Journal of Tissue Viability 32 (2023) 26–32

Contents lists available at ScienceDirect

Journal of Tissue Viability

journal homepage: www.elsevier.com/locate/jtv

Repeatability and reliability of the footwear assessment tool in Spanish patients: A transcultural adaptation

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ARTICLE INFO

Keywords:
Footwear
Shoes
Repeatability
Reliability
Tool

ABSTRACT

Background: The footwear assessment tool was designed to advise an appropriate footwear for each situation and patient. Footwear alterations structures can influence in musculoskeletal disorders, developing foot ulcers, increase the peak plantar pressure, bacterial growth, low back pain. Methods: To validate the study 101 subjects were recruited. The study was tested by two expert podiatrists using the tool for the assessment of footwear characteristics that is composed by five domains, fit, general features, general structure, motion control properties and cushioning system. Each domain analyzes different shoe items. Results: An excellent agreement between the test-retest. A suitable Cronbach's α was suggested for the five domains of fit ($\alpha = 0.952$), general features ($\alpha = 0.953$), general structure ($\alpha = 0.947$), motion control properties ($\alpha = 0.951$), and cushioning system ($\alpha = 0.951$). Test-retest reliability was excellent for all domains. There were no significant differences between any domain ($p > 0.05$). There was only statistically significant difference in the item forefoot height ($p = 0.011$). For all the domains items there were no statistically significant difference ($p > 0.05$). Conclusions: The tool for the assessment European footwear is a suitable repeatability and reliability footwear tool that can be used in Spanish language subjects.

1. Introduction

The characteristics of advanced footwear are in constant development to adapt to the population requirements. Actually, runners increase rate performance due to healthier habits being the footwear a very important factor to avoid injuries [1–3]. Patients with metabolic diseases, as Diabetes Mellitus, requires therapeutic footwears to prevent the risk of developing foot ulcers due to the increase of the peak plantar pressure while walking or standing position [4,5]. Recent studies about musculoskeletal disorders produced by wrong postures maintained over time, increase the risk of suffer lower back pain being necessary a comfort and fit footwear adapted to working requirements [6]. In other hand, subjects who suffers from high bacterial growth needs a high ventilation in the distal sole footwear to decrease the humidity and temperature [7]. Footwear with a low heel, firm strips and anti-slip sole characteristics avoid the fallen risks to older people [8,9].

High heeled shoes are not adapted to the morphological and shape of the foot during the gait cycle [10]. These gait patterns alterations

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https://doi.org/10.1016/j.jtv.2022.12.006
Received 15 July 2022; Received in revised form 28 November 2022; Accepted 19 December 2022
Available online 20 December 2022
0965-206X/

produce low back pain, an increase of the knee and a plantar flexion during the stance phase to get more stability [10–12]. Based on recent published, the cause is not clear about wearing high heeled for long periods of time can produce a risk of suffer knee osteoarthritis [13], but there is an increase of the rate of developing hallux valgus and varus of the fifth toe [14].

Indoor shoes can be described by two types, one is the non-protective footwear where Ugg boot, slipper, back slipper and thong or flip flop and the other type is the protective footwear consist in running shoes, walking shoes and oxford shoes [15].

The footwear assessment tool was designed to advise an appropriate footwear for each situation and patient [16]. Previous studies have demonstrated the relation between the frailty condition in older adults and the health-related quality of life (QoL) [17–19]. In this way, a correct footwear choice advice to prevent foot injuries in patients with frailty and metabolic diseases must be carried out.

The aim of this study was to evaluate the repeatability and reliability of the tool for the assessment of European footwear characteristics through six domains. According to the aim of the study, our hypothesis was if the footwear assessment tool could be repeatability and reliable in Spanish language subjects.

2. Material and methods

The study was performed by two expert podiatrists in footwear assessment with more than 10 years of experience. The study was carried out from January 2022 to Mach 2022 accomplishing all criteria of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [20]. This study was approved by an ethic committee and all the procedures were taken in consideration the ethical standards for human research displayed in the Declaration of Helsinki [21]. Besides, the Ethical Committee of the University of Extremadura approved the study with Registry number: 9/2021.

