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ORIGINAL RESEARCH

Reproducibility and agreement between different protocols of dynamic baropodometry during gait: a preliminary study

Reprodutibilidade e concordância entre diferentes protocolos de baropodometria dinâmica durante a marcha: um estudo preliminar

Reproducibilidad y concordancia entre diferentes protocolos de baropodometría dinámica durante la marcha: un estudio preliminar

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ABSTRACT | The identification of plantar pressure during gait is used by clinicians and researchers to verify burden on the plantar structure. In this study, different protocols have been employed for this purpose. The aim of this study was to verify the reproducibility and agreement of shortened gait protocols to identify dynamic plantar pressure in asymptomatic young people. Fifteen volunteers were submitted to the shortened one-step and three-step protocols and to the standard midgait protocol in three moments: initial, after one day and after seven days. For each of the eight foot masks, the measurements of peak plantar pressure and pressure-time integral were considered. Reproducibility was analyzed by one-way Anova test and intraclass correlation coefficient, while the agreement between the protocols was verified through paired t-test, Pearson's moment-product correlation and Bland-Altman plot. The results showed that the three-step protocol presented higher reproducibility in both measurements of dynamic plantar pressure. Regarding the agreement between protocols, although the shortened ones showed a tendency to underestimate the standard midgait measurements, most foot masks showed no statistical differences between mean scores. Furthermore, through the Bland-Altman technique, there was substantial agreement capacity between the one-step, three-step and midgait protocols measurements. In conclusion, the shortened protocols should be selected according to the measurement of interest of plantar pressure and foot masks to be analyzed. The evidence of reproducibility and agreement was more favorable for the use of the three-step protocol.

Keywords | Foot; Data Accuracy; Gait Analysis.

RESUMO | A identificação da pressão plantar durante a marcha é utilizada por clínicos e investigadores para verificar sobrecarga na estrutura podal. Neste particular, diferentes protocolos têm sido empregados para essa finalidade. O objetivo do estudo foi verificar a reprodutibilidade e a concordância de protocolos abreviados de marcha para identificar a pressão plantar dinâmica em jovens assintomáticos. Quinze voluntários foram submetidos aos protocolos abreviados *one-step* e *three-step* e ao protocolo padrão *midgait* em três momentos: inicial, dia seguinte e após sete dias. Para cada uma das oito máscaras podais, foram consideradas as medidas de pico de pressão plantar e integral pressão/tempo. A reprodutibilidade foi analisada mediante *Anova one-way* e coeficiente de correlação intraclasse, enquanto a concordância entre os protocolos foi verificada através de teste t pareado, correlação momento-produto de Pearson e plotagem de Bland-Altman. Os resultados apontaram que o protocolo *three-step* apresentou mais elevada reprodutibilidade em ambas as medidas de pressão plantar dinâmica. Quanto à concordância entre os protocolos, apesar de os abreviados demonstrarem tendência em subestimar as medidas produzidas pelo protocolo padrão *midgait*, na maioria das máscaras podais não foram identificadas diferenças estatísticas

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entre os escores médios. Ainda, por intermédio da técnica de Bland-Altman, constatou-se substancial capacidade de concordância entre as medidas identificadas pelos protocolos *one-step*, *three-step* e *midgait*. Concluindo, os protocolos abreviados devem ser selecionados de acordo com a medida de interesse da pressão plantar e a máscara podal a ser analisada, surgindo evidências de reprodutibilidade e concordância mais favoráveis para o uso do protocolo *three-step*.
Descritores | Pé; Confiabilidade dos Dados; Análise da Marcha.

