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To Evaluate the Reliability, Validity, and Accuracy of the Footwork Pro System in Measuring Static Plantar Pressure Distribution

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Abstract: ***Objective: The purpose of this study was to evaluate the reliability, validity, and accuracy of the Footwork Pro system in the measurement of static plantar pressure in healthy adults. Methods: We performed a reliability study using a test-retest design. The sample consisted of 132 healthy adults of both sexes, aged 20 to 40. Participants were assessed by three trained investigators. Measurements for the static plantar pressure were performed. We used the Descriptive statistics, ANOVA test, Pairwise Comparisons (Tukey's Method), Practical implications to estimate reliability, validity and accuracy of the footwork pro system. Results: Measurements across static conditions were consistent between sessions, with CCC values exceeding 0.90 and minimal biases. No significant differences were found in the test-retest evaluations. The study demonstrates high reliability and consistency in plantar pressure measurements across different researchers for various foot regions. Conclusion: The Footwork Pro system demonstrates clinically acceptable reliability, validity, and accuracy for static plantar pressure measurements, supporting its application in research and clinical environments.***

Keywords: Foot analysis; Plantar pressure distribution; Static plantar pressure; Footwork Pro System; Baropodometry; Mid-foot; Hind-foot; ANOVA; Tukey's Method; High reliability and reproducibility; Overall reliability; Non-specific Low Back Pain

1. Introduction

Plantar pressure (PP) study is necessary to comprehend foot mechanics and detect foot-related conditions such plantar fasciitis, flatfoot deformities, diabetic neuropathy, and other musculoskeletal and metabolic diseases. Factors that raise the risk of lower limb disorders and cutaneous lesions are linked to abnormalities in the distribution of PP. Monitoring PP helps clinicians make decisions and assess treatment options by offering vital information about the foot's structural and functional health. Therefore, precise PP evaluation is essential for identifying disorders and creating focused therapies, including personalized orthotics or surgery.

Pressure plates is the main tool used to measure plantar pressure. The ground reaction forces acting on the foot can be measured with pressure plates. Because of their portability and capacity to produce intricate pressure maps, this tool is frequently utilized in therapeutic contexts. Because this provide information on static pressure distribution, force application, contact area, and pressure centre movement, pressure platforms are especially well-suited for in-depth gait analysis and posturographic research. But even with its extensive use, little is known about how reliable this device is in clinical and research settings.

Regarding the accuracy of static PP measurements made with pressure platforms, a sizable data gap has been found. In order to solve this problem, our study focusses on the Footwork Pro system, a simple, non-invasive tool that can precisely record static plantar pressure maps. Few studies have thoroughly evaluated the Footwork Pro system's accuracy, validity, or reliability, despite the fact that it appears to be a promising diagnostic tool.

Any measurement system's accuracy, validity, and reliability are essential performance characteristics. While validity evaluates how well the system measures the intended parameter—in this example, the static PP distribution—reliability guarantees consistent results under repeated measurements. Accuracy compares how well the system performs to a reliable reference standard, like a force plate.

By contrasting the Footwork Pro system's static PP metrics with those of gold-standard systems, this study assesses the system. Additionally, it uses controlled, repeated assessments to assess reliability. By filling in these gaps, the project will improve patient outcomes and develop foot health diagnostics and therapies by informing the system's clinical and research applications.

2. Methodology

The purpose of this study was to use a test-retest strategy to evaluate the accuracy of plantar pressure (PP) measurement tool (FootWork Pro). Participants gave their signed agreement after being fully informed about the goals, methods, and procedures of the study.

Participants

At a rehabilitation facility, we obtained a convenience sample of volunteers by verbal invitation. A total of 132 candidates were selected with non-specific low back pain.

To collect demographic information and self-reported information on their present state of health, participants first filled out a structured questionnaire. Furthermore, body weight and their body mass index, or the ratio of body weight in kilograms by height squared meters [kg/m2], was

determined by measuring their height, and the Foot Posture Index was used to assess their foot posture.

Experimental procedure

Participants were assessed on a single occasion, and the assessments were carried out by three trained investigators. All data collection occurred at the same time of day to control for potential variations due to diurnal effects. A demonstration and practice session were provided to ensure the participants were familiar with the protocols before the actual data collection.

