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Posted Date: 25 December 2025

doi: 10.20944/preprints202512.2244.v1

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Abstract

Laboratory-based gait analysis using motion capture and force plates remains the gold standard for quantifying ground reaction forces (GRFs) and temporal gait parameters. However, its high cost and limited accessibility restrict routine clinical use. Wearable smart insoles offer a portable alternative, yet require rigorous validation before clinical adoption. This study evaluates the clinical and technical validity of the SuraSole® smart insole, a low-cost pressure sensor–embedded insole, by comparing its GRF and temporal gait measurements with those obtained from a laboratory force plate and 3D motion capture system. Twenty healthy adults completed five walking trials while wearing standardized footwear equipped with SuraSole insoles, with simultaneous force plate and motion capture data collection. Agreement between systems was assessed using Bland–Altman plots and intraclass correlation coefficients (ICCs). SuraSole demonstrated excellent agreement with force plates for GRF across weight acceptance, mid-stance, and push-off (ICCs 0.97–0.99), with mean differences of 15.93 ± 45.90 N, 2.38 ± 23.98 N, and 8.64 ± 40.45 N, respectively. Temporal parameters showed moderate to good reliability (ICCs 0.62–0.81), with limitations likely related to the insole's 20 Hz sampling rate. These findings indicate that SuraSole provides reliable GRF measurement and acceptable portable gait assessment, supporting its potential for use in clinical practice, rehabilitation, and community health monitoring. Future hardware improvements, particularly higher sampling frequency, may enhance temporal accuracy.

Keywords: smart insole; portable gait assessment ; wearable sensor; gait analysis; plantar pressure; rehabilitation technology

1. Introduction

Gait analysis is essential for evaluating human locomotion and identifying abnormalities associated with musculoskeletal, neurological, and age-related conditions. Traditional gait laboratories rely on three-dimensional motion capture systems and force plates to quantify ground reaction forces (GRFs) and temporal gait parameters with high precision. Although considered the clinical gold standard, these systems require specialized facilities, skilled personnel, and significant financial investment, limiting their availability in routine clinical practice and particularly in community or resource-limited

doi:10.20944/preprints202512.2244.v1

settings. As a result, many patients who could benefit from objective gait assessment—such as older adults, individuals recovering from lower-limb injuries, or those undergoing rehabilitation—lack access to quantitative evaluation tools.

Wearable sensor–based systems have emerged as promising alternatives to address these accessibility barriers. Advances in sensor miniaturization, wireless communication, and mobile computing have enabled the development of smart insoles capable of capturing plantar pressure and gait metrics during natural walking. Several commercial systems, such as OpenGo and Insole3, have demonstrated acceptable accuracy in measuring temporal parameters and estimating GRFs; however, many remain expensive, use proprietary hardware, and have limited availability in Southeast Asia. Furthermore, most validation studies have been performed in research laboratories in high-income countries, leaving a gap in evidence regarding the performance of wearable gait systems in diverse clinical environments and populations.

SuraSole® is a locally developed smart insole system that integrates eight pressure sensors, wireless data transmission, and a mobile application designed for real-time visualization and remote data storage. Unlike many imported alternatives, SuraSole is engineered to be affordable, portable, and suitable for deployment in outpatient clinics, rehabilitation centers, and community health programs. Its potential applications include fall-risk assessment, post-operative monitoring, gait retraining, and remote rehabilitation—areas in which objective gait analysis tools are particularly lacking. Despite its increasing use in community health projects in Thailand, no previous study has quantitatively validated its GRF and temporal parameter measurements against gold-standard laboratory systems.

This study addresses this gap by performing a comprehensive clinical and technical validation of the SuraSole insole compared with laboratory-grade force plates and 3D motion capture. By evaluating agreement in GRF across key gait phases—weight acceptance, mid-stance, and push-off—along with temporal gait parameters such as velocity, cadence, stance time, and swing time, this study provides essential evidence for the device's accuracy, reliability, and suitability for clinical decision-making. Establishing the validity of a low-cost, accessible gait analysis tool has the potential to greatly expand the availability of quantitative gait assessment, especially in regions where laboratory systems are not feasible.

2. Literature Review

Wearable sensor technologies have gained increasing attention as practical alternatives to laboratory-based gait analysis. Traditional systems employing 3D motion capture and force plates remain the gold standard for quantifying ground reaction forces (GRFs), spatiotemporal gait metrics, and lower-limb kinematics. However, their high cost, reliance on controlled laboratory environments, and requirements for specialized personnel limit widespread use, particularly in routine clinical practice and community-based rehabilitation settings. These limitations have motivated the development of portable gait analysis tools capable of delivering clinically meaningful data outside the laboratory.

