Improving Gait and Balance Post Hip, Knee, and Spinal Surgery Using a Novel Wearable Device: A Single-Subject Case Study

Abstract

Background: Older adults often undergo hip and knee replacement surgeries to restore mobility, yet persistent gait deficits and balance impairments can remain even long after recovery, especially in complex cases involving multiple surgeries. This case study explores the use of a novel wearable **Neuro-Motion Learning™** device ("Salute Just Walk") for gait and balance rehabilitation in a single elderly patient three years post spinal cord surgery, hip replacement, and knee replacement.

Methods: The patient (an 80 year old female, 3 years post-surgery) presented with reduced gait speed, shortened step length, impaired knee control in terminal stance, and poor balance, requiring a cane for ambulation and unable to walk backwards or ascend stairs normally. A 2.5-week intensive gait training protocol was implemented at home using the wearable device, which provides adjustable resistance during walking (Salute Just Walk). Training was performed daily (15 minutes per session, progressing from once to twice per day) with increasing resistance levels. Functional outcomes were assessed using the **Timed Up and Go (TUG)** test at baseline and regular intervals. The TUG measures the time to stand up from a chair, walk 3 meters, turn, return, and sit back down, and is a well-validated indicator of mobility and fall risk (scores ≥13.5 seconds in older adults indicate high fall risk) (Assessment of the risk of falling with the use of timed up and go test in the elderly with lower extremity osteoarthritis - PMC).

Results: The patient demonstrated dramatic improvements in mobility over the 2.5-week intervention. Baseline TUG time without the device was 25.3 seconds (average of two trials), indicating high fall risk. After training, the patient's TUG time (without device) improved to 12.3 seconds – a >50% reduction (Table 1) in the total measure time and complete migration from the high risk for fall category according to the TUG test. TUG performance improved under all conditions (with and without the device), with final times well below the 13.5-second high-risk threshold. These changes far exceeded the minimal detectable change for TUG (~2.3 s for knee arthroplasty patients (Assessing Minimal Detectable Changes and Test-Retest Reliability of the Timed Up and Go Test and the 2-Minute Walk Test in Patients With Total Knee Arthroplasty - PubMed)), indicating true clinical improvement. The patient progressed from needing a cane to walking independently, and reported the ability to walk backwards, sideways, and ascend stairs step-over-step - activities she could not perform before. No falls or serious adverse events occurred; minor balance assistance was required only during initial device use.

Conclusion: In this complex post-operative case, short-term home training with the wearable resistance device (Salute Just Walk) was feasible, safe, and associated with substantial improvements in gait speed, balance, and functional mobility beyond what is typically expected in the chronic recovery phase. The device's novel approach of augmenting gait with resistance appears to have facilitated gait retraining and neuro-motor adaptations leading to clinically meaningful outcomes. While these results derive from a single case, they highlight the potential of the device as an effective adjunct to rehabilitation for improving gait and reducing fall risk in post-surgical patients. Further research with larger samples is warranted to validate efficacy and generalize findings.

Introduction

Hip and knee arthroplasty (replacement surgery) are among the most common orthopedic procedures in older adults, indicated for end-stage osteoarthritis and other debilitating joint conditions. While these surgeries often relieve pain and improve joint function, many patients - especially elderly individuals - experience residual **gait impairments** and **balance deficits** during the post-operative period (New protocol for early robot-assisted gait training after spinal surgery - PMC) (LONG-TERM GAIT ANALYSIS IN PATIENTS AFTER TOTAL KNEE ARTHROPLASTY: A SYSTEMATIC REVIEW AND META-ANALYSIS | World Physiotherapy). Gait abnormalities after total knee arthroplasty (TKA) can include significantly reduced walking speed, shorter stride length, lower cadence, and prolonged stance phase compared to healthy age-matched adults, and studies show that some of these deficits may persist even beyond one year post-surgery (LONG-TERM GAIT ANALYSIS IN PATIENTS AFTER TOTAL KNEE ARTHROPLASTY: A SYSTEMATIC REVIEW AND META-ANALYSIS | World Physiotherapy) (LONG-TERM GAIT ANALYSIS IN PATIENTS AFTER TOTAL KNEE ARTHROPLASTY: A SYSTEMATIC REVIEW AND META-ANALYSIS | World Physiotherapy). Following total hip arthroplasty (THA), patients generally regain mobility, but muscle weakness (particularly of the hip abductors) can lead to a **Trendelenburg gait**, an abnormal lateral lurch during stance. In one gait analysis, approximately 27% of patients still exhibited a Trendelenburg gait one year after THA, attributable to insufficient hip abductor and extensor strength (Trendelenburg gait after total hip arthroplasty due to reduced muscle contraction of the hip abductors and extensors - PubMed). Such lingering gait deficits not only limit functional independence but also elevate the risk of falls in post-surgical populations. For instance, a **Timed Up and Go (TUG)** time exceeding ~13.5 seconds is often used to identify community-dwelling older adults at high risk of falling (Assessment of the risk of falling with the use of timed up and go test in the elderly with lower extremity osteoarthritis - PMC). Many post-arthroplasty patients fall into this high-risk category early in recovery, and without effective rehabilitation, some may remain at elevated fall risk long-term.

