Toward a Customizable Body Weight Support System with Interactive Treadmill for Patients with Diverse Gait Impairments

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1.Introduction

- Stroke survivors often face severe gait limitations; conventional therapy is labour-intensive and hampered by fear of falls.
- Existing BWS/exoskeleton setups add safety but stay bulky, costly, and lock patients to preset treadmill speeds.
- Our compact two-cable BWS + self-paced treadmill restores pelvic freedom and speed autonomy, but pelvic-only support can destabilize severely impaired users, calling for overhead-mode refinement and broader clinical testing.

2. Study objective

Goal: Develop an adaptive BWS system for patients with various gait-ability levels.

Hardware: two-cable BWS with movable modules for adjustable unloading modes.

Training modes:

- Pelvic support for mild deficits.
- Overhead support for severe instability.

Validation: pilot tests on stroke patients.

3. System configuration

Framework: two–cable BWS + self-paced treadmill (Fig. 1a).

- **Actuation & Sensing**: BLDC motors + gearbox, dual floating-pulley load-cells with encoders

Control logic:

$$\mathbf{F}_d = \mathbf{K}(\boldsymbol{\theta})\, F_r, \qquad \mathbf{u} = k_p\,\mathbf{e} \;+\; k_d\,\dot{\boldsymbol{\theta}} \;+\; k_i \int \mathbf{e}\, dt, \qquad \mathbf{e} = \mathbf{F_d} - \mathbf{F}$$

- closed-loop tension regulation with damping injection at 1kHz.

Movable cable module

- Linear-guide ceiling slider with a pin-lock mechanism at 5cm intervals (Fig.1b).
- Adjusting module spacing boosts load capacity by up to 43% with the same actuators.
- Adjustable walking range and support mode(pelvic vs. overhead) adapted to patient's gait ability.

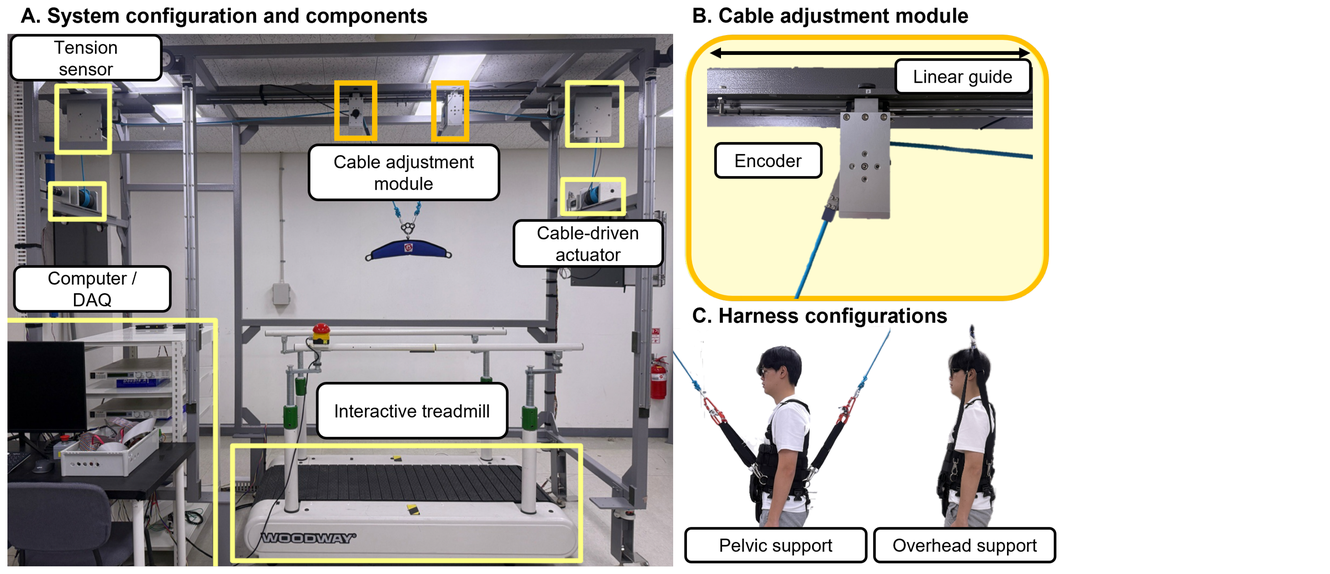


Fig. 1 – System overview

4. Training mode

PFGT (Performance-focused)

- Target : mild gait deficit (FAC 3–4)
- Pelvic-harness enables natural movement
- 1.2m Module spacing for wide walking range

SFGT (Stability-focused)

- Target : severe instability (FAC 1–2)
- Overhead harness for strong vertical support
- 0.45m spacing to stabilize CoG shift

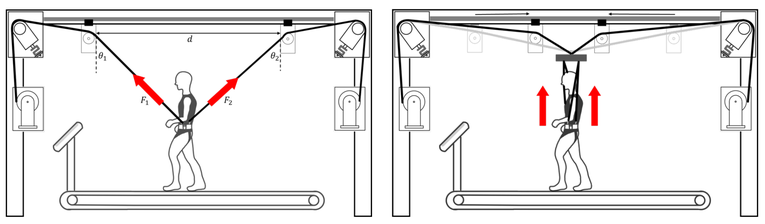


Fig. 2 – Training configurations: (a) PFGT, (b) SFGT

5.Evaluation test

Participants: 3 chronic stroke patients (FAC 4,4,1)