RESUMEN | Los médicos e investigadores utilizan la identificación de la presión plantar durante la marcha para verificar la sobrecarga en la estructura podal. Para ello, emplean diferentes protocolos. El objetivo de este estudio fue verificar la reproducibilidad y la concordancia de los protocolos de caminata abreviados para identificar la presión plantar dinámica en jóvenes asintomáticos. Para esto, participaron quince voluntarios en protocolos abreviados *one-step* y *three-step* y en el protocolo estándar *midgait* en tres momentos: inicial, día siguiente y después de siete días. Para cada una de las máscaras podales, se consideraron la medición máxima de la presión plantar e integral presión/tiempo. Para analizar la reproducibilidad, se usó la Anova *one-way* y el coeficiente de correlación intraclase, mientras que la concordancia entre los protocolos se verificó mediante la prueba t pareada, la correlación del producto-momento de Pearson y el gráfico de Bland-Altman. Los resultados mostraron que el protocolo *three-step* obtuvo una mayor reproducibilidad en ambas las medidas de presión plantar dinámica. En cuanto a la concordancia entre los protocolos, aunque los protocolos abreviados muestran una tendencia a subestimar las medidas producidas por el protocolo estándar *midgait*, en la mayoría de las mascarillas podales no se identificaron diferencias estadísticas entre las puntuaciones medias. En la técnica de Bland-Altman, hubo una capacidad sustancial de concordancia entre las medidas identificadas por los protocolos *one-step*, *three-step* y *midgait*. Se concluye que los protocolos abreviados deben seleccionarse según la medida de interés de la presión plantar y la mascarilla podal que se debe analizar, con evidencia de reproducibilidad y concordancia más favorable para el uso del protocolo *three-step*.
Palabras Clave | Pie; Exactitud de los Datos; Análisis de la Marcha.

INTRODUCTION

The analysis of plantar pressure distribution (PPD) is an important component in the diagnosis and treatment of several pathological conditions[1] and physical performance[2]. The clinical and industrial application of PPD promotes greater efficiency in the design of sports orthotics[3], the prevention of injuries[4], the control and evaluation of diabetic ulcerations[5] and, more recently, in biofeedback therapy[6].

PPD monitoring is performed with an electronic baropodometry system, which, among other elements, uses a pressure platform positioned on the ground. The individual interacts with the equipment under different experimental conditions, including on treadmills and insoles positioned in the shoe/foot[7].

PPD-related measurements of human gait request numerous collections in order to perform representative analysis of the usual pattern. In this sense, different protocols have been proposed to promote more accessible analyses regarding procedure duration, patient fatigue, physical space and reliability of PPD indicators identification in dynamic activities[8].

Among the available resources for gait analysis, the midgait protocol is considered the gold standard to measure PPD. The midgait protocol recommends that the barefoot individual walk in the same direction for around 10 meters, at stable and self-selected gait speed, with the baropodometer positioned in the middle of the course[9]. This protocol may be limited for clinical environments and for individuals with painful processes, locomotion difficulty and at risk of falling, due to the distance that must be performed; which may also cause difficulties in the familiarization with procedures and the length of data collection.

Thus, with the intention of facilitating PPD analysis, shorter gait protocols have been suggested to minimize difficulties related to the midgait protocol[10-12], making the procedures clinically more feasible. Among the recommended shortened protocols, there are the one-step and three-step gait initializations, in which the individual interacts with the baropodometer in the first or third initial step of the gait, respectively.

Although the shortened protocols are less complex—unlike the midgait protocol—they impose different demands on the ability to move, mainly because the analysis is performed in the first steps of the gait. Thus, the shortened protocols demand different things from the postural control system regarding acceleration, balance and external disturbance, triggering disparities in movement patterns during gait. So, it is possible to assume the hypothesis that shortened gait protocols can generate conflicting results in PPD monitoring.

Previous studies have investigated the agreement and reproducibility of different protocols for PPD analysis in the gait of young people and adults under different experimental conditions[13-15]. Although the studies showed good agreement between methods, they did not investigate both shortened protocols simultaneously, comparing with the gold standard, which generates doubt about the most indicated shortened protocol. The goals of the present study were to identify (1) the reproducibility of PPD measurements recorded at three distinct moments (initial, after one day and after seven days) through the use of one-step and three-step protocols and (2) the agreement between PPD measurements recorded through midgait, one-step and three-step protocols in asymptomatic young people.

METHODOLOGY

The volunteers were informed about the methodological procedures and confirmed their participation in the study through a free and informed consent form.

Participants

The study used a non-probabilistic sample of 15 asymptomatic undergraduates of both sexes, aged between 18 and 30 years. The considered exclusion criteria were injury in some segment of the lower limbs in the last six months; recent bone fracture; previous surgical procedures; excess body weight; diagnosis of orthopedic, neurological, cardiorespiratory or vestibular pathologies. The participants completed a structured questionnaire to gather demographic data and self-reported information about current health status. Body weight and height were measured to calculate body mass index (quotient between body weight measurement in kilograms and height in meters squared—kg/m^2).