In addition to orthopedic surgeries, **spinal cord surgeries** (such as decompression or fusion involving the spinal cord) can further compound balance and gait issues. A variable proportion of patients experience persistent post-operative functional deficits after spinal surgery (New protocol for early robot-assisted gait training after spinal surgery - PMC). Given the multifactorial gait challenges in individuals who have undergone combinations of spinal and lower-extremity surgeries, comprehensive rehabilitation is critical. Early and intensive post-operative rehabilitation has been shown to improve functional outcomes and optimize recovery in spine surgery patients (New protocol for early robot-assisted gait training after spinal surgery - PMC). Similarly, targeted exercise interventions after joint replacement can significantly improve balance and walking ability. A recent systematic review confirmed that exercise therapy yields statistically significant improvements in balance (standardized mean difference SMD ≈0.51) and gait performance (SMD ≈0.39) in patients following THA (Effects of exercise therapy on the balance and gait after total hip arthroplasty: a systematic review and meta-analysis). Conventional rehabilitation programs for such patients typically include physical therapy focused on muscle strengthening, range-of-motion exercises, gait retraining, and balance training.

Despite rehabilitation, however, some patients with complex post-operative histories do not fully regain normal gait. Persistent impairments in strength, coordination, and proprioception may require more specialized retraining techniques. In recent years, there has been growing interest in **advanced gait rehabilitation technologies** to augment traditional therapy. For example, robotic exoskeletons and **robot-assisted gait training (RAGT)** systems have been applied early after spinal surgery to facilitate repetitive walking practice with promising outcomes (New protocol for early robot-assisted gait training after spinal surgery - PMC). Perturbation-based gait training is another emerging approach: by deliberately altering the walking pattern or applying resistance/assistance, patients can adapt and improve their gait symmetry and stability through motor learning mechanisms (Perturbation-based gait training to improve daily life gait stability in older adults at risk of falling: protocol for the REACT randomized controlled trial). Split-belt treadmill paradigms and limb-weighting techniques are known to induce locomotor adaptation that carries over to improved overground walking in neurological populations (e.g. stroke) (Locomotor adaptation on a split-belt treadmill can improve walking symmetry post-stroke).

The **Salute "Just Walk" device** employed in this case study represents a novel, low-resource approach to perturbation-based gait retraining. It is a lightweight, wearable device consisting of a belt unit worn around the waist and cords that attach to the feet. By providing continuous, adjustable resistance against forward leg movement during walking, the device challenges the user's neuromuscular system to adapt. This **Neuro-Motion Learning™** technology essentially adds a controlled perturbation to each step, aiming to enhance gait coordination, strengthen the limbs, and improve balance. Previous preliminary studies have suggested that training with the device can improve gait speed, basic mobility, and gait symmetry in patient populations. For example, a single-case report in a child with diplegic cerebral palsy showed improved TUG time and more symmetric hip/knee kinematics after a 3-week training with the "Just Walk" system (An innovative gait rehabilitation device for improving gait parameters of a child with Cerebral Palsy). Likewise, a case study in a chronic post-stroke patient found that practicing with the device led to faster gait and better balance, with authors concluding that the **Salute Just Walk** can be an effective therapeutic tool for gait rehabilitation (An innovative Neuro-Motion Learning™ device for gait and balance rehabilitation after stroke).