Early innovations in wearable gait analysis focused on shoe-integrated pressure sensors and inertial measurement units (IMUs). Bamberg et al. demonstrated one of the earliest shoe-integrated wireless sensor systems capable of capturing gait events and estimating GRFs through force-sensitive components. Subsequent advances in sensor miniaturization and wireless communication enabled more refined smart insole platforms, which combine pressure sensing with mobile application interfaces for real-time visualization and remote monitoring.

Several smart insole systems have since been validated against laboratory-grade equipment. The OpenGo insole incorporates 13 pressure sensors and has demonstrated good agreement with force plates and instrumented treadmills for GRF and temporal parameters, although its center-of-pressure (COP) trajectory shows reduced precision. Its high sensor density allows detailed pressure mapping but increases system complexity and cost. The eSHOEs instrumented insole, containing four pressure sensors, has shown strong agreement with the GAITRite walkway for temporal gait parameters, achieving differences typically <0.05 s. Other systems, such as Insole3, Moticon, and IMU-based gait detectors, have reported acceptable validity for clinical monitoring, fall-risk assessment, and sports performance assessment.

Wearable IMU-based systems offer additional advantages in measuring kinematic parameters such as acceleration, angular velocity, and gait symmetry indices. These devices have shown promise in fall-risk detection and remote gait monitoring for older adults. However, IMUs alone cannot directly measure GRFs or plantar pressure distribution, limiting their ability to capture kinetic information essential for many clinical assessments.

Despite considerable progress, several gaps remain in the current literature. Many validated systems are costly, proprietary, or require imported hardware, reducing accessibility in resource-limited health care settings. In addition, relatively few validation studies have been conducted in Southeast Asian clinical environments, where gait patterns, footwear habits, and infrastructure constraints may differ from those in Western laboratories. There is also limited evidence regarding the validity of low-cost, sensor-embedded insoles for measuring phase-specific GRF peaks—parameters that are clinically relevant for detecting gait abnormalities, monitoring rehabilitation progress, and evaluating fall risk.

The SuraSole® smart insole system was developed to address these accessibility and cost barriers. Incorporating eight strategically placed pressure sensors, wireless data transmission, and a cloud-linked mobile application, SuraSole is designed to be deployed in outpatient clinics, rehabilitation departments, and community health programs without requiring laboratory infrastructure. Although SuraSole has been increasingly used in community screening projects in Thailand, formal validation of its GRF and temporal measurements is necessary before widespread clinical adoption.

This study builds upon previous research by quantitatively validating SuraSole against gold-standard force plates and 3D motion capture, focusing on both kinetic (GRF) and temporal gait parameters. By situating SuraSole among existing wearable systems and evaluating its clinical performance, this work contributes to the growing literature on accessible gait technologies and supports the integration of low-cost, locally developed devices into routine clinical assessment.

A comparison of commonly used smart insole and wearable gait analysis systems, including sensor configuration, sampling rate, and key measured parameters, is summarized in Table 1.

Table 1. Comparison of commonly used smart insole and wearable gait analysis systems, including the SuraSole insole. Reference numbers correspond to cited studies.

Device	**Sensor configuration**	**Sampling rate**	**Measured parameters**
OpenGo (Moticon) [12]	13 pressure sensors	50–100 Hz	GRF estimation, temporal parameters, COP
Insole3 [13]	Multiple pressure sensors	∼100 Hz	GRF estimation, temporal parameters
eSHOEs [4]	4 pressure sensors	50 Hz	Temporal gait parameters
IMU-based systems [11,18]	Accelerometers, gyroscopes	>100 Hz	Kinematics, spatiotemporal parameters
SuraSole (this study)	8 pressure sensors	20 Hz	Phase-specific GRF, temporal parameters

3. Materials and Methods

3.1. Study Design

A cross-sectional validation study was conducted at the Excellence Center for Gait and Motion, King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok, Thailand. Ethical approval was granted by the Research Ethics Committee of the Faculty of Medicine, Chulalongkorn University

(IRB No. 0713/65). Written informed consent was obtained from all participants prior to their inclusion in the study.

3.2. *Participants*

Inclusion Criteria

- Healthy individuals aged over 18 years
- No history of lower limb injuries in the past 3 months
- Shoe size between 36 and 43 (European size)
- Ability to walk independently

Exclusion Criteria

- Patients with neuromuscular disorders
- Individuals with orthopedic conditions (e.g., lower limb fractures, spinal/knee injuries, osteoarthritis, ankle sprains)
- Individuals using gait aids, orthotic devices, or prostheses
- Individuals with chronic conditions (e.g., uncontrolled hypertension, diabetes, stroke history)

A total of 20 healthy participants meeting the criteria were enrolled.

3.3. *Instruments*

3.3.1. SuraSole® Smart Insole System

SuraSole is a lightweight, sensor-embedded insole designed for portable gait assessment. Each insole integrates eight force-sensitive resistor (FSR) pressure sensors located at key plantar regions: heel, midfoot, lateral forefoot, medial forefoot, and toe-off area. The system samples pressure data at 20 Hz, which are transmitted via Bluetooth Low Energy (BLE) to the SuraSole Med mobile application.

