Wearable Technology to Detect Risk of Falling and Frailty

Dr Fay B Horak

Scientia

WEARABLE TECHNOLOGY TO DETECT RISK OF FALLING AND FRAILTY

Accidental falls are one of the leading causes of injuries and accidental death for the elderly, and the risk of falling increases significantly in those with neurological disorders or frailty. **Dr Fay B Horak** and her colleagues at Oregon Health & Science University and APDM Wearable Technologies, USA, are investigating the use of APDM's novel wearable technology to monitor mobility in daily life of individuals at risk of falling to help prevent falls and identify prefrail elderly individuals.

Measuring Mobility

Elderly people, especially those with muscle loss and weakness, a feeling of fatigue, slow walking speed, and low levels of physical activity (known as frailty) have over a 50% chance of falling each year. Individuals affected by neurological disorders, such as Parkinson's disease (PD) and multiple sclerosis (MS), are at an even greater risk of falling and seriously injuring themselves. Falls in older people often lead to hospitalisation, nursing home admission, and even death. Accidental falls are more common in individuals with impaired mobility, in other words, those experiencing difficulty walking, poor balance, sensory loss or muscle weakness.

Past studies have confirmed an association between impaired mobility and fall-related incidents but evaluating the mobility of individuals outside of laboratory or healthcare settings is very challenging. Many clinicians believe that medical examinations do not reflect the actual functional mobility of their patients in their everyday lives. When people are observed performing a short walk they pay attention to their walking and tend to do their best. In everyday life, people need to attend to other things while they walk, meaning that their automatic walking patterns are often more affected by their impairments.

In addition, mobility can fluctuate over time due to many different factors, such as a patient's fatigue, quality of sleep the night before, the effects of medications or characteristics of their surrounding environment. To accurately and reliably measure people's mobility, therefore, walking and turning mobility needs to be monitored continuously throughout their day.

Recent technological advances are opening up new possibilities for the development of tools to monitor mobility in daily life. Wearable devices and inertial sensors, for instance, could allow clinicians to collect valuable data about movement quality and quantity throughout the day. Daily monitoring of abnormal movement patterns could, in turn, help clinicians to estimate a patient's risk of falling and propose suitable interventions that might reduce this risk and keep people active and safe in their home environments.

Dr Fay Horak and her Research Group (Summer 2019)

Smart Socks developed by APDM Wearable Technologies

‘Our research addresses the feasibility, methodological advantages and challenges of measuring digital gait characteristics during free-living activity in PD, MS, ataxia, and elderly fallers.’

Measuring the Quality of Gait

Despite the potential of such wearable technology, there is currently no commercially viable technology for daily monitoring of quality of foot movements while walking in daily life. With this in mind, Dr Fay B Horak, a Professor of Neurology at Oregon Health & Science University, USA, has been working with APDM Wearable Technologies to explore how instrumented socks may help to monitor mobility more effectively. APDM was founded with the objectives of creating novel technologies to enable the scientific community to conduct quality research in movement science, accelerate clinical trials by introducing a new generation of biomarkers and validated endpoints, and improve the quality of life of people with movement disorders through precision medicine for neurodegenerative diseases.

Monitoring Daily Mobility using Wearable Sensors

Over the past decade or so, Dr Horak and her team have conducted extensive research exploring the potential of wearable technology in healthcare settings, particularly for gathering patient data before and after medical examinations. Now they have extended this technology so patients can wear instrumented socks during daily life for weeks in their home environments. ‘Passive, unsupervised monitoring of the quality of mobility in daily life using wearable inertial sensors has great promise for improving the care of patients with neurological disorders that affect walking and balance control,’ Dr Horak explains. ‘Clinical practice would benefit from valid, sensitive, reliable measures of quality of walking in community settings that reflect disease type, disease severity and responsiveness to intervention. The quantification of gait characteristics in unsupervised environments, however, presents considerable challenges.’

According to Dr Horak, effectively and continuously recording data characterising the quality of a patient’s movements, gait (i.e., style of walking), and balance could have many advantages. First, it would allow researchers and clinicians to attain more accurate and sensitive mobility measures, helping them to better understand how neurological disorders affect gait and balance in everyday settings, that is, outside of medical examination rooms.

