Figure 4 which represents the averages of all the accelerations as the person starting falling. This created the threshold at which the device will need to recognize and be able to know that if a person is accelerating with a speed between the threshold, it must inflate.

Discussion:

From this study the threshold found for the left side was -4438.6 to -1274.6. The threshold found for the right side was -3527 to -1818.8. These numbers are simplified to -0.2709 to -0.0777 (left side), -0.2152 to -0.1110 (right side) using the constant of 16384 which corresponds to an acceleration of 1 g (i.e 9.8m/s/s). This constant was used by the code to interpret the number that was read by the IMU Sensor into ordinary numbers. These numbers are very important because they will be the threshold that a new code can be written based upon in which this code will tell the device to inflate when it senses an acceleration between the threshold for each side. Since the participants were non PD patients, it is concluded that this acceleration threshold found is 80% accurate for PD patients. Furthermore with the weakening muscles that comes along with Parkinson's, often patients fall slower since they are not purposely giving themselves the energy and momentum in the first place to fall. In order to orient the threshold to function more accurately for people with PD the threshold would be expanded to recognize slower accelerations as well.

A limitation of the study is that non Parkinson's patients were used, this created a threshold for people who are healthy when they fall over rather than a threshold specifically for people who the device is intended for. Furthermore, in order to find a more accurate and generalized threshold many more participants are needed to be tested. The more participants will allow for a more accurate and greater range of data this will demonstrate if the current threshold needs to be expanded to include more accelerations or it is accurate.

In the future, more participants will be tested. As well as participants will be asked to do different things while sitting in the chair that can help to test of the algorithm is working properly and knows when to inflate. For example, participants will be asked to remain sitting up, falling but then stopping themselves, swaying and more movements that will allow for the most possible data to get the algorithm working properly and only inflate when necessary and the person is actually falling over due to their inability to push themselves back upright in order to help those with Parkinson's Disease in their daily lives.

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