Equipment

For data collection of PPD measurements in the different gait protocols, we used a pressure platform model *Footwork Pro* AM3 – France, with an active surface of 490×490mm, 4mm thickness, 4096 calibrated capacitive pickups, 7.62×7.62mm captors, 200Hz frequency and 120N/cm^2 maximum pressure per sensor.

Experimental procedure

Initially, the participants were shown the three protocols used to analyze plantar pressure distribution measurements, then the participants were familiarized with the process and its procedures. Familiarization consisted of the execution of at least three repetitions of each protocol; in cases where the participant demonstrated that he did not fully understand the procedures or presented difficulty in execution, additional repetitions were performed. Subsequently, separate marks were made on the ground for each protocol, in order to define the appropriate starting position for a successful execution. Then, the equipment was calibrated and the participant information needed for the measurement protocols was inserted into the electronic system.

All participants were submitted to three different gait protocols: midgait, one-step and three-step. The sequence of protocol application of was random. The participants walked naturally at self-selected speed, with their arms along the body, looking in the horizontal plane, moving one, two or five meters before contact with the pressure platform and continued walking the same distance after the initial contact[9,10,12]. Six repetitions of walking movements were performed in each protocol, using as reference only the responses equivalent to the left foot for the PPD analysis, as recommended by Menz et al.[16] In cases where the participants did not present data within the acceptance criteria, the procedures were subsequently repeated until the required amount of steps was reached. The procedure was repeated under similar conditions after one and seven days.

The rejection criteria of the collected data were the following: attempt in which the foot did not fully contact the platform; intentional abnormalities in gait observed by the investigator; change in gait rhythm to adjust the steps prior to contact with the platform; imbalance during gait; start of the gait outside the determined space; or not completing the sequence of steps after contact with the equipment.

Measurements analyzed by dynamic baropodometry

PPD measurements were identified through the different protocols at three different moments: initial, after one day and after seven days. We chose to apply the protocols at three different times in an attempt to ensure consistency of participants' gait characteristics. In this sense, measurements equivalent to peak plantar pressure (PPP) and pressure-time integral (PTI) were gathered. Both measurements were selected due to their clinical application in foot-associated dysfunctions, risk of plantar ulcerations and effectiveness in therapeutic interventions[17,18].

PPP and PTI were scaled using the AutoMask function of the FootWork Pro 2.9.1 software. Eight foot masks were considered: hallux, other fingers, first metatarsal, second and third metatarsal, fourth and fifth metatarsal, midfoot, internal calcaneus and external calcaneus. These regions were selected to provide detailed information on the function of different plantar areas during gait[14,15].

Statistical Analysis

Data statistical analysis was performed using the software Statistical Package for the Social Sciences, version 22 (SPSS, Inc., Chicago, IL, USA). Prior to inferential analyses, the normal distribution of data on PPP and PTI was proven through the Shapiro-Wilk test; therefore, parametric descriptive statistics (mean±standard deviation) were used. Representative scores of PPP and PTI in each protocol were established by calculating the mean of the six executions. Data reproducibility—involving the three moments (initial, after one and seven days) obtained with the different protocols—was identified by Anova One-way and intraclass correlation coefficient (ICC). The agreement between PPP and PTI scores using the midgait, one-step and three-step protocols was analyzed with student's t-test for paired data, Pearson's product-moment correlation, mean difference of individual variations and the respective standard deviation, and Bland-Altman plotting.

RESULTS

Sample characteristics

The sample consisted of eight women and seven men with mean age equivalent to 23.68±2.80 years old, body weight 64.52±10.55 kg, height 168.68±7.93 cm and body mass index 22.87±3.14 kg/m^2.

PPP and PTI reproducibility

Statistical information regarding the reproducibility of PPP and PTI measurement is available in Table 1. In both cases, the F values did not indicate statistically significant differences between the three moments of data collection. The ICC dimensions suggest that the three-step protocol presented PPP and PTI data with higher reproducibility. Foot masks data referring to the second/third metatarsal and the internal calcaneus were the ones that revealed the most improved reproducibility, while data referring to other toes and midfoot were those that demonstrated less improved reproducibility, particularly in the one-step protocol.

