Validity of the Garmin Venu3® and Apple® Watch Series 9 to accurately record step (push) counts during wheelchair propulsion of varying cadences

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Counting More Than Steps: The Smartwatch for Pushes

Technologies

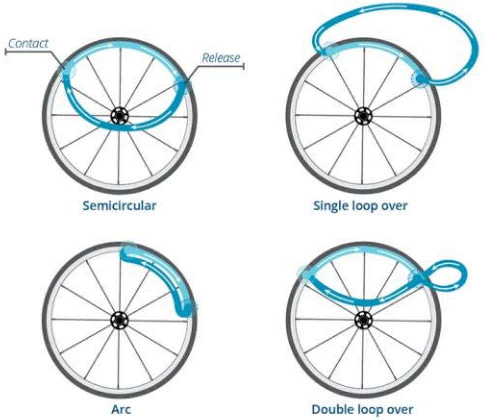
Devices & tools (e.g., wearables, motion sensors, smart wheels, ergometers used to quantify movement, activity levels, and patterns).

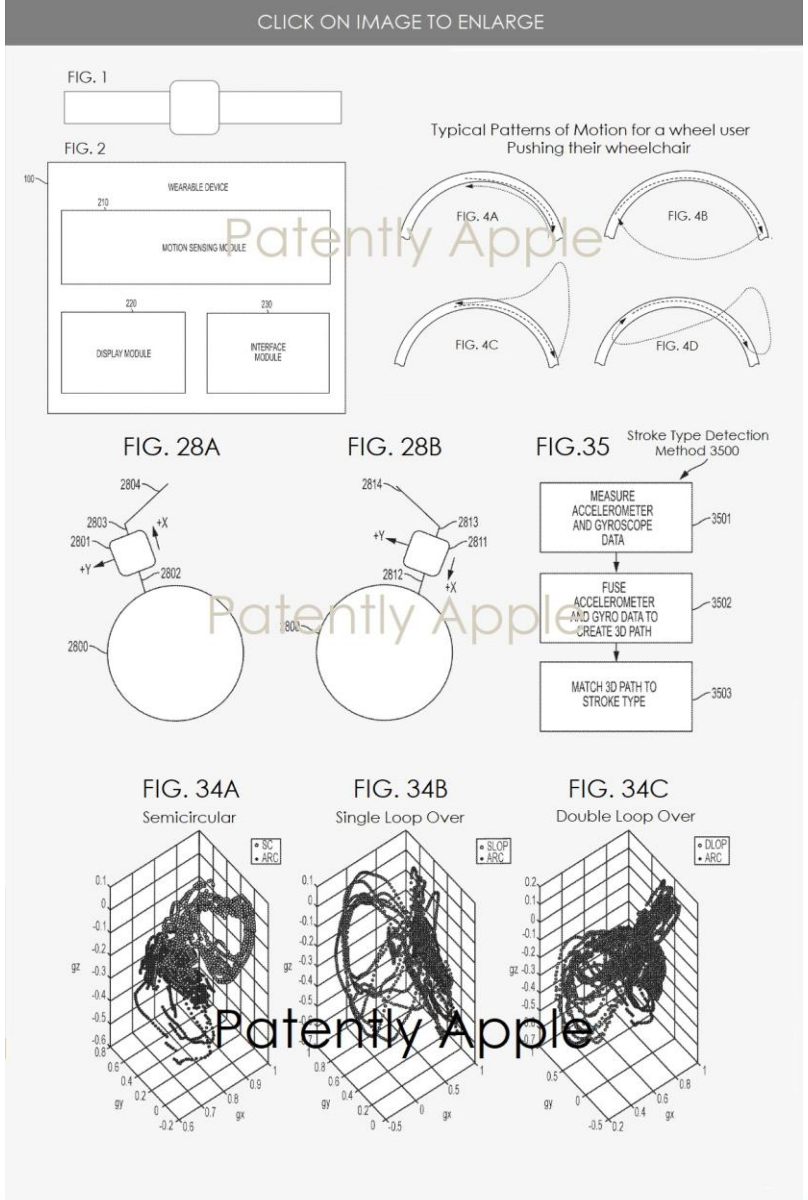
Examples:

