Reliability and Variability of Gait and Running Metrics on the Zebris FDM and HP Cosmos Systems

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Summary
This study evaluates the reliability and validity of maximal vertical force (Fmax), contact time (CT), and flight time (FT) during walking and running using the Zebris FDM and HP Cosmos systems. Significant differences in force and temporal metrics were observed between systems, with implications for clinical and performance applications.

Introduction
Accurate measurement of kinetic and temporal variables during locomotion is crucial for assessing biomechanics in clinical and sports performance settings. Instrumented treadmills, such as the HP Cosmos (HP Cosmos, Germany) and capacitance-based pressure platform such as the Zebris FDM (FDM-THG, Zebris Medical GmbH, Germany), provide valuable insights into Fmax, CT, and FT. However, their reliability and validity, particularly during dynamic activities, remain largely unexplored. This study aims to assess the reliability and variability of Fmax, CT, and FT recorded by the Zebris FDM and HP Cosmos systems during walking and running.

Methods
Eleven participants (age = 23.46 ± 3.08 years, height = 174.17 ± 12.44 cm, mass = 75.03 ± 10.59 kg, BMI = 24.75 ± 2.64) completed three treadmill conditions: walking (5 km/h), running (8 km/h) and (10 km/h), and a 30-minute treadmill run (10km/h). All trials were conducted on an instrumented treadmill (Cosmos) set to a 1% incline with a capacitance-based pressure platform (Zebris) while wearing standardized running shoes (Nike Revolution 7, United States). A test-retest protocol was implemented over two visits, with intra-day testing on the second visit. Data were collected for 30 seconds for each condition and at each time point: 0, 5, 10, 15, 20, 25, and 30 minutes during the 30-minute run.

Raw data from the Zebris system were exported in XML format, while HP Cosmos data were extracted through QTM (Qualisys, Gothenburg, Sweden) using the O'Connor algorithm [1]. Within- and between-day reliability of Fmax, CT, and FT were assessed using intraclass correlation coefficients (ICC), and coefficients of variation (CV) were calculated to determine measurement consistency.

Results and Discussion
Differences were observed between the Zebris and Cosmos systems across all conditions. In walking trials (5 km/h), the Zebris recorded an average Fmax of 771.66±112.22 N (Visit 1) and 768.13±106.33 N (Visit 2) for the left foot, while the Cosmos recorded significantly lower values of 656.32±97.73 N (Visit 1) and 659.51±85.50 N (Visit 2). At higher speeds (10 km/h), the discrepancy increased, with the Zebris recording 1243.73±154.89 N (Visit 1) and 1247.96±189.52 N (Visit 2), whereas the Cosmos reported much higher values of 1787.47±285.88 N and 1781.73±304.25 N, respectively.

CT values were consistently shorter on the Cosmos compared to the Zebris, with the disparity increasing with speed. At 10 km/h, the left foot CT was 0.284±0.03 s (Zebris) vs. 0.207±0.031 s (Cosmos), and the right foot showed a similar trend with 0.283±0.027 s (Zebris) vs. 0.208±0.016 s (Cosmos). FT values were also systematically lower in the Cosmos, with the left foot showing values of 0.091±0.028 s (Zebris) vs. 0.033±0.022 s (Cosmos) at 10 km/h, indicating a fundamental difference in system detection of foot-off events.

Reliability analysis demonstrated strong ICC values for Fmax and CT across speeds and visits. At 10 km/h, ICC (95% CI) for Fmax on the left foot was 0.94 (0.37-0.994) for Zebris and 0.992 (0.939-0.999) for Cosmos, confirming strong repeatability despite systematic measurement differences. CT values exhibited similarly high within-day reliability, with ICC values of 0.997 (0.989-1) for Zebris and 0.98 (0.934-0.998) for Cosmos. However, FT showed lower reliability, particularly on the Cosmos (ICC = 0.796 (-0.29-0.978) at 10 km/h), suggesting a greater degree of measurement variability.

Repeated trials at 10 km/h revealed a gradual decrease in Fmax values on the Zebris, indicating potential measurement drift over time. The left foot Fmax decreased from 1342.70±130.70 N in the first run to 1187.90±192.46 N in the last run, whereas the Cosmos system remained more stable, fluctuating between 1783.84±159.51 N and 1729.65±216.55 N. This discrepancy suggests potential algorithmic differences or pressure sensor cell degradation in extended use cases.

Conclusions
Both the Zebris and Cosmos systems provide reliable measures of Fmax, CT, and FT, though significant systematic differences exist. The Cosmos, which includes a force plate considered the gold standard, recorded higher Fmax and shorter CT and FT values compared to Zebris. These differences should be considered when selecting a system for biomechanical assessments. Despite its lower absolute accuracy, the Zebris remains a valuable tool for intra-subject comparisons in clinical settings. Future research should explore correction factors for inter-system compatibility.

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References
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