Table 1. Reproducibility of measurements equivalent to peak plantar pressure and pressure-time integral found at different moments through the shortened protocols—one-step and three-step

Masks surfaces		Peak plantar pressure (KPa)		Pressure-time integral (KPa/s)	
		One-step	Three-step	One-step	Three-step
Hallux	M_0	368.61±83.72	357.36±95.03	21.11±8.27	23.57±10.53
	M_1	316.31±93.74	328.11±99.77	20.60±9.35	22.78±11.16
	M_7	325.01±122.28	340.35±92.59	20.24±13.09	22.67±9.78
	F Test	2.498 (ns)	0.817 (ns)	0.020 (ns)	0.098 (ns)
	CCI	0.78	0.79	0.96	0.85
Other toes	M_0	289.75±122.32	288.86±134.31	11.55±9.27	11.92±7.37
	M_1	295.36±75.97	249.04±147.36	13.45±12.66	12.03±10.03
	M_7	300.84±78.13	268.62±121.88	13.23±9.96	16.07±10.88
	F Test	0.065 (ns)	0.734 (ns)	0.483 (ns)	2.202 (ns)
	CCI	0.44	0.79	0.63	0.78
1st metatarsal	M_0	295.65±81.77	311.79±54.93	29.67±11.92	34.68±10.87
	M_1	268.36±54.85	279.48±48.65	30.43±13.81	38.95±14.03
	M_7	272.48±60.92	288.61±51.06	27.94 ±13.40	40.25±12.45
	F Test	1.019 (ns)	2.048 (ns)	0.190 (ns)	2.993 (ns)
	CCI	0.54	0.80	0.50	0.88

(continues)

Table 1. Continuation

Masks surfaces		Peak plantar pressure (KPa)		Pressure-time integral (KPa/s)	
		One-step	Three-step	One-step	Three-step
2nd and 3rd metatarsal	M_0	388.72±52.55	402.59±38.87	50.42±9.89	54.99±6.19
	M_1	398.33±52.20	394.33±35.37	52.72±9.38	56.89±4.44
	M_7	396.20±47.88	405.13±54.83	52.42±9.08	57.62±6.09
	F Test	1.014 (ns)	0.757(ns)	1.619 (ns)	2.444 (ns)
	CCI	0.86	0.94	0.84	0.87
4th and 5th metatarsal	M_0	371.93±86.34	373.51±63.47	30.35±13.04	35.58±10.74
	M_1	389.68±74.19	376.60±64.76	36.83±12.64	34.70 ±10.81
	M_7	377.54±66.53	356.12±73.07	32.83±9.61	34.36±9.57
	F Test	0.593 (ns)	1.022 (ns)	2.600 (ns)	0.306 (ns)
	CCI	0.84	0.82	0.79	0.93
Midfoot	M_0	70.57±51.95	61.15±39.44	4.82±3.85	3.73±2.42
	M_1	102.71±67.73	56.43±40.90	6.70±5.04	4.59±2.88
	M_7	97.37±63.55	53.47±42.42	6.67±6.39	3.94±3.07
	F Test	1.442 (ns)	0.391 (ns)	0.485 (ns)	1.737 (ns)
	CCI	0.40	0.74	0.55	0.81
Internal calcaneus	M_0	373.73±37.80	393.43±55.47	40.20±10.35	32.89±7.94
	M_1	377.83±47.73	404.18±37.65	40.56±10.22	33.84±8.41
	M_7	390.38±41.52	403.13±46.41	40.26±10.21	33.72±9.75
	F Test	2.294 (ns)	0.606 (ns)	0.009 (ns)	0.125 (ns)
	CCI	0.82	0.87	0.93	0.90
External calcaneus	M_0	375.32±44.43	402.49±63.29	32.46±9.45	28.15±7.31
	M_1	365.98±43.32	420.62±47.20	31.64±7.08	28.01±6.80
	M_7	381.76±46.76	412.20±50.56	33.58±7.51	27.74±7.57
	F Test	1.153 (ns)	1.282 (ns)	0.383 (ns)	0.029 (ns)
	CCI	0.81	0.86	0.70	0.80

M_0: Initial moment; M_1: After 1 day; M_7: After 7 days.