- Smartwheel (monitors push frequency, force)
- GPS-enabled mobility tracking

Use in research:

- Objective activity tracking
- Monitoring real-world mobility
- Assessing intervention outcomes





https://www.patentlyapple.com/2020/05/apple-won-a-patent-today-for-measuring-activity-performed-by-a-wheelchair-user-wearing-an-apple-watch.html

Previous (selected) research:

- Glasheen et al. (2020) Apple watch various movement frequencies and tasks (treadmill vs. arm crank vs. obstacle).
- Lyng et al. (2024) Apple vs. Fitbit for energy expenditure (EE) and heart rate (HR) using a treadmill (various gradients).

Data interpretation challenges:

- Difficulty distinguishing types of movement (e.g., passive vs. active).
- Lack of context (e.g., quality vs. quantity of movement).

Newer devices and higher frequencies more favourable results!

- Wearable activity monitors like the Garmin Venu3® and Apple® Watch Series 9+ now include wheelchair-specific modes that track push counts, HR and calories (EE) of wheelchair users.

Purpose:

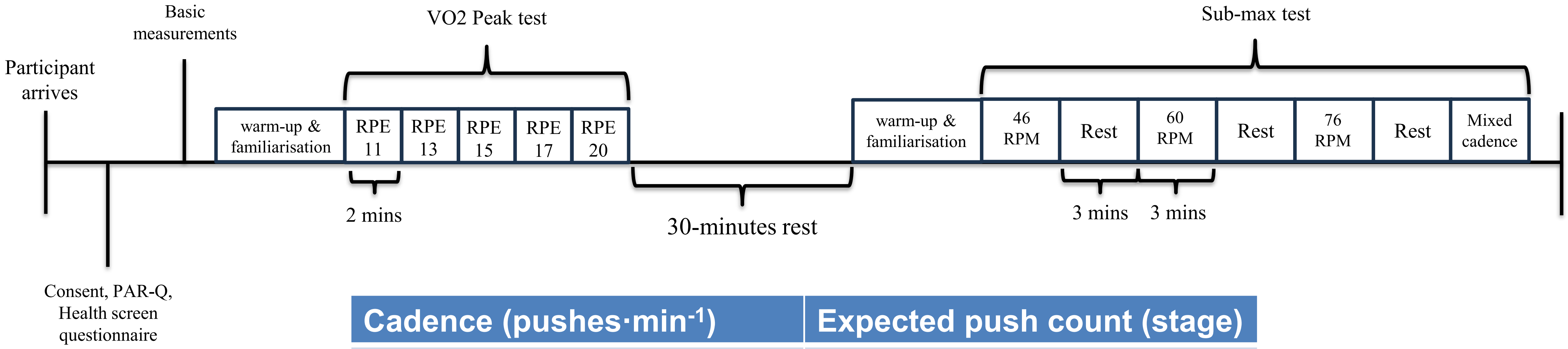
- This study evaluated the accuracy of push counts, HR and EE during manual wheelchair propulsion at varying cadences at a fixed resistance for the Garmin Venu3® and Apple® Watch Series 9.

Participants:

- 32 adults
  - 20 non-disabled (14 ♂ 6 ♀);
    24.4± 2.9 yrs; BM 79.7 ±11.8 kg, BMI 24.6 ± 3.0
  - 12 Manual wheelchair users (MWUs) (spina bifida, MS, SCI, ano) (6 ♂ 6 ♀); 32.5± 9.8 yrs; BM 74.7 ±18.3 kg, BMI 24.6 ± 4.9

Methods

Target Speed = 5 to 6 km·h^{-1}, dual roller system



3 mins random order

Cadence (pushes·min^{-1})	Expected push count (stage)
46	138
60	180
Mixed	182
76	228

Data Collection and Analysis

Aerobic capacity - To determine exercise intensity

Criterion outcomes:

- Ergometer stroke detection (push count)
- Polar H10 electrocardiography (HR)
- Indirect calorimetry (EE)

Validity was assessed:

- Mean absolute percentage error (MAPE)
- Intraclass correlation coefficients (ICCs)
- Bland–Altman bias and limits of agreement (LOAs)

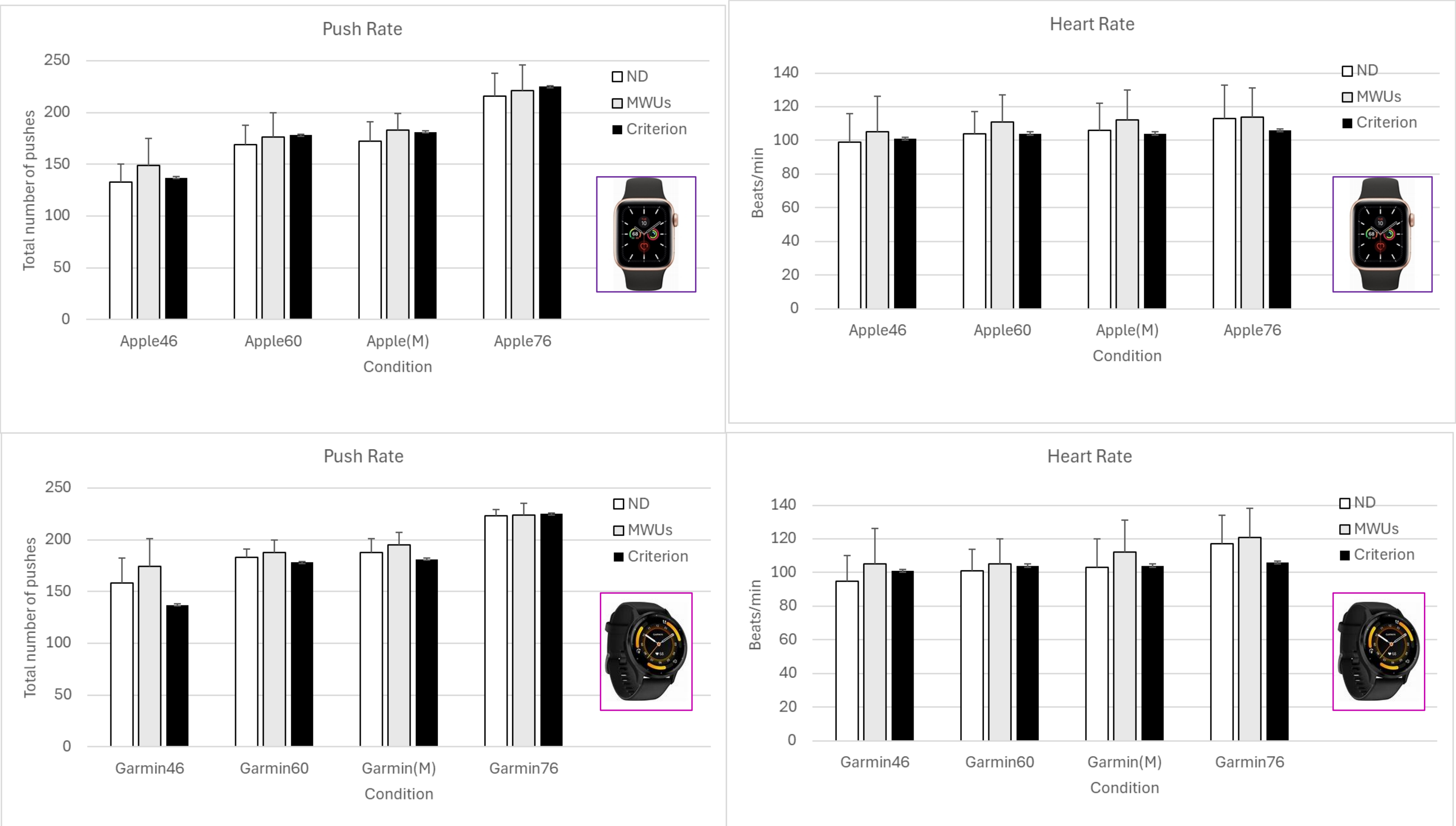
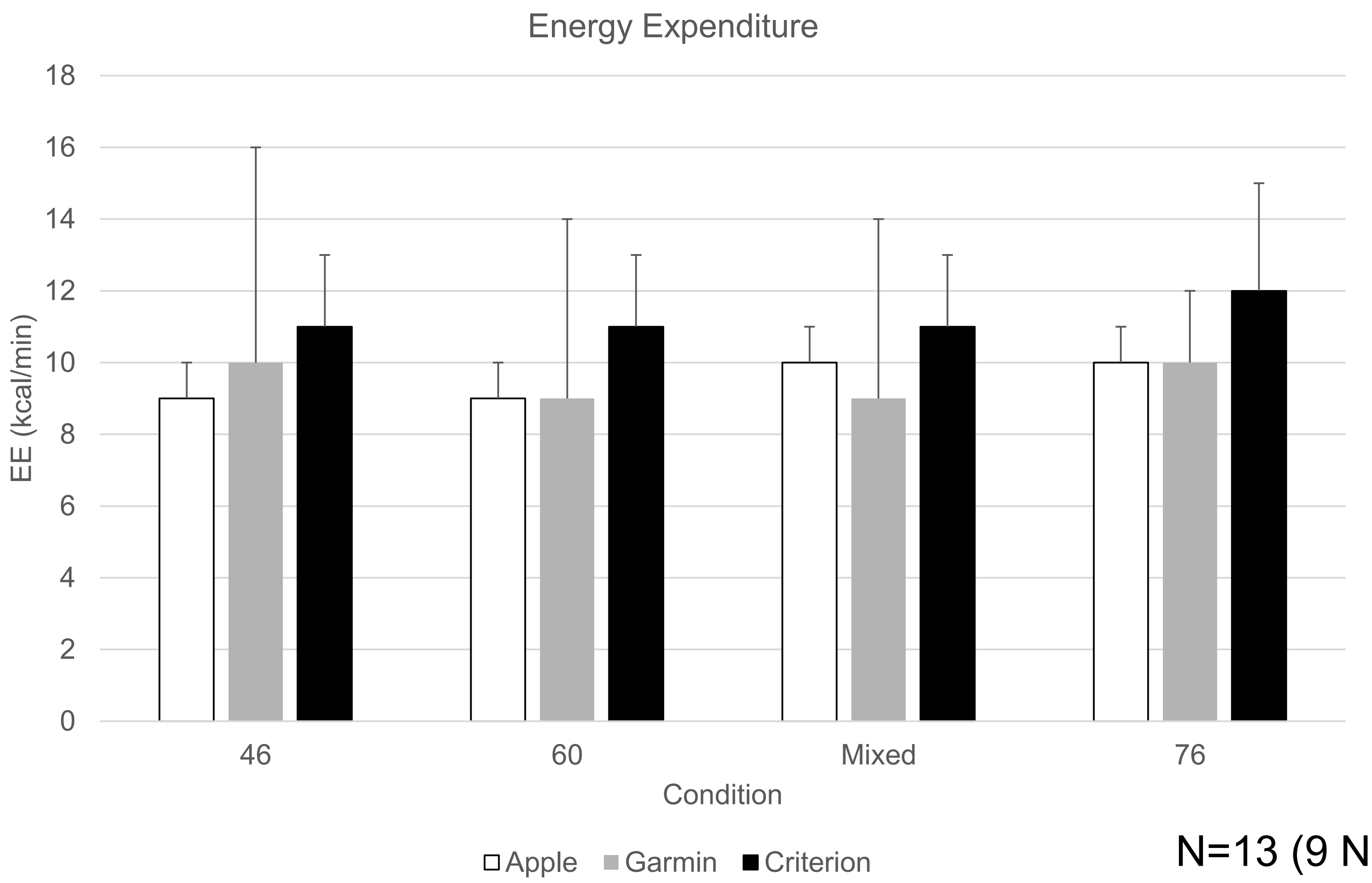
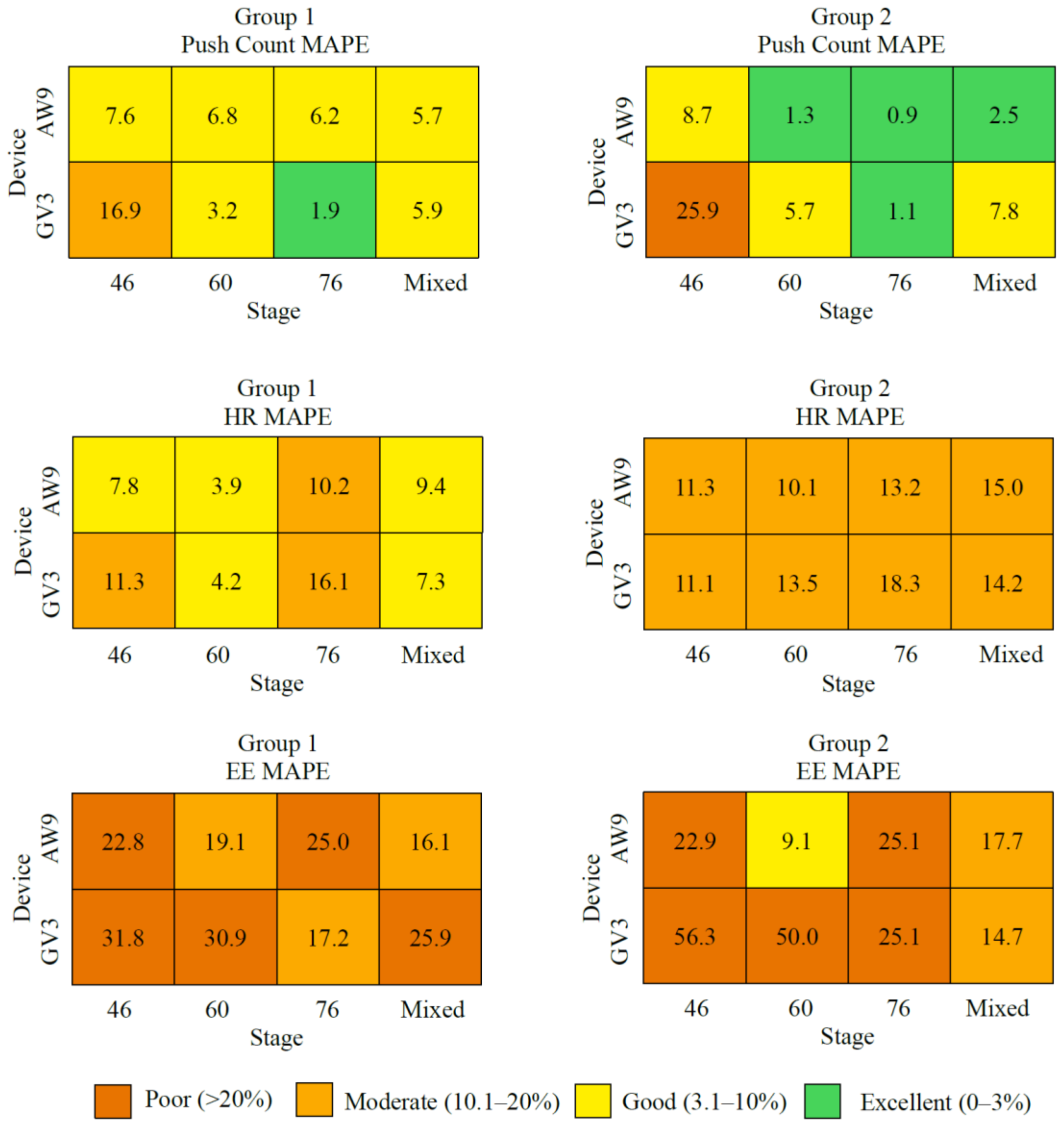