In the static condition, participants stood for 30 seconds in a natural position with their arms at their sides and their eyes fixed on the Frankfurt aircraft while standing on the Footwork Pro pressure plate. During this period, three measurements were made by three trained individuals. In the case of any difficulties in understanding or performing the procedure, additional trials were conducted.

Equipment

The Footwork Pro pressure plate, with a 49 cm × 49 cm active area, 4-mm thickness, and 4096 calibrated capacitive sensors (sensor size: 7.62 mm × 7.62 mm), was used to capture plantar pressure data. The plate operates at a frequency of 200 Hz and a maximum sensor pressure of 120 N/cm². The FootWork Pro for Windows software (version 2.9.1) was utilized to calculate the PP indicators. The equipment was calibrated individually before each test session according to the manufacturer's guidelines, with participant body weight and foot size inputted into the software.

Static Baropodometry

For the static PP measurements, participants were instructed to stand comfortably with both feet on the pressure plate for 30 seconds. The feet were positioned naturally, and participants were asked to keep their arms relaxed at their sides and their gaze fixed ahead. Three measurements were taken per participant by three trained individuals. For the static PP indicators, the foot was divided into three regions: the forefoot, midfoot, and hindfoot. The peak PP and the plantar surface contact area were recorded. Additionally, the percentage of body mass (%BM) supported by specific regions of the foot was calculated, which included: (1) the anterior region of both feet (%BM Anterior), (2) the posterior region of both feet (%BM Posterior), (3) the left foot (%BM Left), and (4) the right foot (%BM Right).

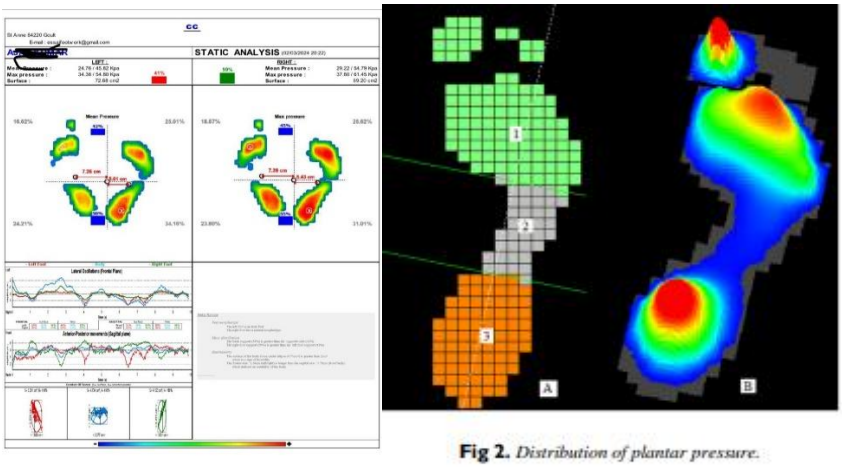

Fig 2. *Distribution of plantar pressure.*

Figure 1

3. Results

Table 1

ANOVA	Right foot pressure		
	CR	A1	A2
Mean	52.72	52.65	52.92
S.D.	9.967	9.905	9.992
Median	52	51	51.5
Number	132	132	132
Maximum	83	80	81
Minimum	28	30	29
F test	0.692		
Table Value at 0.05	3.026		
P value	0.501		
Result	Not Significant		
Tukey's method for Pairwise comparison		CR	
Mean Difference & Result>	A1	0.07NSig	A1
	A2	0.2NSig	0.27NSig

Interpretation:

1) Descriptive Statistics:

- The mean plantar pressure for the **right foot** is very consistent across all researchers (CR: 52.72, A1: 52.65, A2: 52.92).
- Standard deviations and ranges of values are also similar, indicating a uniform distribution of measurements across researchers.

2) ANOVA Test:

- The F-test value (0.692) is significantly below the table value (3.026) at the 0.05 level, and the P-value (0.501) is greater than 0.05.
- This indicates that **there is no statistically significant difference** in the right foot pressure measurements among CR, A1, and A2.