Data agreement equivalent to PPP and PTI

Without statistical differences between the measurements performed at the initial moment, after one and after seven days, the initial scores were used for the agreement analysis between both shortened protocols and the standard midgait protocol. Table 2 shows statistical information on the agreement between PPP data produced by the three protocols.

In comparison with midgait, the one-step protocol showed significant differences in the foot masks corresponding to the internal ($t=3.411$; $p=0.01$) and external calcaneus regions ($t=2.393$; $p=0.03$), while the three-step protocol showed statistical difference only in the plantar surface of the first metatarsal ($t=4.793$; $p<0.01$). The other foot masks did not present statistical differences, which—associated with significant r values and smaller dimensions equivalent to mean differences of individual variations—indicate significant agreement between the midgait and both shortened protocols.

Statistical information associated with the agreement between PTI data produced by the three protocols is available in Table 3. Comparing the standard midgait with the one-step protocol, a significant difference was found only in the foot mask of the first metatarsal region ($t=2.456$; $p=0.03$); while, when establishing comparisons between the three-step and midgait protocols, the significant difference was verified in the fourth/fifth metatarsal regions ($t=2.615$; $p=0.02$). The other foot masks did not present statistical differences and recorded statistically significant r values. The mean differences of individual variations between measurements from the three protocols suggest greater agreement between the standard midgait and shortened three-step protocol.

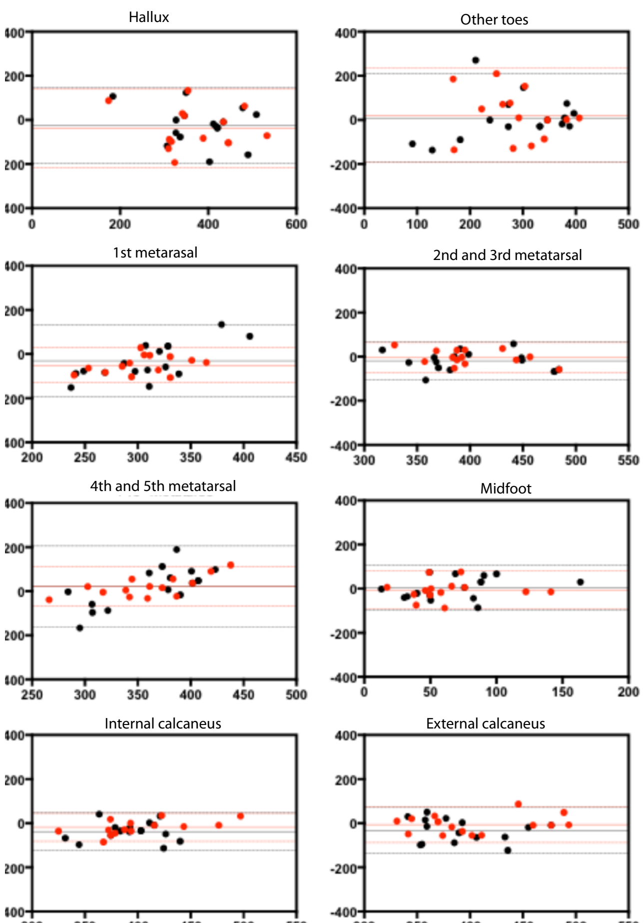
Table 2. Agreement between peak plantar pressure (KPa) measurements found with the midgait, one-step and three-step protocols.