Calibration and preprocessing:

- Participants' height and weight were entered into the system before testing.
- Raw sensor voltages were converted to estimated force values using device-specific calibration curves.
- Data are normalized to body weight and time-synchronized with force plate recordings using event-based alignment (initial contact detection).
- Sensor data were filtered and preprocessed within the mobile application to minimize noise and enhance signal quality.

The application provides real-time visualization of weight distribution and stores processed data on a secure cloud server. Figures 1 and 2 illustrate the device in practical use, the mobile display interface, and the system's data transmission workflow.

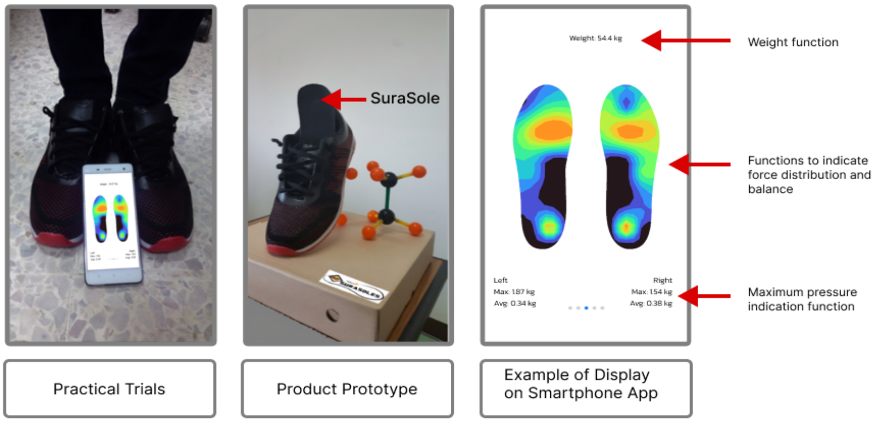


Figure 1. SuraSole insole system: trial setup, product prototype, and app-based plantar pressure display.

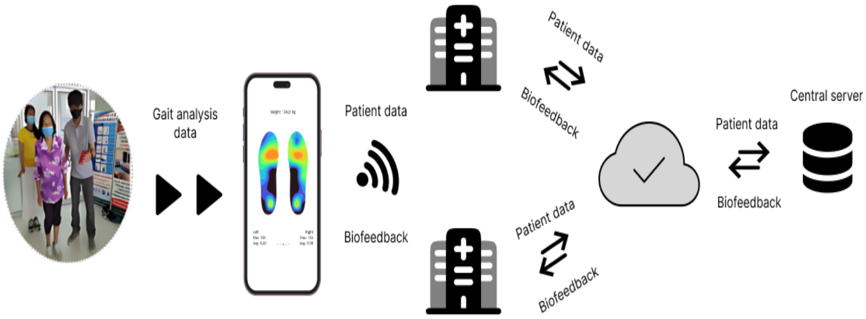


Figure 2. System overview: data flow, cloud storage, and clinical feedback integration.

3.3.2. Laboratory-Based Gait Analysis System

The reference system included:

- Force plates: Bertec FP4060-07-1000, sampling at 1000 Hz, used as the gold standard for GRF measurement.
- Motion capture: OptiTrack® Prime 17W cameras, sampling at 100 Hz, used to determine temporal gait parameters (velocity, cadence, stance time, swing time, and cycle time).

Reflective markers were placed on anatomical landmarks of the foot, including the heel, first and fifth metatarsophalangeal joints, and hallux.

3.4. Experimental Protocol

Participants were fitted with standardized athletic shoes containing SuraSole insoles and reflective markers. The gait assessment protocol consisted of:

- **Preparation:** Standardized shoes were worn to minimize footwear variability. The SuraSole calibration procedure was completed before testing.

- **Walking Trials:** Each participant walked at a self-selected, comfortable pace along a walkway embedded with four force plates. Trials were monitored to ensure clean single-foot contact with force plates; however, participants were encouraged to walk as naturally as possible. A total of five walking trials were recorded per participant.
- **Data Collection:** GRF (ground reaction force) data were collected simultaneously from the SuraSole insole and laboratory-grade force plates. Temporal gait parameters were collected from both the SuraSole app and the motion capture system. Event alignment was performed based on heel-strike timing. The schematic of the experimental setup is illustrated in the Figure 3.