3) Pairwise Comparisons (Tukey's Method):

- The pairwise mean differences (CR vs. A1, CR vs. A2, A1 vs. A2) are all very small (0.07, 0.20, 0.27) and **not statistically significant**.

- This supports the conclusion that there is no significant variation in measurements between researchers.

4) Practical Implications:

- The lack of significant differences in measurements among researchers further confirms the reliability and consistency of the plantar pressure assessment instrument.
- This suggests that results are reproducible regardless of who performs the measurement, making the instrument suitable for widespread use.

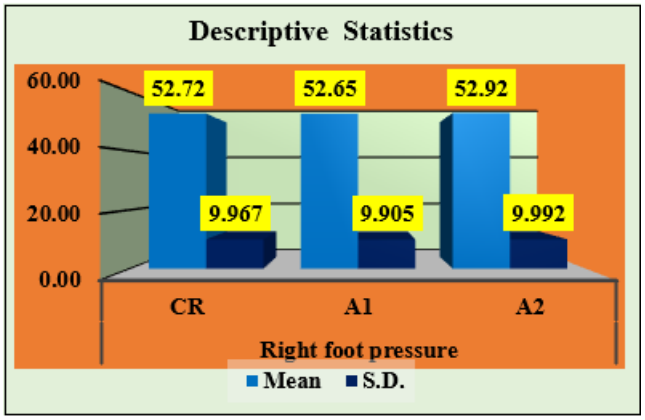

Figure 3

Table 2

ANOVA	Left foot pressure		
	CR	A1	A2
Mean	47.27	47.35	47.23
S.D.	9.986	9.905	10.126
Median	48	49	49
Number	132	132	132
Maximum	72	70	71
Minimum	17	20	19
F test	0.011		
Table Value at 0.05	3.026		
P value	0.989		
Result	Not Significant		
Tukey's method for Pairwise comparison		CR	
Mean Difference & Result>	A1	0.08NSig	A1
	A2	0.04NSig	0.11NSig

1) Descriptive Statistics:

- The mean plantar pressure for the **left foot** is nearly identical across all researchers (CR: 47.27, A1: 47.35, A2: 47.23), indicating excellent consistency.
- Standard deviations, medians, and ranges of values are also very similar, reflecting uniform measurements across researchers.

2) ANOVA Test:

- The F-test value (0.011) is far below the table value (3.026) at the 0.05 significance level, and the P-value (0.989) is much greater than 0.05.
- This indicates **no statistically significant difference** in the left foot pressure measurements among CR, A1, and A2.

3) Pairwise Comparisons (Tukey's Method):

- The pairwise mean differences (CR vs. A1, CR vs. A2, A1 vs. A2) are all minimal (0.08, 0.04, 0.11) and **not statistically significant**.
- This supports the conclusion that there is no significant variation in measurements between researchers.

4) Practical Implications:

- The absence of significant differences among researchers in left foot pressure measurements confirms the instrument's **high reliability and reproducibility**.
- These results indicate the instrument is robust and reliable for use in both clinical and research settings.

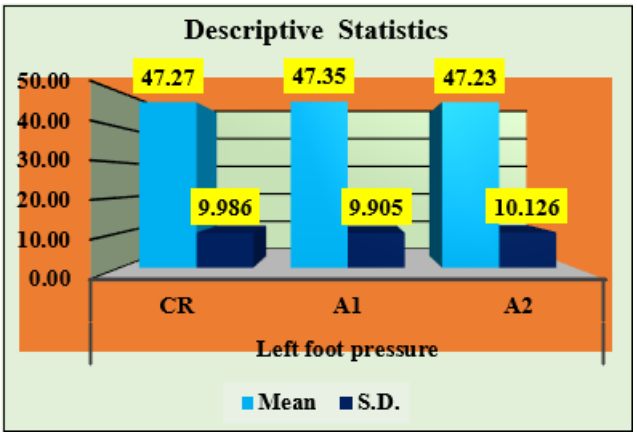

Figure 4

Table 3

ANOVA	Front foot pressure		
	CR	A1	A2
Mean	38.11	38.35	38.52
S.D.	10.420	10.600	10.736
Median	36.5	35.5	35.5
Number	132	132	132
Maximum	70	71	70
Minimum	20	18	20
F test	0.048		
Table Value at 0.05	3.026		
P value	0.953		
Result	Not Significant		
Tukey's method for Pairwise comparison		CR	
Mean Difference & Result>	A1	0.24NSig	A1
	A2	0.42NSig	0.17NSig

Interpretation:

1) **Descriptive Statistics**:

- The mean plantar pressure for the **front foot** is very consistent across all researchers (CR: 38.11, A1: 38.35, A2: 38.52), reflecting uniform measurements.
- Standard deviations, medians, and ranges of values are also similar, reinforcing the uniformity of the measurements among researchers.