Masks surfaces	Protocol	M±SD	T-test	r	Bland-Altman Plot	
					Mean difference	Agreement limits (± 2 SD)
Hallux	Midgait One-step Three-step	389.72±90.95 368.61±83.72 357.36±95.03	1.138 (ns) 1.588 (ns)	0.58 (p=0.02) 0.59 (p=0.02)	−25.9 −37.1	−198.4-146.6 −214.6-140.4
Other toes	Midgait One-step Three-step	281.05±97.93 289.75±122.32 288.86±134.31	0.328 (ns) 0.232 (ns)	0.58 (p=0.02) 0.46 (p=0.04)	8.7 19.8	−192.4-209.8 −193.6-233.1
1st metatarsal	Midgait One-step Three-step	326.62±33.23 295.65±81.77 275.98±46.86	1.442 (ns) 4.793 (p<0.01)	0.41 (p=0.05) 0.52 (p=0.05)	−31.0 −50.6	−194.0-132.1 −130.9-29.6
2nd and 3rd metatarsal	Midgait One-step Three-step	408.11±56.65 388.72±52.55 402.59±38.87	1.684 (ns) 0.603 (ns)	0.67 (p=0.01) 0.78 (p<0.01)	−19.4 −5.5	−106.8-68.0 −74.9-63.9
4th and 5th metatarsal	Midgait One-step Three-step	351.20±34.42 371.93±86.34 373.51±63.47	0.856 (ns) 1.909 (ns)	0.39 (p=0.05) 0.72 (p=0.01)	20.7 22.3	−163.1-204.5 −66.4-111.0
Midfoot	Midgait One-step Three-step	67.21±37.57 70.57±51.95 61.15±39.44	0.253 (ns) 0.541 (ns)	0.46 (p=0.04) 0.44 (p=0.05)	3.4 −6.1	−97.6-104.3 −91.0-78.9
Internal calcaneus	Midgait One-step Three-step	411.53±37.27 373.73±37.80 393.43±55.47	3.411 (p=0.01) 1.957 (ns)	0.34 (ns) 0.82 (p<0.01)	−37.8 −18.1	−121.9-46.3 −81.7-45.5
External calcaneus	Midgait One-step Three-step	408.28±53.69 375.32±44.43 402.49±63.29	2.393 (p=0.03) 0.535 (ns)	0.41 (ns) 0.75 (p=0.01)	−33.0 −5.8	-137.5 – 71.6 -87.8 – 76.2

Table 3. Agreement between measurements equivalent to the integral pressure/time (KPa/s) found with midgait, one-step and three-step protocols.

Masks surfaces	Protocol	M±SD	T-test	r	Bland-Altman Plot	
					Mean difference	Agreement limits (± 2 SD)
Hallux	Midgait One-step Three-step	24.15±7.30 21.11±8.27 23.57±10.53	0.734 (ns) 0.181 (ns)	0.64 (p=0.01) 0.71 (p<0.01)	−2.0 −0.6	−23.0-18.9 −24.8-23.7
Other toes	Midgait One-step Three-step	11.33±6.46 11.55±9.27 11.92 ±7.37	0.097 (ns) 0.378 (ns)	0.67 (p=0.01) 0.61 (p=0.01)	0.2 1.9	−17.4-17.9 −23.1-27.0
1st metatarsal	Midgait One-step Three-step	38.94±11.53 34.68±10.87 29.67±11.92	2.456 (p=0.03) 1.887 (ns)	0.22 (ns) 0.69 (p=0.01)	−9.3 −4.3	−37.9-19.4 −21.4-12.9
2nd and 3rd metatarsal	Midgait One-step Three-step	53.81±8.46 50.42±9.89 54.99±6.19	1.575 (ns) 1.003 (ns)	0.62 (p=0.02) 0.85 (p<0.01)	−3.4 1.2	−19.7-13.0 −7.8-10.1
4th and 5th metatarsal	Midgait One-step Three-step	29.27±7.22 30.35±13.04 35.58±10.74	0.409 (ns) 2.615 (p=0.02)	0.62 (p=0.01) 0.36 (ns)	1.1 6.3	−19.0-21.2 −12.0-24.6
Midfoot	Midgait One-step Three-step	4.40±1.85 4.82±3.85 3.73±2.42	0.384 (ns) 1.847 (ns)	0.43 (p=0.05) 0.81 (p<0.01)	0.4 −0.7	−7.9-8.7 −3.4-2.1
Internal calcaneus	Midgait One-step Three-step	37.88±9.77 40.20±10.35 32.89±7.94	0.847 (ns) 2.089 (ns)	0.44 (p=0.05) 0.47 (p=0.04)	2.3 −5.0	−18.5-23.1 −23.1-13.1
External calcaneus	Midgait One-step Three-step	28.66±6.53 32.46±9.45 28.15±7.31	2.001 (ns) 0.366 (ns)	0.63 (p=0.01) 0.70 (p=0.01)	3.8 −0.5	−10.6-18.2 −11.0-10.0