2.1. Sample size estimation

To estimate the sample size, G* Power 3.1.9.3 software (Heinrich-Heine-Universität Düsseldorf, Germany) was used to test correlation between two paired means regarding correspondence with a Spearman correlation coefficient of 0.40 and a 95% confidence interval (CI) for a two-tailed test, an α error of 0.05 and an estimated analysis power of 80% (error $\beta = 20\%$). For all the analysis, the minimum sample size was of 86 subjects.

2.2. Procedure

The study was developed using the tool for the assessment of footwear characteristics that is composed by five domains and each domain analyze different items respectively [21].

The domain 1 analyzed the Footwear Fit. The items of the fit domain analyzed were the Foot Length (FL) and the Inside Shoe Length (ISL). For the FL the podiatry measured from the longest toe to the distal heel point [22]. This measurement was appointed in millimeters (mm). The ISL was analyzed by the podiatry by two different ways. The first method of the palpation footwear length is the most common according to the literature and the podiatry palp the distance between the longest toe to the front of the shoe [23]. The good measurement must be between 10 and 20 mm. For the second method a flexible plastic straw was employed and measured the length inside the shoe, next the foot length was measured and the difference between these two measures is write down.

The domain 2 analyzed the General Features of the Footwear. In this domain three items were measured. One item was the Weight of the Shoe (WS) and was measured using a digital scale in grams (gr) with a difference of $\pm$ 1 gr. The Length of the Shoe (LS) was the other item, and the measurement was taken from the posterior point of the heel to the most distal side of the toe box. The final item of the domain 2 was the Weight/Length Ratio (WLR) and the measurement was obtained dividing the weight by the length.

The domain 3 analyzed General Structures of the Footwear. The items were composed by the Heel Height (HH), the Forefoot Height (FH), the Longitudinal Profile (LP) and the Last Shape (LSH). The HH measure was annotated as the means of the height laterally and medially from the sole of the heel to the center of the heel sole interface [24]. The FH item was measured from the first metatarsophalangeal joint to the fifth metatarsophalangeal joint and the average is annotated. The average of these measurement was categorized as 0–0.9 cm, 1–2 cm and $>$ 2 cm. The LP can be referred as pitch and this measure is composed by the difference between the forefoot height and the heel height. This item was filed as flat, being the data from 0 to 0.9 cm, small heel rise, from 1 to 3 cm and finally, large heel rise being the measure $>$3 cm. The last item of this domain is the LSH. The data were obtained analyzing the angle obtained by the bisector of the footwear sole between the forefoot and heel areas.

The domain 4 analyzed Motion Control Properties. The Number of Lazes (NL) was noted being the data one, two or three lazes to fix the footwear and the other item was the Motion Control Sub-Scale (MCSS). This item was composed by five items scored. The first item was the Midsole density layers and was categorized as single density being 1 point and dual density, being 2 points. The second item was the Fixation of the footwear. This item was categorized as 0 points when the footwear has no fixation, 1 point when the fixation of the footwear was with alternative laces as strap, Velcro, zip or similar and finally, with 2 points when the fixation was with laces, at least 3 eyelets. The third item was the Heel counter stiffness. This item was categorized as No heel counter with 0 point (no displacement of the heel), Minimal with 1 point, when a displacement was $> 45°$, Moderate with 2 points, when the displacement was $< 45°$ and finally Rigid with 3 points when the displacement was $< 10°$. The fourth item was the Midfoot sagittal stability. The fourth item was the Midfoot sagittal stability. Data obtained were noted as minimal when the torsion was $> 45°$ and was scored as 0 point, moderate when the torsion was $> 45°$ and was scored as 1 point and finally, rigid when the torsion was $< 10°$ and was scored as 2 points. The fifth item was the Midfoot torsional stability. To obtain this measurement the rearfoot and forefoot were caught firmly and twisted the shoe at the midfoot in the frontal plane.