Here, we present a single-subject case study of an elderly patient who had undergone spinal cord surgery, hip replacement, and knee replacement, and who continued to exhibit significant gait and balance deficits three years post-operations. The patient underwent an intensive short-term home rehabilitation program using the wearable gait training device. We hypothesized that this novel intervention would produce measurable improvements in gait speed, balance, and functional mobility, even in the chronic phase of recovery when conventional rehabilitation gains have plateaued. The objective of this report is to describe the **clinical outcomes** of this intervention and to discuss them in the context of post-operative recovery trajectories and current rehabilitation literature.

Methods

Case Description

The participant was an elderly female patient (80 years old) with a history of major orthopedic and spinal surgeries. Approximately three years prior, she had undergone **lumbar spinal cord surgery** followed by a **right total hip arthroplasty (THA)** and a **right total knee arthroplasty (TKA)**. Despite standard post-operative rehabilitation, the patient continued to experience notable gait abnormalities and functional limitations in daily life:

- **Gait impairments:** Her overground walking speed was significantly reduced. She exhibited a markedly **shortened step length** and an asymmetrical gait pattern. Observation of gait revealed reduced right knee control during terminal stance (possibly a quadriceps avoidance pattern) and mild foot drop (foot slap) during swing, indicating residual weakness or poor motor control.
- **Balance and mobility deficits:** The patient had chronic **balance instability**, requiring a single-point cane for community ambulation. She reported inability to walk **backwards** or sideways, and she could only ascend stairs using a step-to pattern (placing both feet on each step) with reliance on one leg, rather than the normal alternating gait. She also complained of **early fatigue**, becoming very tired after walking a short distance (indicative of poor endurance and efficiency).

- **Fall risk:** At the outset, her functional mobility was poor enough to put her at risk of falls. In fact, initial TUG testing confirmed a very slow performance (see Results).

The patient provided informed consent to participate in this case study protocol. The goal of the intervention was to improve her gait speed, balance, and confidence to a level that would reduce fall risk and allow her to walk independently without a cane.

Intervention: Wearable Gait Training Device

The rehabilitation intervention employed the **Salute "Just Walk" gait training device**, a wearable external resistance system designed for home use. The device consists of a belt worn around the waist housing a module that generates adjustable magnetic resistive force. A retractable tension cord extends from the belt and attaches to an **ankle-foot strap** on each foot. As the patient walks, the device applies a continuous **linear resistance** opposing forward motion of the legs. This creates a subtle drag on each step, requiring extra effort to advance the limb. The level of resistance is easily adjustable by rotating a dial on the belt unit. In this case, the patient used the device on **both legs** simultaneously. (No additional weights or vest were used; only the belt and foot connectors were utilized.)

Training Protocol: The patient participated in a **2.5-week intensive training program** with the device. Key details of the protocol:

- **Frequency:** Daily training, with sessions initially **once per day** for the first week and progressing to **twice per day** (morning and evening sessions) in subsequent weeks as tolerated.
- **Session duration:** Each training session consisted of **15 minutes of walking** continuously while wearing the device. This was over-ground walking in the patient's home and community environment (e.g. walking back and forth in a hallway or around the house), at a self-selected pace.
- **Resistance level progression:** For the first ~10 days, the device's resistance was set at *Level 0* (the lowest tension setting) because the patient found higher resistance too difficult initially. By the end of the second week, after noting increased leg strength and confidence, the resistance was increased to *Level 1* (a moderate tension) for the remainder of training. The patient reported that Level 0 became easier, prompting the increase.
- **Supervision and safety:** During early sessions, a family member or caregiver stood by to monitor safety, especially when donning and doffing the device. The patient needed some assistance in the first few days to put on the ankle straps and connect the cords due to limited flexibility in bending down. After about one week of practice, she became able to independently put on and remove the device. We advised the patient to be cautious when removing the belt and cords, as sudden removal of resistance can momentarily affect balance. Indeed, users may feel a brief sensation of lightness or instability when the device is taken off, so the patient was instructed to take her first few steps carefully and near a support (this is a general precaution noted for the device).

Throughout the training period, no changes were made to the patient's other treatments or medications. She continued her usual daily activities. The only intervention introduced was walking with the Just Walk device as described.