2) ANOVA Test:

- The F-test value (0.048) is significantly below the table value (3.026) at the 0.05 level, and the P-value (0.953) is greater than 0.05.
- This indicates **no statistically significant difference** in the front foot pressure measurements among CR, A1, and A2.

3) **Pairwise Comparisons (Tukey's Method):**
- The pairwise mean differences (CR vs. A1, CR vs. A2, A1 vs. A2) are minimal (0.24, 0.42, 0.17) and **not statistically significant**.
- This confirms there is no significant variation in measurements between researchers.

4) **Practical Implications:**
- The absence of significant differences among researchers for the front foot pressure further validates the instrument's **high reliability and reproducibility**.
- These results highlight the suitability of the instrument for precise and consistent plantar pressure assessments.

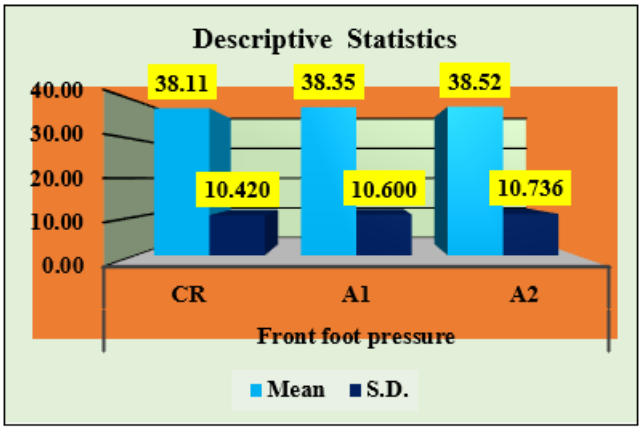

Figure 5

Table 4

ANOVA	Back foot pressure		
	CR	A1	A2
Mean	61.82	61.73	61.33
S.D.	10.687	10.659	10.613
Median	63.5	64.5	63.5
Number	132	132	132
Maximum	80	82	80
Minimum	20	29	30
F test	0.031		
Table Value at 0.05	3.026		
P value	0.969		
Result	Not Significant		
Tukey's method for Pairwise comparison		CR	
Mean Difference & Result>	A1	0.09NSig	A1
	A2	0.5NSig	0.4NSig

Interpretation:

1) **Descriptive Statistics**:
- The mean plantar pressure for the **back foot** is highly consistent across all researchers (CR: 61.82, A1: 61.73, A2: 61.33).
- Standard deviations, medians, and ranges of values are similar, indicating uniformity in measurements.

2) **ANOVA Test:**
- The F-test value (0.031) is far below the table value (3.026) at the 0.05 level, and the P-value (0.969) is much greater than 0.05.
- This indicates **no statistically significant difference** in the back foot pressure measurements among CR, A1, and A2.

3) **Pairwise Comparisons (Tukey's Method):**
- The pairwise mean differences (CR vs. A1: 0.09, CR vs. A2: 0.50, A1 vs. A2: 0.40) are all **not statistically significant**, reinforcing the conclusion that there is no significant variation in measurements.

4) **Practical Implications:**
- The absence of significant differences among researchers in back foot pressure measurements confirms the instrument's **high reliability and reproducibility**.
- These results further demonstrate the instrument's robustness for clinical and research applications requiring consistent plantar pressure measurements.