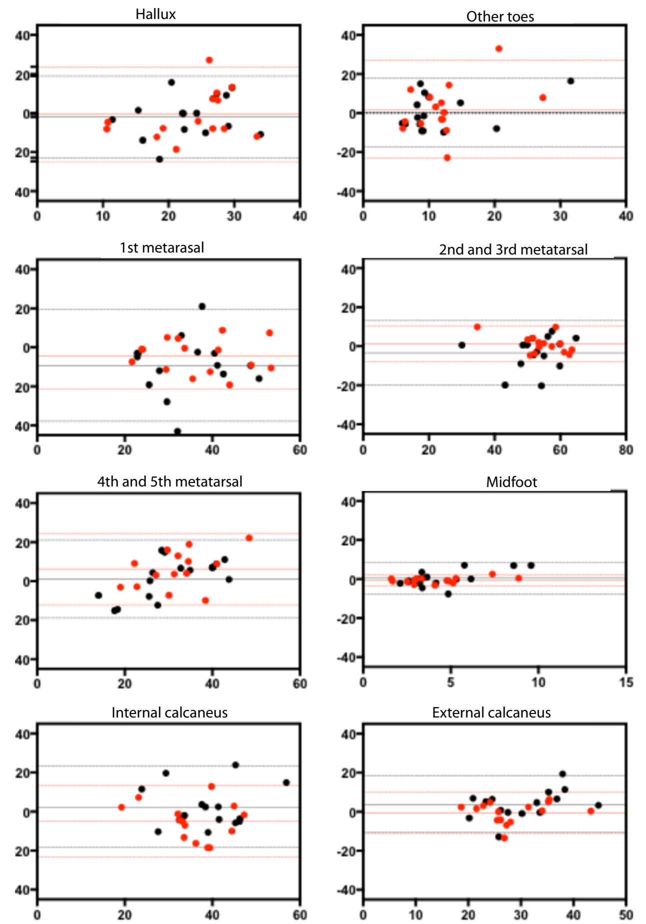
Figures 1 and 2 illustrate the dispersion diagrams with plot of mean data identified by each of the shortened protocols (one-step and three-step) and the midgait (x-axis), in addition to the differences between the individual data identified by the three protocols (y-axis). The analysis proposed by Bland-Altman allows to visualize the individual differences and the extreme limits of agreement (±2 standard deviations of the difference) observed in the comparison between each shortened protocol and the midgait protocol. The graphical arrangement of the data suggests less agreement between the midgait and one-step protocols. When comparing PPP and PTI data produced by each of the three protocols, we found close to zero mean differences and reasonably low agreement limits in the eight foot masks—especially in the case of PPP and the three-step protocol.



Y-axis: differences between the values identified with the midgait, one-step and three-step protocols.

X-axis: mean values identified with midgait, one-step and three-step protocols.

Figure 1. Bland-Altman plotting for the agreement limits between peak plantar pressure (Kpa) measurements identified with midgait, one-step (●) and three-step (●).



Y-axis: differences between the values identified with the midgait, one-step and three-step protocols.

X-axis: mean values identified with midgait, one-step and three-step protocols.

Figure 2. Bland-Altman plotting for the agreement limits between pressure-time integral (Kpa/s.) measurements identified with midgait, one-step (●) and three-step (●).

DISCUSSION

The aim of this study was to identify the reproducibility and agreement of shorter gait protocols (one-step and three-step) directed to plantar pressure distribution analysis, using the standard midgait protocol as a comparison criterion. The results found indicated acceptable reproducibility for PPP and PTI; however, depending on the considered foot mask, the three-step protocol was more favorable. These findings coincide with a previous study that compared the reproducibility of PPD measurements between the shortened one-step and three-step protocols in patients with chronic arthritis[19]. In this specific case, moderate to high magnitude reproducibility was also identified in both protocols, with slight advantage for the one-step protocol. However, the researchers responsible for the study pointed out that the use of the three-step protocol is more timely, considering the similarity in reproducibility indicators and the fact that the one-step protocol does not produce a support phase similar to normal gait.