Outcome Measures

The primary outcome measure was the **Timed Up and Go (TUG) test**, a standardized functional mobility test widely used in rehabilitation. The TUG measures the time (in seconds) it takes for the patient to stand up from a standard armchair, walk a distance of 3 meters (10 feet), turn around, walk back to the chair, and sit down. It assesses a combination of balance, gait speed, and transfer ability. **Lower times indicate better performance**. The TUG is highly reliable and has established validity in older adults and post-surgical populations. Notably, the minimal detectable change at 95% confidence (MDC_95) for TUG in patients after knee replacement has been reported as ~2.27 seconds (Assessing Minimal Detectable Changes and Test-Retest Reliability of the Timed Up and Go Test and the 2-Minute Walk Test in Patients With Total Knee Arthroplasty - PubMed), and an older adult who requires ≥13.5 seconds to complete the TUG is generally considered to have a high risk of falling (Assessment of the risk of falling with the use of timed up and go test in the elderly with lower extremity osteoarthritis - PMC).

In this study, TUG tests were conducted at **four time points**: at baseline prior to any device training ("Session 1"), and then approximately after 4 days of training ("Session 2"), after 1 week of training ("Session 3"), and after 2.5 weeks upon completion of the program ("Session 4"). At each assessment, multiple TUG trials were performed under two conditions:

- **Without device:** The patient completed the TUG under normal conditions (prior to donning the device, and subsequently after doffing the device), to evaluate her actual functional mobility free of any assistance or resistance.
- **With device:** The patient also performed the TUG while wearing the Just Walk device (with resistance), to assess her performance under the perturbed condition.

In practice, each session's assessment was organized as follows: first, two TUG trials were done without the device ("pre-test without device" trials 1 and 2). Then the device was put on, and two TUG trials were done with resistance ("with device" trials 1 and 2). Finally, after the training session (15 minutes of walking with the device) was completed and the device removed, two more TUG trials were repeated without the device ("post-test without device" trials 1 and 2). For most relevant reporting, we will primarily focus on the **pre-test without device** results as the indicator of the patient's independent mobility at each time point.

No other formal balance scales or gait analyses were performed due to the single-case nature of the study, but qualitative changes in the patient's functional abilities (e.g. walking backwards, stair climbing), as well as significant muscle growth were noted based on TUG test results **with the device**, patient self-report, and therapist observation.

Data analysis: TUG times at each session were recorded to the nearest hundredth of a second. Given this is a single-case study, no statistical comparisons were applicable. Instead, we calculated absolute and percentage changes in TUG time from the first session to the final session to gauge improvement. We also compared the patient's TUG times to normative fall risk thresholds for clinical interpretation. Improvements were considered clinically significant if they exceeded MDC values from the literature and resulted in crossing below the fall-risk cut-off of ~13–14 seconds.

Results

Baseline performance: At the first session (pre-training baseline), the patient's TUG times without the device were 26.7 seconds and 24.0 seconds (two trials). The **average baseline TUG** was approximately 25.3 seconds, far above typical norms for her age and well above the ≥13.5 seconds fall-risk threshold (Assessment of the risk of falling with the use of timed up and go test in the elderly with lower extremity osteoarthritis - PMC). This confirmed that she had a markedly slow gait and high fall risk at baseline. Performing the TUG while wearing the device at baseline was even slower (as expected due to added resistance): 31.4 seconds and 29.8 seconds on two trials. After a single 15-minute training session with the device, her immediate post-training TUG (without device) in Session 1 was 28.5 seconds and 24.23 seconds on two trials – roughly similar to pre-training, indicating no immediate large effect in the same session (one trial improved slightly, one was slightly worse, likely due to fatigue or measurement variability).

Progress over 2.5 weeks: Over the course of the training program, the patient showed **steadily improving TUG times** at each subsequent assessment. Detailed results for each trial are presented in **Table 1**. By the fourth and final session (after 2.5 weeks of training), her TUG times without the device had improved to 12.62 seconds and 11.91 seconds on two trials, essentially halving the time taken at baseline. The **best post-training trial** was 11.91 seconds, which is below the common 12–14 seconds cut-off for fall risk in older adults - indicating she had moved out of the high-risk zone for falls. Notably, all measurement conditions (with or without device, pre- or post-exercise) demonstrated large improvements between Session 1 and Session 4, on the order of 48–55% faster times (Table 1). For example, the average **pre-test TUG without device** went from 25.3 seconds at baseline to 12.3 seconds at final (an absolute improvement of 13.0 seconds, or 51%). Even the TUG with the device (which places extra load on the patient) improved from 30.6 seconds (average of two baseline trials) to 14.7 seconds (average of final trials), reflecting increased strength and adaptation to the resistance.