The domain 5 analyzed Cushioning System. One item analyzed was the Midsole hardness with a durometer categorizing as: Hard when the examiner presses with his thumb in the midsole and the pressure variation was $<$0.5 mm, Firm when the pressure variation was between 0.5 mm and 1.5 mm and Soft when the pressure variation was $>$1.5 mm. The other item was the Heel sole hardness with a durometer and was analyzed as the previous item.

2.3. Statistical analysis

The sociodemographic characteristics of the sample size was composed by age, weight, height and Body Mass Index (BMI). These variables were described using standard deviation (SD) and a 95% confidence interval (95% CI).

The Shapiro-Wilk test was used when the distribution of the variables was considered normal with a p value ≥ 0.05. For parametric data the independent t student test and for non-parametric data the Mann-Whitney *U* test were used to analyze the differences between groups. Besides, the paired *t*-test or Wilcoxon signed-rank test was employed for parametric and non-parametric values, severally, for the aim of testing systematic differences among test and retest. A higher coefficient, ranged between 0 and 1, was regarded more uniform for the domain with an excellent option of regarding an individual support variable in the tool.

The study was performed to analyze the reliability and repeatability and calculate the Intraclass Correlation Coefficient (ICC). Regarding

Table 1
Socio-demographic characteristics of the sample population.

	Total group n 101	Men n 46	Women n 55	
	Mean ± SD Range	Mean ± SD Range	Mean ± SD Range	P Value
	N = 101	N = 46	N = 55	
Age (years)	33.021 ± 18.902 (29.326–36.715)	29.1521 ± 15.947 (24.416–33.887)	28.1345 ± 15.874 (24.434–33.889)	0.024
Weight (kg)	64.552 ± 13.703 (61.874–67.230)	66.728 ± 14.528 (62.413–71.042)	67.767 ± 14.456 (62.385–71.042)	0.537
Height (cm)	1.653 ± 0.178 (1.618–1.687)	1.670 ± 0.063 (1.643–1.696)	1.669 ± 0.065 (1.642–1.710)	0.003
BMI (kg/m2)	23.113 ± 4.227 (22.286–23.939)	24.072 ± 5.201 (22.017–26.139)	25.764 ± 5.894 (23.221–28.318)	0.314

Abbreviations: BMI, body mass index; SD, standard deviation. In all the analyses, $P < 0.05$ (with a 95% confidence interval) was considered statistically significant. P-values are from U-Mann-Whitney test.

each dimension, its scores, total scores, ICC and the Cronbach's α were analyzed. This parameter was used to sum up the internal correlations of all items on a scale. Cronbach's α was employed to trace the internal effect of the items in one dimension. According to these analyses, ICCs values were considered as poor (ICCs <0.40), fair (ICCs = 0.40–0.59), good (ICCs = 0.60–0.74), and excellent (ICCs ≥0.75) [25,26].

Correlations were analyzed for all the items for group score. Further, authors analyzed if Cronbach's α was improved by removing any item. Correlations of the items were calculated with the total score employing non-parametric Spearmen test or parametric Pearson test.

Bland-Altman plots were analyzed to check heteroscedasticity and agreement [27].

According to each item and domain scores the reliability, correlation and internal consistence were calculated using Spearman (r_s), ICC and Cronbach's α, respectively. Internal consistency was assessed by Cronbach's α and used to outline the internal consistency of each item of the dimension. Internal consistency above 0.7 was acceptable.

The statistical software IBM SPSS ver. 20.0 (Windows; IBM Co., Chicago, IL, USA) was used to carry out all statistical analyses. Significance level was set at $p < 0.05$.

3. Results

The sociodemographic variables weight and BMI showed a normal distribution ($p > 0.05$) and the age and height showed a non-normal distribution ($p < 0.05$).

The sociodemographic results are displayed in Table 1.

The total results and every dimension analyzed during the test and retest displayed a non-normal distribution ($p < 0.05$); hence, the distribution was calculated using the non-parametric paired Wilcoxon signed rank test for test systematic differences among the test and retest showed in Table 2.

