

Smart Insoles Enable Objective Balance Assessment in Multiple Sclerosis: Validation Against Force Platforms

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Introduction

- Balance impairments are common in people with MS (PwMS) and increase fall risk [1].
- Clinical scales (e.g., Berg Balance Scale, EDSS) are time-consuming and may miss subtle or longitudinal changes [2].
- Force platform (FP) centre of pressure (COP) analysis is quick (~30 s) and sensitive, but expensive, complex and not portable [3].
- Smart insoles are a portable and low-cost alternative, but require validation against FP for balance assessment in PwMS.

Objectives

- Validate a comprehensive set of COP-derived balance features from smart insoles against FPs in healthy individuals and PwMS.

Methods

- **Participants**
 - 19 PwMS (13 F/6 M, 54 ± 16 y) and 20 young healthy adults (9 F/11 M, 29 ± 4 y).
- **Protocol**
 - 30 s quiet standing, eyes open and eyes closed, feet ~10 cm apart (insole centre to centre).
 - Simultaneous recording: FP (Bertec, USA; 1000 Hz) and smart insoles (Moticon, Germany; 50 Hz).
- **Analysis**
 - Data streamed to a balance measurement platform (Celestra Health Systems, Canada); 65 COP features computed across four domains: positional, dynamic, frequency and nonlinear.
 - Insole-FP agreement: ICC(2,1) (two-way random effects, absolute agreement, single measurement), healthy and MS pooled.
 - Group-difference concordance: do insoles and FP detect the same healthy vs MS differences? (t-test or Mann-Whitney U, $p < 0.05$).

References

- [1] Cimino V, et al. (2018). Mult Scler Relat Disord. 26:46–51., [2] Downs S, et al. (2013). J Physiother. 59(2):93–9., [3] Quijoux F, et al. (2021). Physiol Rep. 9(22):e15067. [4] Prosperini L, et al. (2013). Neurorehabil Neural Repair. 27(1):45–52.

Results

- Positional features showed good-to-moderate agreement (16/17 features ICC ≥ 0.5) and near-complete t-test concordance (16–17/17) under both conditions (Table 1; Figure 1 example).

Table 1. Agreement between insole- and force plate-derived balance features by domain: number of features with good or moderate reliability, and number with the same Healthy vs MS t-test result.

Domain	n	Good ICC (0.75–0.9)		Moderate ICC (0.5–0.75)		T-test concordance	
		Eyes Open	Eyes Closed	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed
Positional	17	9	10	7	6	16	17
Frequency	20	4	2	2	4	8	7
Dynamic	20	0	0	1	1	5	7
Nonlinear	8	0	0	0	0	3	2

Discussion

- Positional features (COP dispersion and support location) from smart insoles showed absolute agreement with FP and detected the same healthy vs MS differences.
- Positional measures are among the most clinically used COP outcomes and relate to fall risk in MS [4]; dynamic, frequency and nonlinear features likely require higher sampling rates
- Next steps: longitudinal and at-home monitoring in larger MS cohorts, and testing whether insole measures track disability (e.g., EDSS).

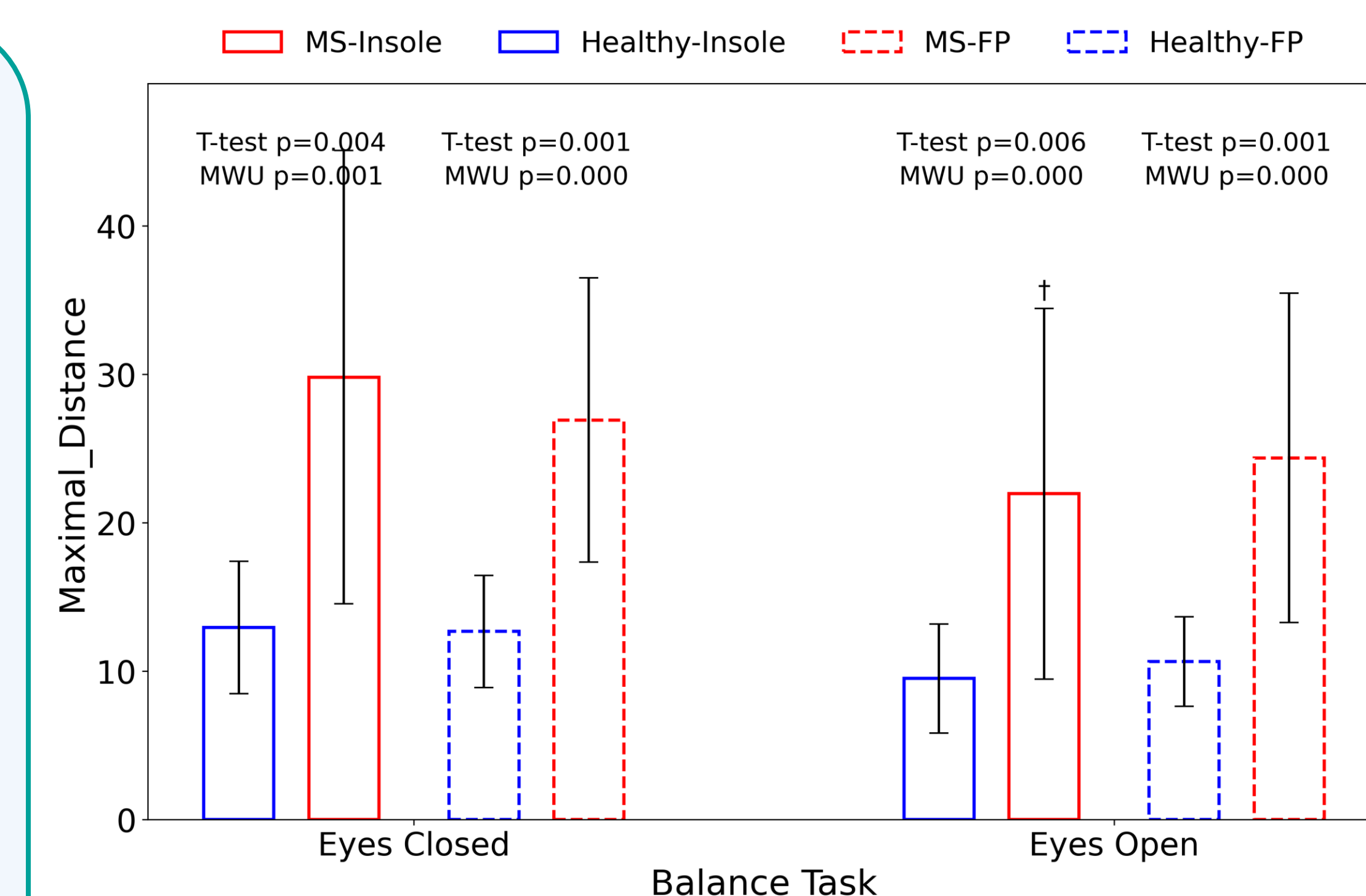


Figure 1. Example of one of 65 features: maximal COP distance from smart insoles (solid) and force plate (dashed) in healthy (blue) and PwMS (red), eyes open and closed (mean ± SD).

Disclosures

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