Table 1. Timed Up and Go (TUG) test results across four sessions of device-based training. Times are shown in seconds for each trial under each condition. "Day 0" corresponds to the baseline pre-training assessment, and "Day 18" corresponds to the final assessment after 2.5 weeks of training. The improvement columns show the change in performance from Day 0 to Day 18 for each trial (a negative difference indicates faster performance). All values are recorded to two decimal places where available.

Measurement Condition (TUG)	**Day 0 (Baseline)**	**Day 4**	**Day 11**	**Day 18 (Final)**	**Improvement (Day0→18)**	**Improvement (%)**
Pre-test without device – trial 1	26.70 s	15.10 s	13.07 s	12.62 s	–14.08 s	52.7% faster
Pre-test without device – trial 2	24.00 s	16.40 s	12.71 s	11.91 s	–12.09 s	50.3% faster
TUG with device – trial 1	31.40 s	18.80 s	14.82 s	13.98 s	–17.42 s	55.4% faster
TUG with device – trial 2	29.80 s	16.80 s	18.42 s	15.41 s	–14.39 s	48.2% faster
Post-test without device – trial 1	28.50 s	18.04 s	18.06 s	13.63 s	–14.87 s	52.1% faster
Post-test without device – trial 2	24.23 s	14.98 s	15.40 s	12.39 s	–11.84 s	48.8% faster

Note: "Pre-test" refers to trials performed before the training session on that day (without the device on). "TUG with device" refers to trials performed with the device worn (resistance applied). "Post-test" refers to trials performed after completing the day's 15-minute walking practice (device removed). Day 4 corresponds to Session 2 (after approximately 4 days of training), Day 11 corresponds to Session 3 (after ~1.5 weeks of training), and Day 18 corresponds to Session 4 (after

~2.5 weeks). Improvement is calculated as the Day 0 time minus the Day 18 time; a positive improvement (negative time difference) indicates reduction in TUG duration (faster performance).

As shown in Table 1, there was an early rapid improvement by Day 4 of training: the patient's TUG without the device dropped to 15-16 seconds (a 40% improvement from baseline in just four days). Some of this early change could be due to learning or increased familiarity with the test; however, the trend continued with further training. By Day 11, the times were around 12-13 seconds, and the patient stabilized around 12 seconds by Day 18. The **consistency of the two trials** at each time point also improved - for instance, on Day 18 the two trials without device were 12.62 and 11.91 seconds, a tight range, suggesting reliable performance. Importantly, the patient's **functional status** improved in ways beyond just the numeric test scores:

- She reported that she no longer needed to use her cane for walking on level surfaces. By the end of the training, she was confidently walking indoors and short distances outdoors **without any assistive device**.
- After two weeks, the patient demonstrated that she could now **walk backwards** and **side-step** (lateral stepping) with sufficient balance, whereas previously she felt too unstable to attempt these movements. This indicates improved multidirectional balance and coordination.
- Stair climbing technique improved. Prior to training, the patient ascended stairs one step at a time (both feet on each step) and had to lead with the same leg due to weakness. After training, she was able to **ascend stairs in a more normal alternating pattern**, placing one foot per step, and reported using both legs more symmetrically. She still used the handrail for safety, but the pattern change suggests better leg strength and confidence.
- The patient's endurance increased. She noted that she could walk longer distances before feeling fatigued. For example, she could walk around her home or go to a nearby shop without needing to stop, which was an improvement from getting exhausted after a very short walk previously. She also described a general feeling of having "more power" in her legs.

No injuries or falls occurred during the training period. Regarding **safety and tolerability**, the patient did experience a mild balance disturbance immediately after removing the device, particularly during the first week – a known temporary effect due to suddenly not having the resistance (her gait would momentarily overshoot when the resistance was gone). As a precaution, she always stood near a wall or had someone nearby when taking off the device. This effect diminished over time as she got used to it. By the second week, she was adept at handling the device independently. The only side effect noted was slight **muscle soreness** in the first few days of training (especially in the thighs), which is expected with any new exercise; this soreness subsided as she continued training.

