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Feasibility and Effects of a Soft-Wearable Robotic Suit Assisting Hip Extension in Older Adults

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Background

- The global population of older adults is rapidly increasing, accompanied by a higher prevalence of gait impairment and fall risk resulting from age-related neuromuscular decline and altered lower-limb biomechanics.
- Soft-wearable robotic suits have emerged as a lightweight and compliant alternative to rigid exoskeletons.
- Clinical evidence of the soft-wearable robotic suits in older adults remains limited.
- This pilot study evaluated the feasibility and functional effects of a cable-driven soft-wearable robotic suit (H-Medi) that assists hip extension during gait training in community-dwelling older adults.

Methods

- This single-center, single-arm pilot study enrolled 22 community-dwelling older adults aged ≥ 65 years.
- Participants completed six training sessions over three weeks, each consisting of 20 minutes of robot-assisted gait training and 20 minutes of strength exercise.
- The H-Medi weighs less than 4.5 kg including a lumbar actuation unit, a waist belt, and thigh straps (Figure 1). The control algorithm tracks the Gait Cycle Percentage (GCP) using inertial measurement unit (IMU) sensor signals to synchronize assistance in real-time. In this study, the assistance strategy was specifically calibrated to augment hip extension using a half-sine force profile aligned with real-time gait events. this force profile initiates assistance at 13% prior to heel contact, a peak at 21%, and an offset at 38% of the gait cycle.