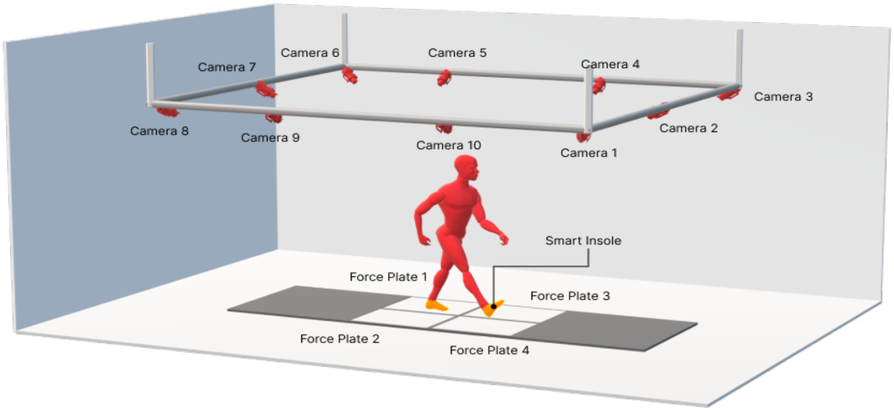


Figure 3. System Experimental setup for synchronized gait data collection, showing motion capture cameras, force plates, and smart insole integration.

3.5. Outcome Measures

- Demographic data: Age, sex, height, weight, and BMI were recorded.
- Ground Reaction Force (GRF) data: Peak GRF values were extracted for three gait phases—weight acceptance, mid-stance, and push-off. Although GRF signals were normalized to body weight during preprocessing, values are reported in Newtons to allow direct comparison with laboratory force plate measurements.
- Temporal Gait Parameters: The following parameters were measured: Walking velocity (m/s), cadence (steps/min), cycle time (s), stance time (s), and swing time (s).

3.6. Statistical Analysis

All analyses were performed using SPSS version 22.0.

- Descriptive Statistics: Means ± standard deviations (SD) for continuous variables; frequencies and percentages for categorical variables.
- Agreement Analysis: Bland–Altman plots were used to evaluate agreement between SuraSole and the laboratory systems for both GRF and temporal parameters [14]. Mean differences and 95% limits of agreement (LoA) were calculated.
- Reliability Analysis: Reliability and agreement between measurement systems were assessed using intraclass correlation coefficients (ICCs), interpreted according to [15]. A 95% confidence interval was applied. Interpretation followed the guidelines of Koo and Li, where ICC values < 0.50 indicate poor reliability, 0.50–0.75 indicate moderate reliability, 0.75–0.90 indicate good reliability, and > 0.90 indicate excellent reliability.

doi:10.20944/preprints202512.2244.v1

4. Results

4.1. Participant Demographics

Twenty healthy adults participated in the study, including 9 females (45%) and 11 males (55%). The mean age was 33.55 ± 12.9 years, mean body weight was 67.4 ± 11.9 kg, and mean height was 164 ± 7.3 cm. The average BMI was 25.1 ± 4.5 kg/m². A detailed summary of participant characteristics is presented in Table 2.

Table 2. Participants Demographic (n = 20).

Characteristic	Study population (n = 20)
Sex	
Female	9 (45%)
Male	11 (55%)
Age (years)	33.55 ± 12.9
Body Weight (kg)	67.4 ± 11.9
Height (cm)	164 ± 7.3
BMI (kg/m^2)	25.1 ± 4.5

4.2. Ground Reaction Force (GRF) Analysis

Agreement between the SuraSole insole and the laboratory force plate was assessed for three phases of the stance cycle: maximum weight acceptance, mid-stance, and push-off. Intraclass correlation coefficients (ICCs) indicated excellent reliability across all phases, with values ranging from 0.97 to 0.99 (Table 3).

Table 3. Intraclass correlation coefficient (ICCs) for GRF parameters.

Gait Phase	ICC	95% CI (Lower)	95% CI (Upper)
Maximum Weight Acceptance	0.97	0.94	0.98
Mid-stance	0.99	0.98	0.99
Push-off	0.98	0.97	0.99