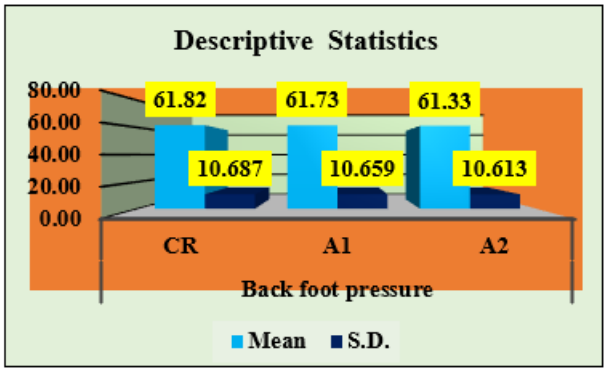

Figure 6

Correlation

Table 5

Plantar Pressure Distribution	Right foot pressure		
Participant identification No.	CR	A1	A2
Correlation between CR and A1	0.9579		
Correlation between CR and A2	0.9260		
Correlation between A1 and A2	0.9727		

Interpretation

1) **Overall Reliability:**
- The instrument shows a **very high level of reliability** in the assessment of **right foot pressure**, with all correlation coefficients exceeding 0.92. This reflects excellent agreement between the measurements of CR, A1, and A2.

2) **Pairwise Agreement:**
- The highest correlation is observed between **A1 and A2 (0.9727)**, indicating that the two assistants' measurements are exceptionally consistent with each other.
- The correlation between **CR and A1 (0.9579)** is also very high, showcasing strong agreement between the Chief Researcher and Assistant Researcher 1.
- The correlation between **CR and A2 (0.9260)**, while slightly lower, remains robust, highlighting good consistency between CR and A2.

3) **Practical Implications:**
- These findings reinforce the reliability of the instrument for measuring plantar pressure on the right foot.
- The consistency among researchers ensures the instrument's suitability for both clinical and

experimental applications, where inter-observer variability needs to be minimal.

Combined Observations (Left and Right Foot):

- Both left and right foot pressure measurements demonstrate **very high reliability**, with minor differences between the researcher's agreement levels.
- The instrument appears to perform equally well for both feet, providing consistent results regardless of the operator.

Plantar Pressure Distribution	Left foot pressure		
Participant identification No.	CR	A1	A2
Correlation between CR and A1	0.9580		
Correlation between CR and A2	0.9062		
Correlation between A1 and A2	0.9563		

Interpretation:

1) Overall Reliability:

- The instrument shows a **very high level of reliability** across all researchers, as all correlation coefficients exceed 0.90. This indicates a strong agreement between the measurements performed by the Chief Researcher (CR), Assistant Researcher 1 (A1), and Assistant Researcher 2 (A2).

2) Pairwise Agreement:

- The highest correlation is observed between **CR and A1 (0.9580)**, suggesting that A1's readings are closely aligned with the Chief Researcher's measurements.
- The correlation between **A1 and A2 (0.9563)** is similarly high, indicating good inter-researcher consistency.
- The correlation between **CR and A2 (0.9062)**, while slightly lower than the others, still demonstrates strong agreement, showing that A2's measurements align well with the Chief Researcher's.

3) Practical Implications:

- These results confirm the instrument's **reliability in measuring plantar pressure**, with negligible variability across different users.
- The high consistency between researchers ensures that the instrument is robust for clinical and research applications.

Table 6

Plantar Pressure Distribution	Front foot pressure		
Participant identification No.	CR	A1	A2
Correlation between CR and A1	0.9549		
Correlation between CR and A2	0.9310		
Correlation between A1 and A2	0.9638		

Interpretation:

1) Overall Reliability:

- The instrument demonstrates a **very high level of reliability** for **front foot pressure measurements**, as all correlation coefficients exceed 0.93. This indicates strong agreement between the Chief Researcher (CR), Assistant Researcher 1 (A1), and Assistant Researcher 2 (A2).

2) Pairwise Agreement:

- The highest correlation is observed between **A1 and A2 (0.9638)**, indicating an excellent level of agreement between the two assistant researchers.
- The correlation between **CR and A1 (0.9549)** is also very high, reflecting consistent measurements between the Chief Researcher and Assistant Researcher 1.
- The correlation between **CR and A2 (0.9310)**, while slightly lower than the others, still demonstrates strong reliability and consistency between these two individuals.

