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Application of wearable technology in clinical walking and dual task testing

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Clinical tests of physical capacity of over-ground walking, such as the time for completing six-minute walking test (6MWT), is a sensitive and widely used method for patients suffering from chronic illness, such as Parkinson's disease, stroke, and respiratory diseases.[1–3] The method is also widely used for differential diagnosis, prognosis, and outcome evaluation of drug interventions.[1–3] However, as described in European Respiratory Society and American Thoracic Society guidelines on 6WMT that the utility and accuracy of 6MWT can be influenced by several technical factors including testing environment, walkway design, the need of an accompanying evaluator who provides verbal encouragements.[3] These technical limitations not only have hindered adoption of 6MWT in routine clinical use but limited its utility as a screening tool in tracking physical capability changes during large scale community based research and services.[1–3]

Recent research on wearable technology in Parkinson's disease has shown that six-minute walking test can be automated using wearable technology to eliminate human supervision and many other technical factors that confound the results with conventional testing.[4] Parkinson's disease (PD) is a progressive neurodegenerative disorder that is associated with high prevalence of depression and dementia.[5–9] Among all the functional deficits of PD, those affecting walking and balance can cause the highest morbidity by inducing falls and loss of functional independence.[10–13] Fear of falling, anxiety and depression can lead to excessive avoidance of physical and social activities, which can form a vicious cycle resulting in rapid deterioration in health conditions and the emergence of non-motor symptoms including dementia.[10–15] Hence, for people living with PD, technology that can enable accurate assessment of physical capability and endurance at home is an urgent and unmet medical need of significant clinical relevance.

The 6-minute walking test (6MWKT) is a gold standard diagnostic test for evaluating gait impairment, cardiovascular fitness and treatment outcomes in many chronic illnesses including physical therapy and exercise.[1–3] During the test, a person is instructed to walk for six minutes in a space of marked distance. The walking distance or speed are usually used as the outcome measure.[1–3] Despite its broad clinical acceptance, conducting 6MWKT is not only a time-consuming task, but the test results are often influenced by many procedural variables such as walking space, the nature of the instructions given to the subjects, physical effort by the patients, and inability to complete the test due to fatigue. In a cross-sectional observational study involving fifty-seven Parkinson's patients, we evaluated whether the Ambulosono Sensor System can be used to standardize and automate 6MWKT for walking speed assessment.[4] The Ambulosono wearable sensor runs off the iOS GaitReminder App that can issue auditory instructions while continuously recording step size via iOS gyro and accelerometers (after corrections for limb length, angular excursion, signal filtering, and drift).[4,16–19] During the test, patients uniformly received a set of standardized auditory instructions, as stipulated by clinical guidelines,[4] through wireless headphones, which contain verbal

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encouragement, specific walking speed (*e.g.*, comfortable or fast), and reminders of completed walking time.[4] Step parameters obtained via GaitReminder App have an average of < 10% difference when tested against direct video measurements, and a similar error rate was also found when the App was used for treadmill walking or over-ground ambulation where the actual speed can be obtained from direct machine reading or physical measurement of time and walked distance (markings on the floor).[16–20] A new generation of the Ambulosono sensor has been recently developed and shown a < 5% error rate in gait measurement.[17]

The use of wearable technology and data automation in extracting high quality information will likely, in the future, become an important diagnostic tool. For example, 6MWT walking speed data can be fed into a machine learning model to identify and visualize different cognitive and motor dimensions associated with fear of falling.[4,19–25] Robust machine-learning algorithms have also been developed for automatic detection of episodic freezing of gait (FOG) using a single Ambulosono sensor to capture regular gait cycles during walking or stepping.[19]

Another example of wearable technology application is related to dual tasking test in Parkinson's disease. PD-FOG is a cognitive-motor symptom that often occurs when a patient is distracted by a secondary motor or cognitive task, which can precipitate injurious fall and hospitalization.[19–25] We previously reported that PD patients can exhibit marked gait incoordination and hesitation when instructed to perform concurrent arm-swing and on-the-spot stepping.[18–20] Quantitative measurement methods of such cognitive–motor interactions and the related functional impairment, however, remain poorly developed. In a recent study, we describe a stepping-in-place (SIP) test in which the height of stepping is measured as primary task marker by using the Ambulosono sensor.[20,25] The secondary mental task, consisting of serial auditory instructions of backward numeric subtraction or word memory recall, was automatically and concurrently delivered via the device during SIP. The step height measurements were derived from hip flexion data captured by the sensor and the accuracy of the stepping height was compared to and validated by kinematic video analysis software.[20] The results show that PD subjects tend to have a significantly lower stepping height relative to controls under all conditions. The dual-task performance of PD freezers was particularly worse than PD non-freezers and the controls during concurrent serial 7 subtractions, even controlled for disease severity.[18,20] Therefore, wearable technology combined with SIP can be a new method for evaluating dual-task deficits in PD. In an unpublished study, the SIP dual-task test was tested in a cohort of patients diagnosed with mild cognitive impairment (MCI). Similar to the dual-task test in PD, subjects with MCI substantially lowered their step height during dual tasking. The above results indicate cognitive tasks that demand attention from limited cognitive resource can worsen motor performance in both movement and non-movement disorders. Given that the SIP-based dual-task paradigm is not limited by space requirements and the impairments can be quantified using a mobile tracking device with auditory task instructions, the test may be used to standardize clinical assessment of cognitive–motor deficits under a variety of conditions.

Wearable technology opens many new frontiers in exercise and brain health research. Many of diagnostic tests, such as 6MWKT, and exercise training can then be implemented in a user's home supported by social medium supervision, quality data control, and AI engines that can effectively manage the diverse sets of clinical data. With reduced cost and increased test standardization, the technology can be adopted for population-based screening of cardiovascular fitness and gait rehabilitation training efficacy associated with many medical conditions.

Conflict of Interest

None declared.

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