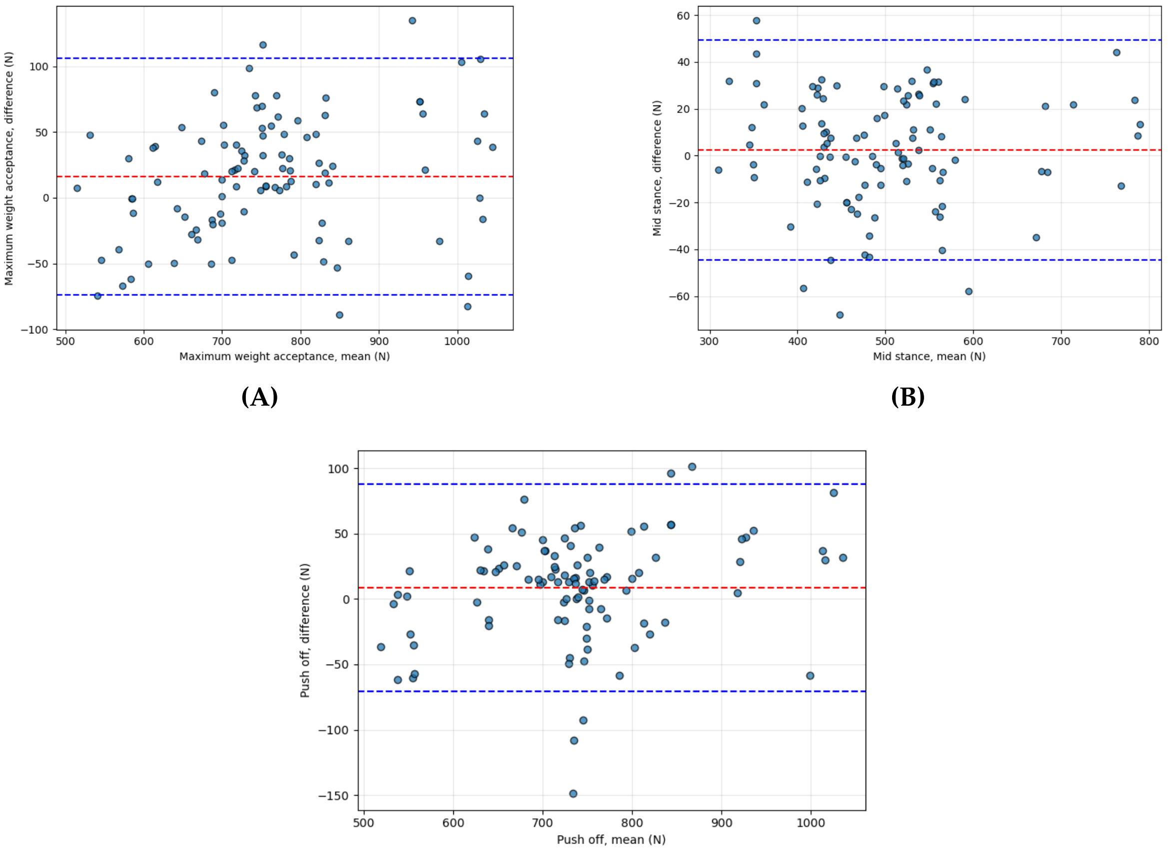
Bland-Altman analysis demonstrated small mean differences between systems:15.93 N (maximum weight acceptance), 2.38 N (mid-stance), 8.64 N (push-off). The corresponding 95% limits of agreement were narrow and consistent with high measurement agreement (Table 4). Bland–Altman plots (Figure 4) illustrate the distribution of differences and confirm systematic consistency between the two methods.

Table 4. Comparison of GRF values between SuraSole and laboratory system.

Gait Phase	Lab Mean (SD)	SuraSole Mean (SD)	Mean Diff (SD)	95% LoA (LL, UL)
Maximum Weight Acceptance (N)	768.52 (135.09)	752.59 (124.00)	15.93 (45.90)	−74.04, 105.90
Mid-stance (N)	500.28 (103.30)	497.90 (102.93)	2.38 (23.98)	−44.61, 49.37
Push-off (N)	743.75 (116.10)	735.11 (105.45)	8.64 (40.45)	−71.64, 87.92

Note: LoA = limit of agreement; LL = lower limit of agreement; UL = upper limit of agreement.

GRF curves for selected participants showed similar waveform patterns between SuraSole and the force plate across the gait cycle, further supporting agreement in kinetic measurements (Figure 5a,b).