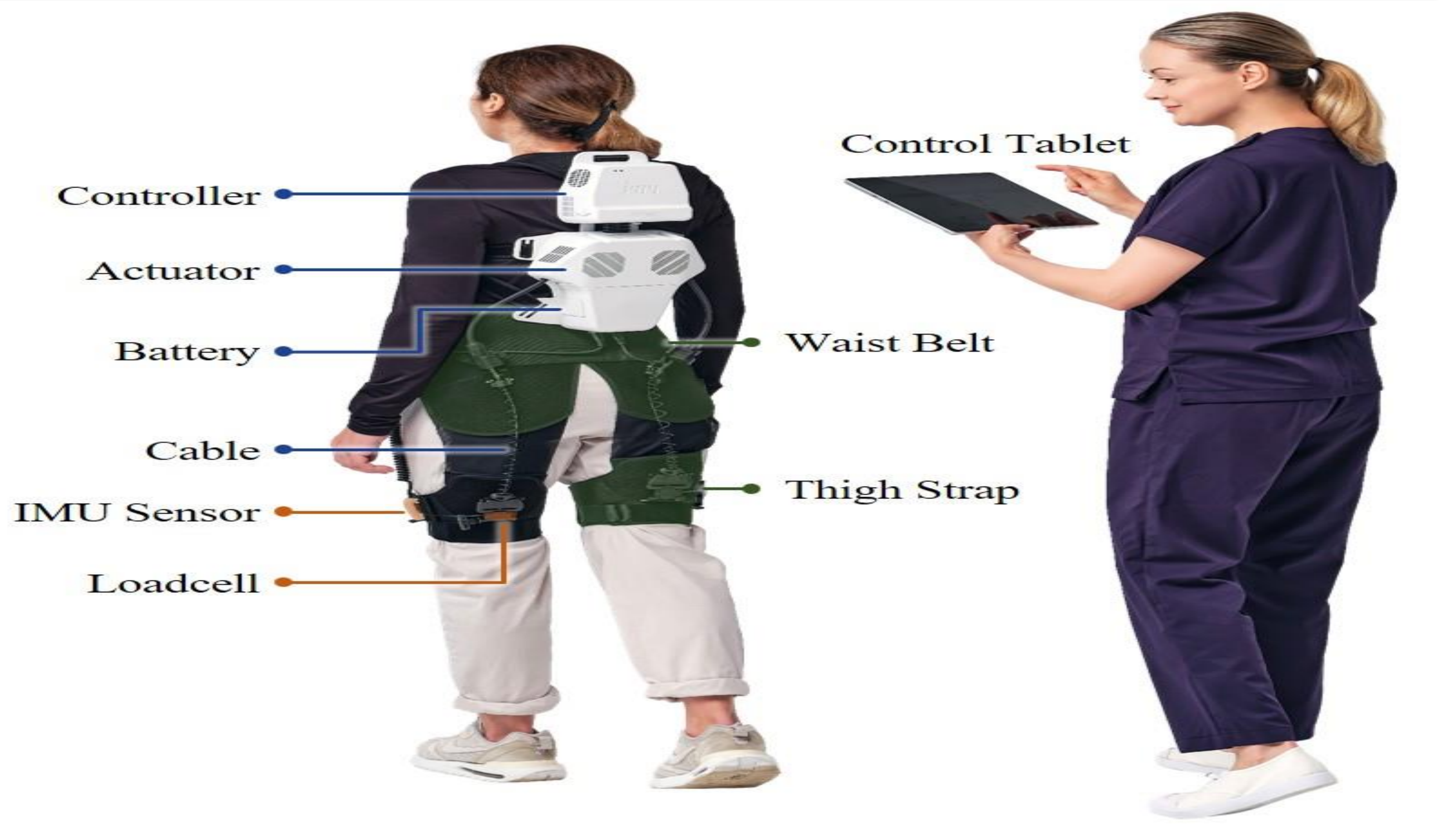

Figure 1. The cable-driven soft-wearable robotic suit **(H-Medi)**

- Feasibility was assessed through adherence and safety monitoring.
- Functional outcomes were evaluated before and after the intervention (without robotic assistance) using gait speed measured by the 4-meter walk test (4MWT), Timed Up and Go test (TUG), Short Physical Performance Battery (SPPB), Berg Balance Scale (BBS), and range of motion (ROM) of lower limb joints.
- Pre and post training comparisons were conducted using paired t-tests or Wilcoxon signed-rank tests as appropriate. A linear mixed-effects model was applied to further analyze gait speed.

Results

- Twenty of the 22 participants (90.9%) completed all sessions, with no adverse events reported, indicating high feasibility and safety.

Table 1. Baseline characteristics of participants

Baseline Characteristics	All Participants (N=20)
Age, years	72.1 ± 4.4
Sex (Male : Female)	7 (35%) : 13 (65%)
Height, kg	156.4 ± 9.1
Weight, kg	58.6 ± 13.8
Body mass index, kg/m^2	23.7 ± 3.5

- Gait speed improved significantly from 0.96±0.16 to 1.08±0.12 m/s (Δ = 0.13±0.11 m/s, p<0.001), exceeding the minimal clinically important difference (0.1 m/s).
- TUG time decreased from 11.0±1.9 to 9.8±1.5 seconds (p<0.001).
- Sagittal-plane ankle ROM increased significantly (33.7±4.3° to 37.0±6.4°, p=0.004), while frontal plane-hip ROM showed a trend toward improvement (10.2±1.6° to 11.7±2.7°, p=0.066).

Table 2 Outcome assessments comparing pre- and post-exercise.

Outcome Assessments	Pre-Exercise	Post-Exercise	Delta	*p*-value	Effect Size
Gait speed, m/s	1.00 [0.80 ~ 1.10]	1.10 [1.00 ~ 1.20]	0.10 [0 ~ 0.20]	0.0011*	0.80
TUG, sec	11.0 ± 1.9	9.8 ± 1.5	-1.2 ± 1.3	<0.001*	0.98
BBS	56 [55 ~ 56]	56 [55 ~ 56]	0 [0 ~ 1]	0.28	0.31
SPPB	12 [12 ~ 12]	12 [12 ~ 12]	0 [0 ~ 0]	0.42	0.22
ROM of lower-limb joints, degree					
Hip, sagittal-plane	45.4 ± 4.8	45.8 ± 5.8	0.4 ± 3.6	0.60	0.13
Hip, frontal-plane	10.2 ± 1.6	11.7 ± 2.7	1.5 ± 3.2	0.066	0.46
Knee, sagittal-plane	56.3 ± 6.8	57.7 ± 5.6	1.4 ± 6.0	0.35	0.23
Ankle, sagittal-plane	33.7 ± 4.3	37.0 ± 6.4	3.3 ± 4.2	0.0044*	0.77

- Linear mixed-effects model confirmed time and age as significant determinants of gait speed. On average, post-training gait speed improved by 0.13 m/s than pre-training, after adjusting for age and sex (p<0.001). Age was associated with a 0.02 m/s decrease in gait speed per additional year. The intraclass correlation coefficient (ICC) was 0.61, indicating substantial between-subject variability.

Table 3. Linear mixed-effects model of gait speed.

Fixed effect	Estimate	Standard error	Degrees of freedom	*p*-value
Intercept	2.03	0.42	20.26	<0.001*
Time	0.13	0.02	20.00	<0.001*
Age	-0.02	0.01	20.23	0.016*
Sex	0.05	0.05	20.01	0.36
Random effect	**Variance**	**Standard deviation**		
Individual	0.0093	0.096		
Residual	0.0059	0.077		

Conclusions

- Short-term training using a **soft-wearable robotic suit assisting hip extension (H-Medi)** was safe, feasible, and associated with **improved gait speed** and mobility performance in **older adults.**
- These findings support the potential role of soft-wearable robots in improving mobility.

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