3.1. Test-retest analyses

Test-retest reliability data and systematic differences of the Footwear Assessment Tool by items and total scores are shown in Tables 2 and 3. A suitable Cronbach's α was suggested for the five domains of fit [α = 0.952, IC 95% = (0.938–0.970)], general features [α = 0.953, IC 95% = (0.876–0.960)], general structure [α = 0.947, IC 95% = (0.945–0.956)], motion control properties [α = 0.951, IC 95% = (0.948–0.969)] and cushioning system [α = 0.951, IC 95% = (0.944–0.988)]. The Spearman's correlation (r_s) among test-retest were suitable for foot length (r = 0.892), inside shoe (r = 0.765), footwear weight (r = 0.909), footwear length (r = 0.920), footwear weight/length ratio (r = 0.855), heel height (r = 0.941), forefoot height (r = 0.814), longitudinal profile (r = 0.892), last shape (r = 0.896), number of laces (r = 0.946), motion control subscale (r = 0.904), midsole durometer (r = 0.794) and heel sole durometer (r = 0.900).

No systematic differences were shown for each domain ($p > 0.05$) and for the item total correlation only forefoot height shown systematic difference with a p = 0.011.

Fig. 1 display the Bland – Altman graphs for the agreement between test and retest for the individual subscales and the total score of the dimensions. The analysis of the difference among the means of each test within the 95% confidence interval in all dimensions.

4. Discussion

This study was carried out to evaluate the repeatability and reliability of the tool for the assessment of European footwear characteristics through six domains. Based on the results of the research, the footwear assessment tool can be employed as a valid tool to measure the footwear characteristics as fit, general features, general structure,

Table 2
Results of test-retest reliability, Item–total correlation and systematic differences of the Footwear Assessment Tool according to each domain.

	Test (N = 101)			Retest (N = 101)			Correlation	Reliability	Systematic differences
							Test-retest	Test-retest	Test-retest
Domain	Mean ± SD (95% CI)	Item–total correlation r (P)*	Alpha if item removed	Mean ± SD (95% CI)	Item–total correlation r (P)*	Alpha if item removed	Item–total correlation r (P)*	Alpha if item removed ICC (IC 95%)	P value
Fit	331.232 ± 56.389 (320.211–342.252)	0.792 (<0.01)	0.796	332.463 ± 62.847 (320.181–344.746)	0.839 (<0.01)	0.796	0.792 (<0.01)	0.952 (0.938–0.970)	0.312
General features	585.178 ± 166.879 (552.563–617.792)	0.903 (<0.01)	0.793	600.016 ± 154.791 (569.764–630.269)	0.897 (<0.01)	0.756	0.914 (<0.01)	0.953 (0.876–0.960)	0.695
General Structure	8.015 ± 1.650 (7.693–8.338)	0.944 (<0.01)	0.806	7.908 ± 1.701 (7.575–8.240)	0.932 (<0.01)	0.806	0.965 (<0.01)	0.947 (0.945–0.956)	0.068
Motion control Properties	8.504 ± 2.477 (8.020–8.988)	0.898 (<0.01)	0.806	8.561 ± 2.301 (8.112–9.011)	0.875 (<0.01)	0.806	0.865 (<0.01)	0.951 (0.948–0.969)	0.625
Cushioning system	1.402 ± 1.002 (1.201–1.598) Total Cronbach alpha test: 0.911	0.847 (<0.01)	0.806	1.460 ± 0.986 (1.267–1.653) Total Cronbach alpha retest: 0.914	0.824 (<0.01)	0.806	0.935 (<0.01)	0.951 (0.944–0.988)	0.280

Abbreviations: SD, Standard Deviation; CI 95%; Confidence Interval 95%; ICC, Intraclass Correlation Coefficient; * Spearmen test; ** Wilcoxon signed-rank test. P value < 0.05 are considered significative.

Table 3
Results of test-retest reliability, Item–total correlation and systematic differences of the Footwear Assessment Tool according to each item.