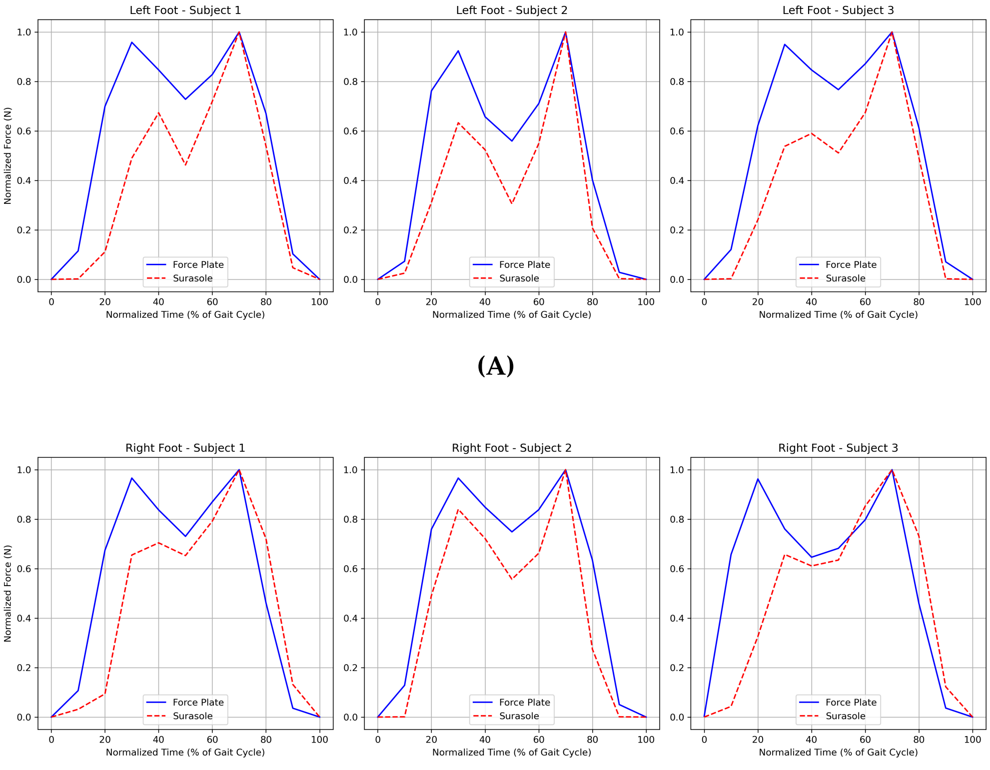


(A)

(B)

(C)

Figure 4. Bland–Altman plots for GRF agreement: (A) Maximum weight acceptance; (B) Mid-stance; (C) Push-off.



(A)

(B)

Figure 5. Normalized ground reaction force (GRF) curves for three subjects, comparing force plate and SuraSole measurements across the gait cycle. (A) Left foot; (B) Right foot.

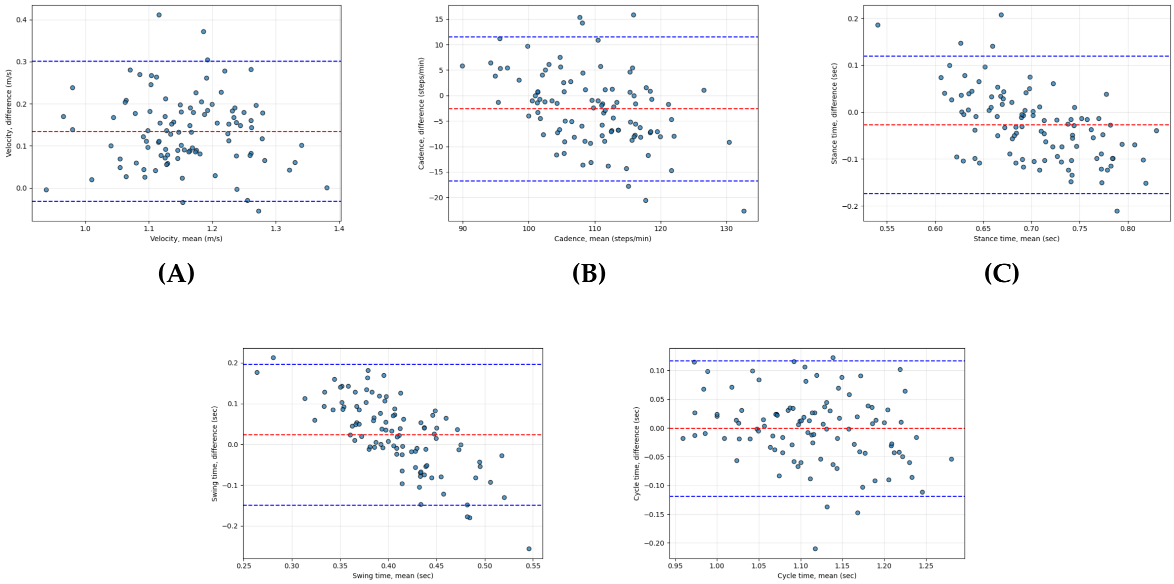
4.3. Temporal Gait Parameter Analysis

Temporal gait parameters, including velocity, cadence, stance time, swing time, and cycle time—were compared between SuraSole and the motion capture system. ICC values ranged from 0.62 to 0.81, indicating moderate to good reliability depending on the parameter (Table 5). The highest agreement was observed for cycle time (ICC = 0.81), while stance time demonstrated the lowest reliability (ICC = 0.62).

Table 5. Intraclass correlation coefficient (ICCs) for temporal parameters.

Parameter	ICC	95% CI (Lower)	95% CI (Upper)
Velocity	0.62	0.35	0.82
Cadence	0.78	0.58	0.90
Stance time	0.73	0.45	0.88
Swing time	0.67	0.38	0.84
Cycle time	0.81	0.63	0.92

Mean differences from the Bland–Altman analysis were 0.13 m/s for velocity, –2.64 steps/min for cadence, –0.03 s for stance time, 0.02 s for swing time, and –0.001 s for cycle time; full comparison data, and limits of agreement (LoA) are presented in Table 6 and illustrated in Figure 6.



(A) **(B)** **(C)**

(D) **(E)**

Figure 6. Bland–Altman plots for temporal parameters: (A) Velocity; (B) Cadence; (C) Stance time; (D) Swing time; (E) Cycle time.

Table 6. Comparison of temporal parameters between SuraSole and laboratory system.