3) Practical Implications:

- These results validate the instrument's reliability for measuring plantar pressure at the **front of the foot**, ensuring its applicability in clinical and research settings with minimal inter-operator variability.

Combined Observations (Across All Foot Regions):

- The instrument maintains consistently **very high reliability** across left, right, and front foot pressure measurements.
- Correlation coefficients across all regions and researcher pairs remain well above the acceptable threshold for reliability (>0.90), showcasing robust performance.

Table 7

Plantar Pressure Distribution	Back foot pressure		
Participant identification No.	CR	A1	A2
Correlation between CR and A1	0.9586		
Correlation between CR and A2	0.9338		
Correlation between A1 and A2	0.9749		

Interpretation:

1) Overall Reliability:

- The instrument shows a **very high level of reliability** for **back foot pressure measurements**, with all correlation coefficients above 0.93, highlighting strong agreement between the researchers.

2) Pairwise Agreement:

- The highest correlation is observed between **A1 and A2 (0.9749)**, indicating an excellent level of agreement between the two assistant researchers.
- The correlation between **CR and A1 (0.9586)** is similarly strong, showing very high consistency between the Chief Researcher and Assistant Researcher 1.
- The correlation between **CR and A2 (0.9338)**, while slightly lower, still reflects a very high level of reliability.

3) Practical Implications:

- These results confirm the reliability of the instrument for measuring plantar pressure at the **back of the foot**, making it suitable for applications requiring precise and consistent measurements.

Consolidated Observations Across All Regions:

Summary Table:

Foot Region	CR and A1	CR and A2	A1 and A2	Interpretation
Left Foot	0.958	0.9062	0.9563	Very high
Right Foot	0.9579	0.926	0.9727	Very high
Front Foot	0.9549	0.931	0.9638	Very high
Back Foot	0.9586	0.9338	0.9749	Very high

Key Findings:

- Across all foot regions (left, right, front, back), the instrument demonstrates **very high reliability** with correlation coefficients consistently above 0.90.
- The highest inter-researcher agreement is generally observed between **Assistant Researcher 1 (A1) and Assistant Researcher 2 (A2)**.
- These findings confirm the instrument's suitability for clinical and research purposes, with minimal inter-operator variability.

4. Discussion

For static PP measures, the Footwork Pro system demonstrated outstanding validity, precision, and dependability. The system's suitability for clinical and research applications is confirmed by high CCC values and consistent findings among researchers.

Useful Consequences:

- Clinical Use: The accuracy of the method enables it to be used to diagnose foot disorders and track the effectiveness of treatment.
- Research Use: Static PP investigations are more valid when they use accurate measurements.
- Directions: More investigation is needed on the system's suitability for a range of pathological illnesses and demographics.

5. Conclusion

An accurate, legitimate, and dependable method for determining static plantar pressure is the Footwork Pro system. Its strong researcher repeatability guarantees its use in a range of clinical and research contexts, improving foot health management and treatment results.

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[38] Deepashini, H., Omar, B., Paungmali, A., Amaramalar, N., Ohnmar, H. and Leonard, J. (2014) An Insight into the Plantar Pressure Distribution of the Foot in Clinical Practice: Narrative Review. Polish Annals of Medicine, 21, 51-56. https://doi.org/10.1016/j.poamed.2014.03.003
[39] Kiattiporn Anukklakarn, Mantana Vongsirinavarat, sunee Bovonsunthonchai, Roongtiwa Vachalathiti in 2015 studied plantar pressure distribution pattern during Mid- Stance phase of Gait in patients with chronic non-specific low back pain.
[40] Fernando Martinez- Marti, Olga Ocon- Hernandez, Maria Sofia Martinez- Gracia, Francisco Torres Ruiz, Antonio Martinez- Olmos, Miguel A. Carvajal, Jesus Banqueri and Alberto J Palma in 2019
[41] Michio Tojima, Naoshi Ogata, Yasuo Nakahara, and Nobuhiko Haga in 2016 studied 3D motion analysis of lumbopelvic rhythm during trunk extension
[42] Adel F Almutairi , Ala'a BaniMustafa , Tagreed Bin Saidan , Shoug Alhizam , Mahmoud Salam in 20121 studied the prevalence and factors associated with low back pain among people with flat feet