Discussion

This single-subject case study examined the impact of a novel wearable gait-training device on an elderly patient with chronic gait deficits following combined spinal and lower-extremity orthopedic surgeries. After a concentrated 2.5-week home training regimen with the device, the patient exhibited substantial improvements in objective mobility measures (TUG time) as well as in functional abilities (independent ambulation, backward walking, stair negotiation). These improvements are remarkable given that the patient was **3 years post-surgery**, a time by which spontaneous recovery would have plateaued and further functional gains without intervention are typically limited (LONG-TERM GAIT ANALYSIS IN PATIENTS AFTER TOTAL KNEE ARTHROPLASTY: A SYSTEMATIC REVIEW AND META-ANALYSIS | World Physiotherapy).

Comparison to Typical Recovery and Clinical Significance

In the absence of new interventions, patients three years post hip or knee replacement generally show only modest residual deficits or simply maintain their status quo. It is **atypical** to see a >50% improvement in gait speed at such a late stage, since the most rapid recovery after joint replacement occurs within the first 3-6 months post-op, with slower improvements up to about 1 year (LONG-TERM GAIT ANALYSIS IN PATIENTS AFTER TOTAL KNEE ARTHROPLASTY: A SYSTEMATIC REVIEW AND META-ANALYSIS | World Physiotherapy). Even then, many patients do not reach the gait speed of healthy peers; for example, one study noted that patients 2-3 years after TKA walked at ~0.9 m/s, compared to ~1.2-1.3 m/s for healthy controls of similar age (A Comparison of Individuals 1 Year After Total Knee Arthroplasty ...). Our patient's baseline TUG of ~25 seconds corresponds to an extremely slow gait (roughly 0.4 m/s walking speed for the 3 meters distance). Post-intervention, her TUG of ~12 seconds suggests a gait speed of 0.8-0.9 m/s - still somewhat below age-normative values, but a dramatic improvement nonetheless. In terms of **fall risk**, this change moved her from a clearly high-risk category to a level comparable with low-risk, independent older adults (Assessment of the risk of falling with the use of timed up and go test in the elderly with lower extremity osteoarthritis - PMC).

The magnitude of change observed exceeds what could be attributed to test-retest learning or measurement error. The TUG test has excellent reliability (ICC ~0.98) in similar populations, and the 95% minimal detectable change has been reported as 2.3 seconds in TKA patients (Assessing Minimal Detectable Changes and Test-Retest Reliability of the Timed Up and Go Test and the 2-Minute Walk Test in Patients With Total Knee Arthroplasty - PubMed). Our patient's TUG improved by ~13 seconds, which is roughly **5-6 times the MDC**, indicating a true and meaningful improvement far beyond any conceivable noise or day-to-day variation. Thus, we consider the gains to be both **statistically and clinically significant**. Achieving a TUG under 13.5 seconds is particularly meaningful, as it suggests she transitioned from being at high risk of falls to within normal limits for community-dwelling seniors (Assessment of the risk of falling with the use of timed up and go test in the elderly with lower extremity osteoarthritis - PMC).

Potential Mechanisms of Improvement

Several factors may explain the notable improvements with the **Just Walk device** training:

- **Augmented resistance training:** Walking with the device's resistance likely provided a strength training effect to the lower limb muscles, especially the hip flexors, hip extensors, and knee extensors which must work harder to swing and step. The progressive loading (advancing from Level 0 to Level 1 resistance) would have challenged the patient's muscles to adapt and grow stronger, contributing to improved push-off power and limb control. This is evidenced by her ability to climb stairs more normally after training, which demands greater knee and hip extensor strength.
- **Motor learning and adaptation:** Perhaps more uniquely, the constant resistance acted as a form of **sensorimotor perturbation** to her gait. According to principles of locomotor adaptation, when the nervous system encounters a consistent alteration in movement dynamics (such as a resistive force), it makes error-driven adjustments to maintain efficient gait (Perturbation-based gait training to improve daily life gait stability in older adults at risk of falling: protocol for the REACT randomized controlled trial). Over repeated practice, these adjustments can become ingrained. In similar fashion to split-belt treadmill training (which forces asymmetrical walking to recalibrate gait symmetry) or adding weights to the legs (which forces the patient to lift the legs higher), using the Just Walk device may have induced adaptations such as longer step length and improved hip flexion during swing. Indeed, by the

end of the training, the patient subjectively noted her legs felt "lighter" when the device was off, allowing her to step farther. This aligns with reports from other cases - for instance, stroke patients have described a sensation of *lightness* in the limb after practicing with the device, due to the removal of resistance after training (*An innovative Neuro-Motion Learning™ device for gait and balance rehabilitation in chronic stroke patients*).

