Freezing of Gait: Assessment of gait locations using wearables for Parkinson's disease patients

By Swetha Vaidyanathan

Moving forward on an enigmatic clinical phenomenon

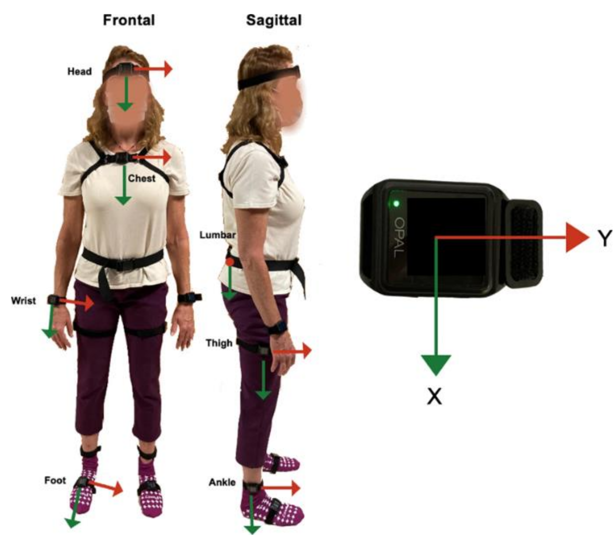
"Parkinson's is my toughest fight. It doesn't hurt. It's hard to explain", said former boxer Muhammed Ali who suffered from Parkinson's disease. The increasing tremors in limbs, the painful slowness of gait, balance problems, and whispers of falls were indicative of the fact that Parkinsonism began its relentless march through Ali's nervous system. The inability to move the feet forward despite the intention of walking is an enigmatic clinical phenomenon, a common symptom of PD, called Freezing of Gait (FOG). FOG is characterized by episodes of intermittent inability to step that occur on initiating gait or on turning while walking. FOG affects at least 50% of people suffering from PD.

Among the several ways of assessing FOG, objective and detailed analyses of gait are usually performed in specialized clinics by experienced raters that observe and video record patients' walking around the clinic. Other subjective tools include the FOG questionnaire, patient surveys, and posture assessments by neurologists in a clinical setting. The visits to neurology clinics require patients to travel to purpose-built facilities and be tested in a clinical environment. This could affect gait patterns and could lead to infrequent assessment, resulting in less accurate tracking of disease progression and less effective tuning of therapy. Therefore, it is necessary to have a gait monitoring device that can enable FOG characterization in the patient's daily surroundings and during normal activity. Inertial measurement units (IMU) are wearable devices that serve the purpose of successfully detecting and tracking movement enabling insights into FOG in any environment. Though several studies have used IMUs to detect FOG, they posed several limitations. Firstly, there is no consensus on where the IMUs are to be placed, nor did they account for the patient's preference regarding the best body locations to place IMUs. The studies often relied on hand-engineered features, requiring extra labor, and potentially removing valuable information from the data collected.

To address these challenges, researchers from Stanford University, led by Prof. Helen Bronte-Stewart and Prof. Scott Delp, assessed IMUs that people with PD can reliably wear based on FOG detection performance and patient preferences and discussed their findings in a recent report. A FOG detection algorithm was also created from a combination of patient surveys, IMU measurement data, and machine learning techniques. The dataset and framework developed by this study were intended to aid future research protocol development for FOG detection and monitoring and fine-tuning the personalization of the patient's care.

Movement sensor survey and sensor wearability preferences

The first dataset consisted of IMU preferences as reported by a survey conducted with PD patients who had 1 to 50 hours of prior in-clinic experience wearing IMUs. For the survey, sixteen individuals with PD completed a questionnaire imagining a scenario of wearing the same sensors used in a clinical setting for FOG detection at home for 12 hours. They were surveyed about their preferences for wearing individual sensors either on the wrist, ankle, lumbar, foot, chest, thigh, and head, as well as for wearing IMUs on different pre-set combinations of places on the body.



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Survey results demonstrated a preference for the "ankle" and "wrist", then followed by the "lumbar region" for individual IMUs. For a set of two IMUs, results were tied for "wrist and ankle" and "both ankles". The top three preferences for a set of three IMUs were "one wrist and both ankles", "chest, one wrist, and one foot", and "lumbar and both ankles". The least preferred placement options for IMU sets were "head", "chest and wrist", and "chest, lumbar and feet". The major factor for the wearability of most people was comfort and ease of applying the sensors.

Model development with an acquired dataset

The second study generated IMU data from a walking course carried out by seven participants. All the participants wore six IMUs strapped on both feet, the sides of the shanks (closer to the ankles), the lumbar, and the chest. Four of the seven participants had additional five IMUs on their heads, both wrists, and the outer sides of both thighs, accounting for a total of 11 IMUs. Each walking trial consisted of two ellipses and two figures of eight around tall barriers with 5 to 14 walks per participant over 2 to 6 clinical visits. A total of 88 minutes of walking across 60 distinctive trials elicited 211 distinct FOG events accounting for 23.9% of the total time spent. A video of each walk was synchronized with the IMU system. The IMU data collected between the start and end times of each FOG event was split into windows of 2-second duration. These 2-second windows were used to train a one-dimensional, two-layer convolutional neural network.

This turning and barrier walking course was designed to mimic obstacles in the home environment, which is how the dataset contains so many FOG episodes.

Among the 6 IMUs worn by all participants, the set of three IMUs placed on the "lumbar and both ankles" gave the best technical performance and produced clinically relevant data that agreed with expert raters' assessment as well as matched the top preference ranked by participants. This is the key feature of the authors' model. The findings showed that having many IMUs did not better the performance and could lead to too much noise in the signal. A single IMU on the ankle, which is the best performing placement of a single IMU, performed within 3.9% accuracy of the 3-IMU set. The participants' preference for wearing a single ankle IMU would make data collection easier if slightly lower accuracy were acceptable.

The reported work was focused on detecting one type of FOG associated with continuous walking. Future research could explore FOG associated with gait initiation. The authors proposed that a larger training dataset across differing symptomatology and treatment conditions containing both these FOG behaviors will enable real-world assessment of FOG for patients as they go about daily life.

"We hope these results empower patients, clinicians, and researchers trying to weigh FOG detection performance with other monitoring needs across sensor locations," the authors state.

Prof. Helen Bronte-Stewart, Prof. Scott Delp, Ph.D. students (co-first authors) - Johanna O'Day, Marissa Lee, and Kirsten Seagers, Stanford University (from left to right). Johanna is now a Program Manager for the Wu Tsai Human Performance Alliance

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