Wearable robot helps man with Parkinson's disease to walk

In one person with Parkinson's disease, freezing of gait was averted through the use of a soft robotic apparel that provided a moderate level of hip-flexion assistance during the swing phase of walking. This approach delivered instantaneous effects and consistently improved walking quality and function across a range of conditions.

The problem

Freezing of gait (FoG) is a disabling disturbance of walking experienced by a large proportion of people with Parkinson's disease (PD). It is characterized by an episodic absence of or marked reduction in forward movement of the feet despite the intent to walk. FoG has profound negative consequences on daily mobility (including causing falls) and quality of life. Current pharmacological interventions (for example, levodopa), surgical interventions (for example, deep brain stimulation) and behavioral interventions (for example, cueing strategies, which use visual, auditory or other stimuli to inform a person to take a step) have modest effects on reducing FoG, and in some cases, they might worsen it[1]. Most behavioral rehabilitation interventions to manage FoG require some level of cognitive processing and attention. However, cognitive deficits commonly co-occur with FoG. This discrepancy substantially narrows down the population of patients who can benefit from such approaches. Thus, there are currently no interventions that prevent FoG.

The solution

We demonstrate proof of the concept that FoG can be averted through the use of a soft robotic device — a machine that aims to apply physical assistance to movement with minimal restriction, an approach that is fundamentally different from rigid exoskeletons (Fig. 1). The wearable device augments hip flexion (swinging of the leg forward) and is based on technology originally conceived to augment healthy locomotion[2]. It uses cable-driven actuators (the components that enable physical movement by converting electrical energy into mechanical force) and sensors worn around the waist and thighs. Using motion data collected by the sensors, algorithms estimate the phase of the walking cycle and generate assistive forces in concert with biological muscles. In this trial, a 73-year-old man with PD and severe FoG used the soft robotic apparel when walking, in either unpowered mode or powered mode, and repeated measurements were taken at five time points spanning 6 months to elucidate the effect of the assistance. The patient demonstrated a robust response to the robotic apparel. When the device assisted with hip flexion during the terminal stance phase of walking (while lifting the toe), FoG was instantaneously eliminated during indoor walking, accompanied by clinically significant improvements in walking speed and distance. The beneficial effects of the device against FoG were repeatable across multiple days, types of conditions that elicit FoG (attention-demanding contexts through single-task walking and dual-task walking (with simultaneous talking)) and environmental contexts (laboratory and outdoor walking), which demonstrates the potential of the device for community use. These effects were immediate without any prior training, unlike what is often observed with behavioral approaches.

To identify potential mechanisms underpinning the effects of the robotic apparel, we examined the biomechanics of walking. When assistance of the device was activated, we observed a direct effect on increasing hip range of motion and stride length, with a marked reduction in stride length variability. These effects also led to improvements in foot orientation at heel strike and foot clearance during the swing phase (when the foot is lifted, until it touches the ground again), with resultant movement patterns similar to those observed in healthy people.

The implications

This study demonstrated that FoG was averted through the use of soft robotic apparel in a person with PD and will spur technological advancements to address this relevant yet unmet need. People with PD are at an increased risk of falls; thus, these biomechanical improvements are likely to also reduce fall risk.

Although our results support the perspective that FoG is a continuous gait disturbance and can be averted by the correction of fundamental issues with walking mechanics and rhythmicity, we do not fully know the mechanism of action behind the changes observed[3]. Furthermore, given the heterogeneity of presentation for people with PD, we do not know how the proposed approach will apply more broadly in this population. Finally, as FoG can often occur during other movements of walking, such as gait initiation and turning, technological advancements to enable appropriate timing of assistance under these conditions are needed, as are studies to elucidate the potential to avert FoG under such conditions. These promising findings prompt further investigation to validate the effects of the robotic apparel in a broader range of people with PD who are experiencing FoG and across various FoG phenotypes and environment and task contexts, complemented with FoG metrics that include quantification of the severity of the freezing episodes.

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EXPERT OPINION

"This paper provides some positive initial results on a device that provides biomechanical gait assistance via an apparel and is less dependent for its output on the detection of FoG, a burdensome mobility problem in PD. Automatic FoG detection is still problematic, and, therefore, this new device may be advantageous. This paper is an interesting and original exploration of a different approach to preventing FoG during ongoing walking." **Alice Nieuwboer, KU Leuven, Leuven, Belgium.**

FIGURE

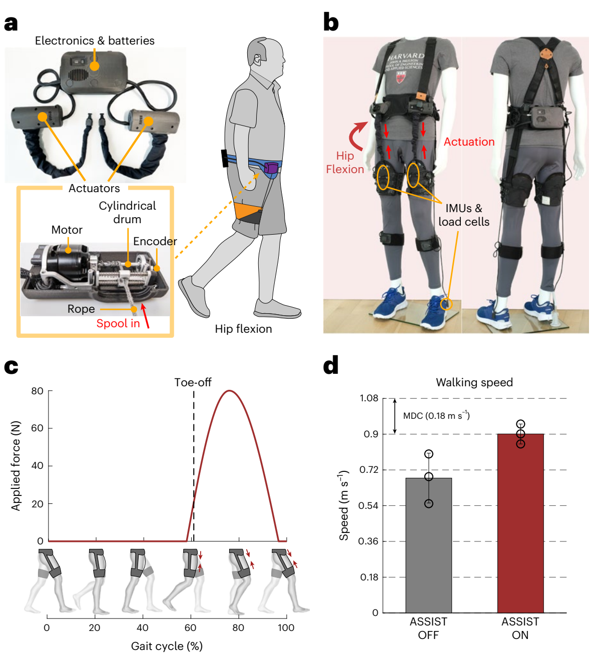

Fig. 1 | Soft robotic apparel for assistance with FoG. a, Hardware components are secured around the waist, with batteries and electronics on the lower back, and one hip-flexion actuator on each hip around the lower abdomen. **b**, The full system includes bilateral thigh inertial measurement units (IMUs) (movement sensors) and load cells. Data collected by the IMUs enable gait detection and tracking of forces delivered by the device. Additional IMUs on both feet are used for estimation of stride length and FoG assessment. **c**, Hip-flexion-assistance profile. Forces (arrows indicate direction) are delivered just before the toe-off subphase of the gait cycle. **d**, Walking speed from 10-meter walking trials when assistance is off or on. MDC, minimal detectable change. © 2024, Kim, J. et al.

BEHIND THE PAPER

Jooeun Ahn and Neville Hogan showed that if pulses that force flexion are periodically applied to the ankles of unimpaired people walking at constant speed, the people match the imposed pace even if it differs from their preferred cadence[4]. That finding led us to become interested in leveraging soft wearable robots to deliver mechanical cues to disrupt aberrant gait mechanics and prevent FoG in people with PD. Achieving this goal required collaboration among engineers, rehabilitation scientists, physical therapists, biomechanists and apparel designers. Our findings suggest the potential benefits of a 'bottom-up' rather than a 'top-down' solution to overcoming this major unmet challenge in the field. We found that restoring almost-normal biomechanics altered the peripheral dynamics of gait and may influence the central processing of gait control. There was an instant enthusiastic response from the participant, which confirmed the potential value of this approach. **C.J.W. & T.D.E.**

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FROM THE EDITOR

"This study marks an important juncture in advancing technology-based solutions for movement disorders, as it provides evidence that soft wearable devices can be used to treat complex walking deficits in people with PD." **Editorial Team, *Nature Medicine*.**