Parameter	Lab Mean (SD)	SuraSole Mean (SD)	Mean Diff (SD)	95% LoA (LL, UL)
Velocity (m/s)	1.23 (0.09)	1.09 (0.10)	0.13 (0.09)	−0.03, 0.30
Cadence (steps/min)	108.43 (7.16)	111.07 (10.05)	-2.64 (7.22)	−16.79, 11.51
Stance time (s)	0.69 (0.05)	0.72 (0.08)	-0.03 (0.08)	−0.17, 0.12
Swing time (s)	0.42 (0.03)	0.40 (0.09)	0.02 (0.09)	−0.15, 0.20
Cycle time (s)	1.11 (0.07)	1.11 (0.09)	-0.001 (0.06)	−0.12, 0.12

LoA = limit of agreement; LL = lower limit of agreement; UL = upper limit of agreement.

Although the SuraSole system produced consistent temporal trends, the magnitude of differences suggests that temporal precision is limited by the device's 20 Hz sampling frequency compared with the 100 Hz motion capture system.

4.4. Summary of Key Findings

- SuraSole demonstrated excellent agreement with the laboratory force plate for GRF measurements across all three stance phases.
- Temporal gait parameters exhibited lower reliability, with performance varying by parameter and influenced primarily by sampling frequency.
- These findings support the use of SuraSole for clinical GRF assessment and general temporal analysis, but not for applications requiring high temporal precision (e.g., detailed gait event timing).

5. Discussion

This study evaluated the clinical and technical validity of the SuraSole® smart insole system by comparing its ground reaction force (GRF) and temporal gait parameter measurements with those obtained from laboratory-grade force plates and a 3D motion capture system. The findings demonstrate that SuraSole provides highly reliable GRF estimates across key phases of the gait cycle—maximum weight acceptance, mid-stance, and push-off—while offering moderate reliability for temporal gait parameters. These results support the feasibility of using a low-cost, portable, locally developed sensor-embedded insole for clinical gait assessment and community-based health monitoring.

5.1. Agreement in Ground Reaction Force Measurement

The GRF results showed excellent agreement between SuraSole and the laboratory force plate, with ICC values ranging from 0.97 to 0.99. The mean differences across gait phases were small, and Bland–Altman plots demonstrated narrow limits of agreement, indicating that SuraSole can reliably capture phase-specific GRF characteristics during walking. These findings align with previous smart insole validation studies, such as the Moticon OpenGo insole, which reported strong correlations with force plate measurements during walking and running activities [12]. Similarly, Cramer et al. validated the Insole3 system and reported robust GRF estimation during dynamic activities [13].

SuraSole uses eight strategically placed force-sensitive resistor sensors, which may explain its ability to capture GRF patterns with good fidelity. Although SuraSole has fewer sensors than Moticon's 13-sensor system, its placement in key load-bearing regions provides sufficient data for phase-specific GRF estimation. This suggests that sensor configuration, rather than sensor quantity alone, plays a critical role in accurately capturing GRF trends.

5.2. Temporal Parameter Reliability and Sampling Rate Considerations

In contrast to the GRF findings, agreement for temporal gait parameters ranged from moderate to good (ICC = 0.62–0.81). These results reflect a common limitation in pressure-based insoles with lower sampling frequencies. SuraSole samples at 20 Hz, whereas motion capture systems typically operate at 100–200 Hz, and some validated insoles operate at 50–100 Hz. Lower sampling frequencies limit the temporal resolution required to accurately detect gait events such as heel strike, toe-off, and mid-swing, resulting in small but meaningful discrepancies in stance and swing time measurements.

Comparable results have been reported in the literature. The eSHOEs system, which samples at 50 Hz, demonstrated high accuracy for step and stride timing but was less precise for rapid gait transitions [4]. IMU-based systems, which often exceed 100 Hz, have shown superior temporal precision but cannot directly measure GRF [11,18]. Thus, the moderate temporal agreement observed in SuraSole is consistent with expectations for a device operating at a lower sampling frequency and designed primarily for portability and affordability.

doi:10.20944/preprints202512.2244.v1

5.3. Clinical and Practical Implications

Despite limitations in temporal accuracy, the strong GRF agreement observed in this study positions SuraSole as a promising tool for clinical gait assessment, especially in settings where access to laboratory equipment is limited. GRF patterns provide essential information for evaluating weight-bearing behavior, gait symmetry, post-surgical recovery, and fall risk. In Thailand and many other countries, gait laboratories are available only in tertiary hospitals, limiting their use for screening older adults or monitoring rehabilitation progress. A portable insole-based solution can help bridge this gap by providing clinicians with quantitative data during routine outpatient visits.

SuraSole's integration with a mobile application and secure cloud platform enables remote monitoring and potential use in home-based rehabilitation programs. Such capabilities align with the growing emphasis on telemedicine and community-based care, particularly for populations with mobility impairments. Because the device is locally manufactured, it offers a cost advantage over imported systems, reducing financial barriers to implementation in public hospitals and community clinics.