Regarding the agreement between protocols, although the shortened ones showed a tendency to underestimate the standard midgait measurements, most foot masks showed no statistical differences between mean scores and r values were significant. When analyzing additional information using the Bland-Altman technique, we found a substantial agreement capacity of PPP and PTI measurements produced by the shortened protocols and standard midgait protocol. In general, these findings are consistent with previous studies[13,14].

At first, considering that PPP and PTI are of fundamental importance for diagnosis due to their relationships with pain processes, risk of ulceration, plantar deformities and musculoskeletal disorders[1,4,5]—and shortened protocols being more accessible for clinical use—these findings may offer important positive implications. Although both PPD measurements are very useful, researchers and clinicians should not make assumptions or inferences based exclusively on the magnitude of plantar pressure measurements. The PPP and PTI demonstrate wide individual variation and, so far in the literature, we have not found evidence that PPD can be used as an isolated reference for plantar region disorders.

On the other hand, the results of the present study may disagree with previous findings[20,21], which found a tendency for measurements obtained through the use of the one-step protocol being higher than with other protocols. However, researchers draw attention to the fact that, although it is possible to identify this trend, no significant differences were pointed out between the scores. This phenomenon is justified by the assumption that there is a direct relationship between increased velocity and higher plantar pressure measurement[22]. Due to the one-step protocol starting from an absolute resting position and the individual coming into contact with the platform in the gait acceleration phase, PPD measurement should be higher.

In this study, however, gait speed was not controlled, participants were instructed to walk at comfortable and self-selected speed. The association between gait speed and PPD behavior has been addressed in several contexts and, to date, the findings have shown that cadence, rhythm, type of trajectory and slope of the terrain trigger different PPD behaviors[22,23]. Thus, shortened protocols provide different demands to the neuromuscular and skeletal systems, regarding the interaction of motor control and biomechanical variability of the task, triggering different fluctuations in the center of mass on the support base and in the levels of disturbance that challenge stability and coordination[22].

For the analysis of baropodometric data, we chose, in the present study, to stratify the foot structure in eight masks, considering that these areas have greater clinical application in cases of diabetic ulceration, sports activities and physical therapy interventions. The division of plantar segments, however, is not uniform in the literature. For example, a study[24] stratified the forefoot into five masks when addressing the reproducibility of plantar pressure distribution in asymptomatic individuals, while our study did so in three plantar areas. Besides, the methods used for segmental division of the foot vary according to the baropodometry system used and are subject to weaknesses due to the resolution of the system, the type of platform sensor and the degree of mastery of the technique[25].

Deschamps et al.[26] carried out an experiment with the purpose of establishing the reliability of manual masking from the identification of 2D plantar pressure for PPP analysis and contact time in individuals with hallux valgus. The results showed high inter- and intra-examiner reliability, demonstrating a similar pattern in the definition of foot masks, despite presenting biased lower global values when masked manually. The researchers concluded that the use of smaller masks, such as those comprising the region of the heads of the metatarsals, should be analyzed with caution. This finding is in line with other studies[27,28] that have demonstrated lower reliability in masking small plantar regions, attributing this effect to the technological limitations of the equipment, such as size and sensitivity of captors to isolate small plantar areas. For this reason, in our study, we decided to mask plantar regions through the automatic definition provided by the equipment software itself.

This study presents some limitations that should be considered when interpreting its results. At first, the participants submitted to the procedures were young and healthy—consequently, the external validity of the findings becomes impaired when considering subjects with some dysfunction or of other age groups. Moreover, the lack of control of possible confounding variables—gait speed and level of physical effort made prior to data collection—can impact on PPD reproducibility. In addition, the characteristics of the pressure platform, such as captor size, spatial resolution and maximum pressure per sensor, may affect the sensitivity and accuracy of PPD data, thus making it difficult to compare with previous investigations with other equipment.

CONCLUSION

Due to the acceptable reproducibility and agreement indicators observed in the different foot masks, shortened gait protocols can be satisfactorily used to identify plantar pressure distribution measurements. Although no significant differences were found, the one-step protocol tended to underestimate PPP and PTI values, while the three-step protocol presented more adequate reproducibility and data closer to the standard midgait protocol. Therefore, in the impossibility of using the standard midgait protocol to identify PPD measurements, we suggest that the three-step protocol should preferably be used in asymptomatic young people.

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