Figure 1: Comparison of push rate and HR with the criterion between the two devices Apple and Garmin and across the groups (ND and MWUs).



N=13 (9 ND, 4 MWUs)

Figure 2: Comparison of EE with the criterion between the two devices Apple and Garmin and across a mixed group.



Heat maps of MAPE for push rate (count), HR, and EE measured by the AW9 and GV3 compared with criterion devices across different stages (46, 60, 76 pushes·min^{-1}, and mixed cadence).

Stage-level MAPEs are presented separately for Group 1 (ND) and Group 2 (MWUs).

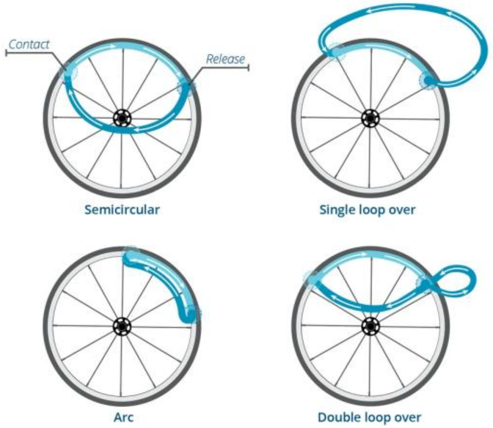
MAPEs were classified as poor (>20%; dark orange), moderate (10.1%–20%; light orange), good (3.1%–10%; yellow), and excellent (0%–3%; green).

"jerk" is a technical biomechanical term that refers to the rate of change of acceleration (i.e., how quickly acceleration changes over time).

When applied to wheelchair propulsion, "wheelchair jerk" describes how abruptly or smoothly force is applied during a push.

It's often used to evaluate the skill level, efficiency, or technique of wheelchair users.

Experienced wheelchair users typically show lower jerk values, indicating smoother, more controlled pushes.



Key Points

Push Count:

Both devices clinically acceptable (<10% MAPE), Apple 9 smaller errors. Apple have been found acceptable for activity monitoring (Byrne et al., 2023; Glasheen et al., 2020).

Lower frequencies greater errors (push generated acceleration signals; ‘jerk’). This has limitations for slower speeds or higher-level SCI.

Heart Rate:

Cyclical upper-limb propulsion can distort the optical light path (Lee et al., 2022).

Energy Expenditure:

Least valid of the outcomes.

To date, no commercially available device with acceptable accuracy for manual wheelchair propulsion (<10% error) (Choe & Kang, 2025).

Misalignment between commercial EE algorithm and unique demands of manual wheelchair propulsion.

Relevance of outcomes in clinical setting:

- **Accurate push tracking:** Apple Watch 9 gives reliable push-count data for monitoring wheelchair activity.

- **Useful heart rate info:** HR tracking is fairly accurate for general effort but less reliable during fast movement.

- **Energy data unreliable:** Both watches underestimate calories burned, so not suitable for precise energy tracking.

- **Clinical takeaway:** Findings support selective use of wearables for functional activity monitoring while emphasizing the need for tailored algorithms and device innovation to achieve accurate, clinically meaningful physiological data in wheelchair population.

Table: ICCs for each outcome and device, showing the lowest and highest ICC values by stage and group, along with the corresponding overall reliability interpretation.

Outcome	Device	Lowest ICC (Stage, Group)	Highest ICC (Stage, Group)	Overall Interpretation
Push Count	AW9	−0.012 (76, G1)	0.959 (76, G2)	Poor – Excellent
	GV3	0.002 (46, G1)	0.914 (76, G2)	Poor – Excellent
Heart Rate	AW9	0.594 (Mix, G2)	0.896 (60, G1)	Moderate – Excellent
	GV3	0.206 (76, G2)	0.877 (60, G1)	Poor – Excellent
Energy Expenditure	AW9	−0.360 (76, G2)	0.654 (Mixed, G2)	Poor – Moderate
	GV3	−0.227 (60, G2)	0.825 (76, G2)	Poor – Excellent*

(*Caution: wide confidence intervals.)