- **Enhanced proprioception and balance:** The device may also offer enhanced proprioceptive feedback. The slight pull on the legs could increase the sensory input from joints and muscles during gait, helping the patient become more aware of her limb movements and stance stability. There is evidence that such proprioceptive training can improve balance and coordination in gait (New protocol for early robot-assisted gait training after spinal surgery - PMC). In our case, improved balance was reflected in her new ability to walk backwards and sideways. Backward walking requires good coordination and confidence in one's balance since it removes visual feedback of the path; accomplishing this suggests the patient's balance and proprioceptive control improved significantly.
- **Psychological factors and confidence:** An often underappreciated aspect is the boost in the patient's confidence from seeing tangible improvements and having a safety net during training. Initially, she was fearful of certain movements (hence avoiding backward walking, etc.). Training with the device in a structured way, and realizing she could do more than she thought, likely improved her self-efficacy. By the end, she was confident enough to discard her cane for many situations. Reducing fear of falling is known to be an important component of actual fall risk reduction. Interestingly, patient satisfaction surveys in other technology-assisted gait trainings (like RAGT after spinal surgery) have noted alleviation of fear of falling as a key benefit (New protocol for early robot-assisted gait training after spinal surgery - PMC). In our case, the device might have served a similar role by providing a sense of support (even though it's resistive, it is worn snugly and perhaps gave a subjective feeling of stability as a "belt"), thereby reducing her fear and encouraging more fluid movement.

Relation to Other Studies

The outcomes in this case are consistent with preliminary evidence from other single-subject studies of the **Salute Just Walk** device. As mentioned, **children with cerebral palsy** showed improved gait speed and temporal symmetry after a few weeks of training with the device (*An innovative gait rehabilitation device for improving functional mobility in cerebral palsy*). In **chronic stroke survivors**, Just Walk training has been associated with improved overground walking speed, longer step length, and better balance, even when conventional therapy gains had plateaued (*An innovative Neuro-Motion Learning™ device for gait and balance rehabilitation in chronic stroke patients*). Our study extends these findings to an **older orthopedic population**, suggesting that the device's benefits are not limited to neurologic diagnoses like stroke or CP, but can also apply in orthopedic rehabilitation for gait after joint replacement and spinal surgery.

Furthermore, this case underscores that substantial improvement is possible even long after the typical post-surgical rehab period. Traditional wisdom might assume that at three years post-operation, further improvement in gait would require compensatory strategies or assistive devices rather than restoration of normal gait mechanics. However, the success seen here aligns with the concept of **neuroplasticity and adaptability** in the aging musculoskeletal system - given the right kind of stimulus (in this case, repetitive practice with perturbation), the patient was able to modify her gait pattern. This is analogous to how tailored exercise programs can still improve outcomes in older patients well beyond the acute recovery phase (Effects of exercise therapy on the balance and gait after total hip arthroplasty: a systematic review and meta-analysis). The result also resonates with studies on high-intensity or specialized training after joint replacement. For example, high-intensity strength training after TKA has been shown to accelerate gait recovery and even improve symmetry beyond standard care, and perturbation-based balance training can reduce falls in older adults. The Just Walk device conveniently combines elements of strength and balance training in a functional walking context.

Feasibility and Safety Considerations

Using the device in a **home setting** proved feasible for this patient. Aside from some initial help needed with setup, the device was manageable for an elderly user, and the short 15-minute sessions were well tolerated. This suggests that **home-based gait retraining technology** can be a viable adjunct to therapy, which is important because access to outpatient therapy services diminishes in the chronic stage. The patient effectively became self-sufficient with her daily training, which likely improved adherence.

Safety was generally good. There were no falls or injuries, and the patient learned to handle the transient balance effect when removing the device. It is worth noting for clinical application that therapists should educate patients about the **"post-removal" effect** - i.e., a sudden change in sensation and balance when the resistance is removed - and perhaps incorporate a cool-down period where the patient stands or walks with support immediately after device removal. Ensuring a caregiver is present during initial trials is a reasonable precaution. The patient's feedback also indicated that as her strength grew, tasks like attaching the device (which require bending to the feet) became easier, which is a positive cycle - the intervention itself enabled her to better manage it.