Conditions: PFGT & SFGT with 0–85% BWS

Protocol: self-paced treadmill, 1 min × 5 trials /condition

Measurements: Vicon 3D kinematics + derived spatiotemporal metrics

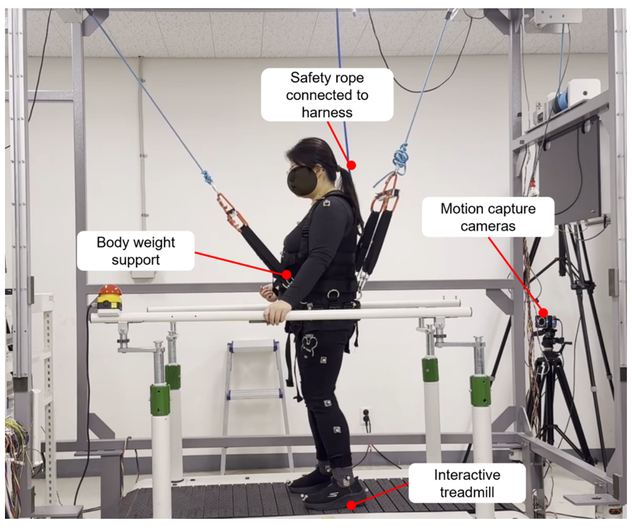


Fig. 3 – Experimental setup

6. Results

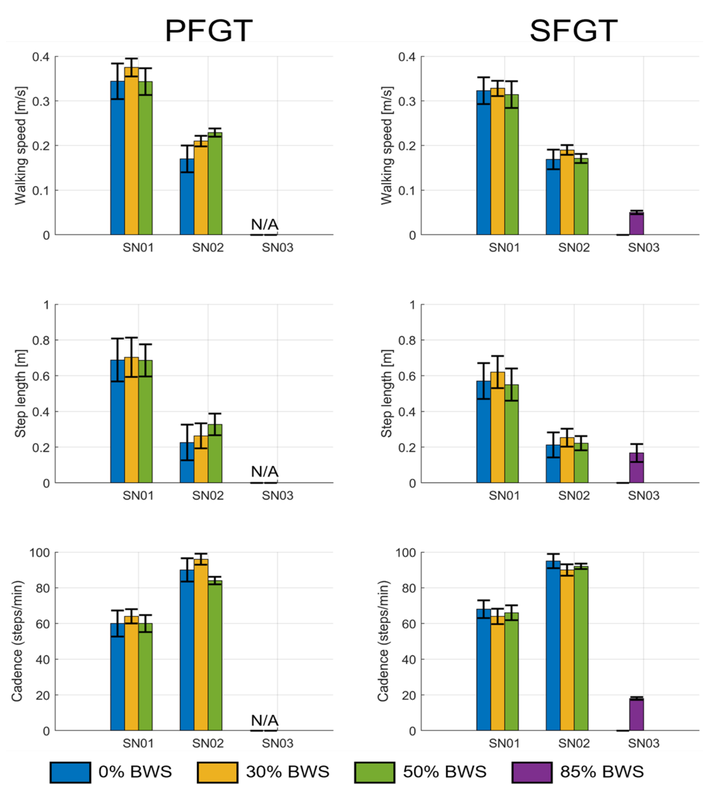


Fig. 4 – Spatiotemporal data

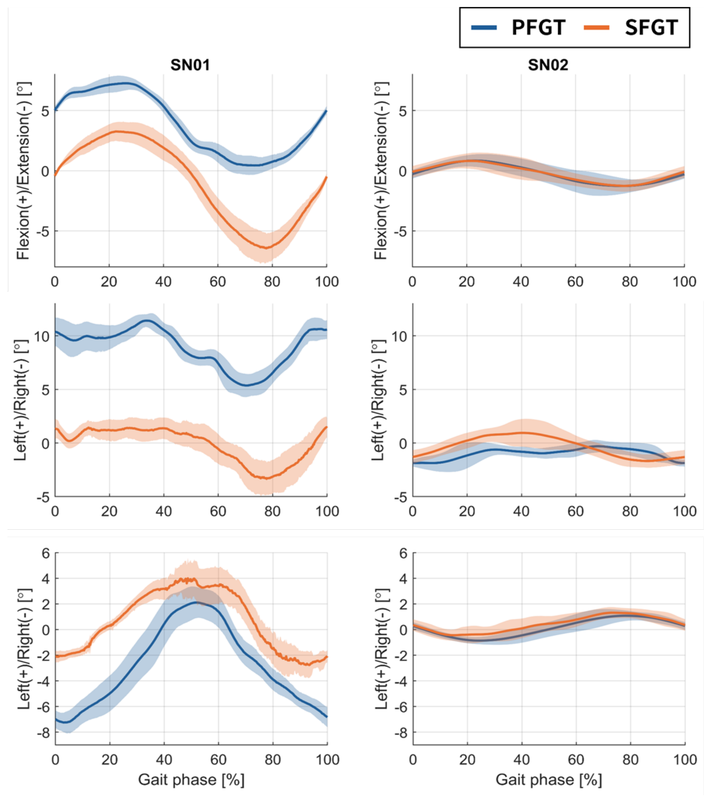


Fig. 5 – Trunk Kinematics

PFGT: 30%: speed ↑ 9–24%, SL ↑, cad ↑
50%: (SN02) speed +35%, SL +45%.

SFGT: 30%: speed ↑ 7%, cad ↓ 6%
85%: (SN03) first walk 0.05 m/s.

SN01: SFGT reduced sagittal/frontal tilt by 7.3°

SN02: change < 1.3° (across all planes)

7. Discussion

Clinical insight

- **FAC 1**: first independent steps with SFGT
- **FAC 3–4**: with PFGT, speed ↑ 24% & symmetry ↑
- ***Take-away***: one platform spans stability performance without hardware swap

Limitations & Future Works: Evidence derives from a single session, 3 participant pilot; forthcoming work will involve multi session trials with an expanded FAC 2–3 cohort.

8. Acknowledgements

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