The collection of much more and more accurate data would enable faster and cheaper clinical trials with smaller groups of participants as well as measuring behaviour that better reflects their mobility in everyday settings. In addition, wearable sensors could help to identify patterns and variations in a patient’s mobility over time, which might indicate progression of disease, responses to medication, fatigue, or symptoms of a specific neurological disorder. This information could allow doctors to identify recovery or degenerative patterns after treatment, without the patient having to return to the doctor’s office.

The Benefits of Continuous Monitoring

The wearable devices used by the researchers in most of their studies are Opal Sensors and more recently, prototype Smart (instrumented) Socks, developed by the innovative medical device company known as APDM Wearable Technologies, based in Portland, Oregon.

Dr Horak and her colleagues carried out a study exploring the benefits of daily monitoring, in which they compared gait metrics collected in the laboratory to those gathered using wearable sensors 14 hours a day for 7 days of daily life. Interestingly, continuous monitoring allowed them to differentiate specific gait characteristics of people with PD and MS, as well as those of healthy subjects, better than short walks in the clinic. The differences between gait metrics collected in the laboratory and at home were particularly accentuated in individuals with PD. For example, they found that people with PD walk much more slowly in daily life than they do when observed by medical professionals.

Discriminating Neurological Disorders with Gait Metrics

In a different set of studies, Dr Horak and her team tried to uncover digital gait patterns or characteristics that might be particularly useful for measuring the quality of mobility. The key goal was to determine specific gait, turning, and movement-related metrics that could help to predict future fall risk in PD and MS patients. They found that quality of turning while walking was even more sensitive than quantity of turning or walking (activity or step counts) to discriminate mobility in daily life from people with PD and same age adults without PD. People with PD turned more slowly with many more steps, even when the disease was very mild and their walking speed was still normal.

'We also study how gait and turning characteristics versus activity measures during daily life can discriminate people with pathology and detect risk (i.e., prodromal neurological disease before motor signs are clinically obvious, fall risk, and so on),' Dr Horak comments. 'We have found that the quality, but not the quantity, of mobility in daily life is sensitive to PD, whereas the quantity of mobility is sensitive to MS.' For example, although turning speed is slow in PD, they turn over 100 times an hour and have long walking bouts, just like people without PD. In contrast, people with MS show shorter and fewer walking bouts than age-matched people without MS. People with MS also show abnormalities in quality of walking such as slow speed and more variability of walking.

Dr Horak and her colleagues found that some gait measures are particularly important when distinguishing walking patterns in daily life of people with different neurological disorders. For example, the angle of the foot at heel strike is lower in people with PD but the height of the foot off the floor is higher in people with Spinocerebellar Ataxia (SCA). This suggests that different mobility metrics are particularly discriminative when assessing the mobility of people with different disorders, and thus, medical interventions should be designed accordingly.

In addition, very short bouts of walking might be more helpful to differentiate mobility and motor signs associated with PD than longer bouts. In fact, the duration of continuous walking performed by people alters their gait characteristics. That is, healthy people and people with MS walk with faster steps per minute the longer the walking bout. In contrast, people with PD do not increase their steps per minute when walking longer distances.

Developing Effective Technology to Monitor Daily Mobility

Dr Horak and her colleagues are using these findings to develop a new technology to measure gait-related activity in people with mobility impairments and assess their risk of falling called Smart Socks, developed by APDM Wearable Technologies.

Smart Socks are comprised of an instrumented ankle bandage with software and cloud storage that calculates hundreds of gait-related characteristics. The instrumented socks continuously monitor not only how many steps and turns a person makes per day but also the quality of those steps and turns. Unlike many existing techniques for measuring gait with sensors, the system can also characterise gait in people that shuffle their feet by detecting the angle and height of the foot while walking, as well as coordination and asymmetries of steps which is not possible with gait sensors place on the waist or wrist. The instrumented socks are comfortable, easy to wear, and only need to be charged at night like mobile phones.

New and Efficient Tools to Assess the Risk of Frailty and Falls

The research carried out by Dr Horak and her colleagues has important implications. Their work suggests that monitoring gait-related metrics on a daily basis could help to better assess the risk of falling for people with limited mobility, allowing doctors to gain insight about their patients both inside and outside of healthcare facilities.