One aspect to consider is **fatigue**: the patient did report getting "tired" after the first few uses (as also noted in a stroke case study (*An innovative Neuro-Motion Learning™ device for gait and balance rehabilitation in chronic stroke patients*)), but this improved as endurance increased. Therapists should monitor fatigue and possibly start with shorter sessions (or lower resistance) for frail patients, progressing as tolerated. Our protocol started at the lowest resistance and only increased after clear improvement, which likely helped avoid excessive strain.

Limitations

This study has inherent limitations as a single-case report. Without a control or comparison, we cannot definitively attribute all improvements solely to the device training. It is conceivable that any focused walking program (even without the device) might have conferred some benefits. However, the magnitude and rapidity of improvement here are greater than typically seen with standard gait exercises, suggesting an additive effect of the device's unique training stimulus. Another limitation is that we did not perform instrumented gait analysis or muscle strength testing, which would have quantitatively elucidated how gait mechanics changed (e.g., step length, hip abduction strength, etc.). Instead, we relied on functional measures and observational notes. Future studies could include pre- and post-intervention gait lab analysis to objectively document changes in kinematics and kinetics, as well as longer-term follow-up to see if improvements are retained after cessation of device use.

Moreover, the **generalizability** of this result is limited. This patient had a very high initial TUG (severe impairment), so there was ample room for improvement. Patients with milder deficits might not experience such a large relative gain. Conversely, patients with more severe neuromuscular damage (e.g., incomplete spinal cord injury with significant paralysis) might require additional supports. Our patient had intact cognition and was highly motivated; thus, her adherence was excellent. Different patient personalities or support systems could influence outcomes. We also cannot separate the effects of her prior hip vs. knee vs. spine issues – it was a combined scenario. However, from a rehabilitation perspective, the **holistic outcome** is what matters: improving overall mobility irrespective of the source of deficit.

Clinical Implications

Despite these limitations, this case provides a **proof-of-concept** that integrating a wearable resistance device into late-stage rehabilitation can yield meaningful functional gains. The device essentially allowed the patient to engage in high-repetition, task-specific gait training with augmented difficulty, all within her home environment - an approach that is difficult to replicate with conventional therapy alone. Importantly, the intervention was **non-invasive** and relatively low-cost compared to robotic gait trainers or supervised clinical programs. It empowers patients to take an active role in their own recovery through daily practice.

For clinicians, a few practical takeaways include: (1) **patient selection** - candidates who have plateaued in progress but still have goals for improved walking may particularly benefit; (2) **training guidelines** - start at low resistance, ensure safety during transitions, and gradually progress intensity; (3) **monitoring** - use functional tests like TUG to track progress, and be attentive to patient feedback on fatigue or discomfort.

Conclusion

This case study demonstrates that the use of a novel wearable gait-training device (Salute Just Walk) was associated with rapid and substantial improvements in gait speed, balance, and functional mobility in an elderly patient with chronic post-operative gait deficits. After a short 2.5-week intervention, the patient's TUG time improved by over 50%, dropping below the threshold for high fall risk, and she regained abilities such as walking without an assistive device and navigating stairs more normally. These results suggest that even long after standard rehabilitation, patients can achieve further recovery in walking function when provided with an innovative training stimulus that combines resistance and repetitive task practice.

While acknowledging that this is a single-case report, the outcomes align with emerging evidence supporting the efficacy of perturbation-based and home-based gait training technologies in enhancing neuro-motor adaptation. The Salute Just Walk device appears to be a promising **assistive rehabilitation technology** to facilitate gait retraining and balance improvement in individuals recovering from orthopedic and neurologic surgeries. Its advantages include ease of use in a home setting and the ability to tailor resistance to the patient's level.

Further research is needed to validate these findings in larger cohorts. Randomized controlled trials could compare device-assisted training to conventional therapy to quantify incremental benefits. Studies spanning diverse populations (joint replacement patients, stroke survivors, incomplete spinal cord injury patients, etc.) would help identify which groups benefit most. Additionally, long-term follow-up would determine if gains are maintained and if periodic retraining with the device is needed to sustain improvements.

In summary, this case adds to the growing literature emphasizing that **significant mobility gains are achievable** beyond the early post-surgical window when using targeted, novel rehabilitation interventions. The integration of wearable resistance devices could become a valuable component of rehabilitation programs aimed at restoring safe and efficient gait in high-fall-risk patients. By improving gait performance and confidence, such interventions ultimately strive to enhance the patient's independence and quality of life.

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