5.4. Comparison with Previous Wearable Insole Studies

The performance of SuraSole compares favorably with several established smart insole systems. Moticon's OpenGo demonstrated excellent GRF validity but remains relatively expensive and less accessible in Southeast Asia. Insole3 provides strong temporal and kinetic accuracy but relies on proprietary hardware not widely available. SuraSole's validation contributes new knowledge by assessing a low-cost, regionally developed device in a real clinical environment, addressing a gap in the literature where validation studies have predominantly been performed in high-income countries.

Additionally, most previous studies focused on either kinetic or temporal validation, while this study evaluates both domains simultaneously. This dual validation provides a more comprehensive characterization of device performance and informs realistic expectations for clinical use.

5.5. Interpretation of Findings and Future Development

The excellent GRF performance indicates that the current hardware configuration is adequate for capturing functional loading patterns. However, the moderate temporal accuracy suggests opportunities for improvement. Increasing the sampling rate to 50–100 Hz, integrating IMU sensors to detect gait events more precisely, or implementing machine learning–based event detection algorithms could substantially enhance temporal validity.

Future studies should evaluate SuraSole in diverse populations, including older adults, patients recovering from orthopedic surgery, and individuals with neurological conditions such as stroke or Parkinson's disease. Longitudinal studies are also warranted to determine the device's sensitivity to clinical change over time and its applicability for fall-risk prediction.

6. Limitations

This study has several limitations that should be acknowledged when interpreting the findings. First, the sample consisted of healthy adults, which limits the generalizability of the results to clinical populations with gait impairments such as older adults, post-operative patients, or individuals with neurological disorders. Validation in these groups is necessary to determine applicability in real clinical settings. Second, participants walked at a self-selected speed, which may have introduced variability in temporal gait parameters. Controlled-speed protocols or treadmill-based assessments may reduce variability in future studies. Third, the SuraSole insole samples at 20 Hz, considerably lower than the 100–1000 Hz sampling rate of motion capture and force plate systems. This difference likely contributed to reduced temporal accuracy. Fourth, the study required participants to achieve accurate foot placement on embedded force plates, which may have influenced natural walking behavior. Finally, the SuraSole system estimates GRF based on pressure sensor output and does not directly measure shear forces or center-of-pressure trajectories, which may limit its use in applications requiring detailed kinetic modeling.

7. Conclusions

The SuraSole® smart insole demonstrated excellent agreement with laboratory force plates for phase-specific ground reaction force measurements and moderate accuracy for temporal gait parameters. These results indicate that SuraSole is a viable, low-cost, and portable alternative for gait assessment in clinical and community settings, particularly where access to laboratory-based systems is limited. Its reliable GRF performance supports use in routine evaluations of weight-bearing behavior, gait symmetry, and rehabilitation progress. While improvements in sampling frequency and sensor integration may enhance temporal measurement precision, the current system already offers substantial value for clinical screening and tele-rehabilitation applications. As a locally developed technology, SuraSole holds promise for expanding access to quantitative gait assessment in resource-limited environments and enabling scalable community-based mobility monitoring initiatives.

Author Contributions: Conceptualization, T.L., T.V. and P.Y.; methodology, T.L. and T.V.; software, D.K.A., W.J. and K.C.; validation, T.V. and P.Y.; formal analysis, T.L., D.K.A. and T.V.; project administration, T.V.; funding acquisition, T.L. and T.V.; investigation, T.L., D.K.A., T.V. and P.Y.; resources, W.J., and K.C.; data curation, T.L., T.V., W.J. and K.C.; writing—original draft, T.L., D.K.A. and T.V.; writing—review and editing, D.K.A. and S.L.; visualization, D.K.A.; supervision, T.V. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Ratchadapisek Somphot Fund, Graduate Affairs, Faculty of Medicine, Chulalongkorn University (Grant Number GA66/57).

Institutional Review Board Statement: This study was conducted at the Excellence Center for Gait and Motion, King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok, Thailand, and approved by the Research Ethics Committee of the Faculty of Medicine, Chulalongkorn University (IRB No. 0713/65) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has also been obtained from the patients for the publication of this paper.

Data Availability Statement: The data presented in this study are available from the corresponding author upon reasonable request, subject to ethical considerations.

Acknowledgments: We thank all participants for their time and effort in this study. We also acknowledge Chulalongkorn University for granting access to the Excellence Center for Gait and Motion, which was vital for this research. This work was supported by the Ratchadapisek Somphot Fund, Graduate Affairs, Faculty of Medicine, Chulalongkorn University (Grant Number GA66/57).

Conflicts of Interest: The SuraSole® system was developed locally; however, the authors declare that the study was conducted independently, and the funders had no role in study design, data analysis, or interpretation.

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