'Our research addresses the feasibility, methodological advantages and challenges of measuring digital gait characteristics during free-living activity in PD, MS, ataxia, and elderly fallers,' Dr Horak explains. 'We also compare gait characteristics collected during free-living walking versus laboratory walking and how they relate to patients' severity of disease and perceived quality of life.' They are now following people for a year after wearing the socks for a week to determine if they can predict risk of future falling better than from clinical or instrumented assessments.

The researchers will now evaluate this passive, unsupervised mobility monitoring system in a rigorous series of tests and trials, so that it can eventually be put on the market and aid clinicians, clinical trialists and other research teams in evaluating their patients' mobility and assessing their risk of falling.

Meet the researcher

Dr Fay B Horak
Professor of Neurology,
Oregon Health & Sciences University
Portland, OR
USA

Dr Fay B Horak is a professor and the director of the Balance Disorders Laboratory at Oregon Health & Sciences University (OHSU). At APDM Wearable Technologies, she holds the title of APDM Fellow which represents the company's pre-eminent technical and research distinction. It is the highest level of scientific/technical achievement and it is granted in recognition of outstanding foundational contributions to APDM combined with a sustained record of scholarly leadership demonstrated by research, invention, and scholarly publications at the highest levels of international excellence. Dr Horak is also is a Senior Research Fellow at the University of Bologna (Italy), as well as an adjunct professor at Simon Fraser University (Canada), the University of Waterloo (Canada), and Pacific University (USA). Dr Horak holds a BS in Physical Therapy from the University of Wisconsin, an MS in Neurophysiology from the University of Minnesota and a PhD in Physiology and Biophysics from the University of Washington. Before she started working at OHSU, she held teaching and therapeutic roles at several other institutions, including the University of Washington and the University of Minnesota. Dr Horak's research focuses on neurological disorders that affect balance and gait in the elderly including Parkinson's disease and multiple sclerosis. She has published over 300 scientific articles in prestigious journals and has received numerous honours and awards, including a Merit Award from the National Institutes of Health.

CONTACT

E: horakf@ohsu.edu
W: https://www.ohsu.edu/school-of-medicine/neurology/balance-disorders-laboratory

KEY COLLABORATORS

Dr Martina Mancini
Dr John Nutt
Dr Patricia Carlson-Kuhta
Dr Laurie King
Dr James McNames
Dr Mahmoud El Gohary
Dr Vrutangkumar Shah

OREGON HEALTH & SCIENCE UNIVERSITY

FUNDING

The NIH: National Institutes on Aging, National Center of Medical Rehabilitation Research of the National Institute of Child and Maternal Health, National Institute of Stroke and Neurological Disease, National Cancer Institute, the Department of Veterans Affairs, Department of Defense, and Medical Research Foundation of Oregon.

FURTHER READING

N Hasegawa, W Shah, P Carlson-Kuhta, et al, How to select balance measures sensitive to Parkinson's Disease from body-worn inertial sensors-separating the trees from the forest. Sensors (Basel), 2019, 19, 3320.

AJ Espay, JM Hausdorff, Á Sánchez-Ferro, et al, Movement Disorder Society Task Force on Technology, A roadmap for implementation of patient-centered digital outcome measures in Parkinson's disease obtained using mobile health technologies, Movement Disorders, 2019, 34, 657–663.

M Mancini, C Curtze, S Stuart, et al, The impact of freezing of gait on balance perception and mobility in community-living with Parkinson's disease. 2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2018, 3040–3043.

M Mancini, H Schlueter, M El-Gohary, et al, Continuous monitoring of turning mobility and its association to falls and cognitive function: A pilot study. The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 2016, 71, 1102–8.

M Mancini, M El-Gohary, S Pearson, et al, Continuous monitoring of turning in Parkinson's disease: Rehabilitation potential, NeuroRehabilitation, 2015, 37, 3–10.

F Horak, L King, M Mancini, Role of body-worn movement monitor technology for balance and gait rehabilitation, Physical Therapy, 2015, 95, 461-70.

FB Horak, M Mancini, Objective biomarkers of balance and gait for Parkinson's disease using body-worn sensors, Movement Disorders, 2013, 28, 1544–51.