	Test (N = 101)			Retest (N = 101)			Correlation	Reliability	Systematic differences
							Test-retest	Test-retest	Test-retest
Item	Mean ± SD (95% CI)	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Mean ± SD (95% CI)	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	r (P)*	ICC (IC95%)	P value
Item1: Foot length (mm)	241.965 ± 29.519 (236.195–247.734)	0.776 (<0.01)	0.798	238.740 ± 370.335 (231.503–245.978)	0.722 (<0.01)	0.796	0.892 (<0.01)	0.868 (0.805–0.911)	0.783
Item2: Inside shoe length (straw)	89.376 ± 40.785 (81.405–97.347)	0.803 (<0.01)	0.803	93.870 ± 41.176 (858.227–101.917)	0.791 (<0.01)	0.804	0.765 (<0.01)	0.762 (0.650–0.840)	0.059
Item 3: Footwear Weight (gr)	343.847 ± 145.883 (315.336–372.359)	0.919 (<0.01)	0.776	359.116 ± 129.099 (333.884–384.347)	0.902 (<0.01)	0.769	0.909 (<0.01)	0.922 (0.884–0.947)	0.432
Item 4: Footwear Length (mm)	240.094 ± 61.0149 (228.169–252.019)	0.346 (<0.01)	0.793	239.570 ± 61.551 (227.541–251.600)	0.416 (<0.01)	0.792	0.920 (<0.01)	0.958 (0.938–0.971)	0.987
Item 5: Footwear Weight/length ratio	1.6545 ± 1.369 (1.386–1.922)	0.622 (<0.01)	0.806	1.712 ± 1.283 (1.461–1.963)	0.563 (<0.01)	0.806	0.855 (<0.01)	0.979 (0.969–0.986)	0.604
Item 6: Heel height	1.908 ± 0.709 (1.770–2.046)	0.750 (<0.01)	0.806	1.928 ± 0.680 (1.795–2.061)	0.752 (<0.01)	0.806	0.941 (<0.01)	0.969 (0.954–0.979)	0.464
Item 7: Forefoot height	2.662 ± 0.564 (2.551–2.777)	0.526 (<0.01)	0.806	2.564 ± 0.629 (2.441–2.687)	0.545 (<0.01)	0.806	0.814 (<0.01)	0.885 (0.830–0.922)	0.011
Item 8: Longitudinal profile	1.624 ± 0.6596 (1.495–1.753)	0.716 (<0.01)	0.806	1.594 ± 0.649 (1.467–1.721)	0.732 (<0.01)	0.806	0.892 (<0.01)	0.946 (0.921–0.964)	0.251
Item 9: Last shape	1.828 ± 0.516 (1.727–1.929)	0.474 (<0.01)	0.806	1.828 ± 0.5349 (1.724–1.933)	0.493 (<0.01)	0.806	0.896 (<0.01)	0.944 (0.917–0.962)	1.000
Item 10: Number of laces	1.866 ± 0.405 (1.783–1.945)	0.313 (<0.01)	0.806	1.8474 ± 0.443 (1.760–1.934)	0.315 (<0.01)	0.806	0.946 (<0.01)	0.943 (0.916–0.962)	0.593
Item 11: Motion Control Sub-Scale	6.641 ± 2.360 (6.179–7.102)	0.988 (<0.01)	0.806	6.7178 ± 2.198 (6.283–7.147)	0.990 (<0.01)	0.806	0.904 (<0.01)	0.948 (0.923–0.965)	0.500
Item 12: Midsole Durometer	0.505 ± 0.570 (0.394–0.617)	0.838 (<0.01)	0.806	0.5453 ± 0.6187 (0.424–0.662)	0.848 (<0.01)	0.806	0.794 (<0.01)	0.859 (0.792–0.905)	0.280
Item 13: Heel Sole Durometer	0.898 ± 0.619 (0.777–1.019)	0.827 (<0.01)	0.806	0.9177 ± 0.606 (0.799–1.036)	0.830 (<0.01)	0.806	0.900 (<0.01)	0.945 (0.919–0.963)	0.450

Abbreviations: SD, Standard deviation; 95% CI; 95% confidence interval; ICC, Intraclass Correlation Coefficient; N/A, not applicable; * Spearman (r_s) test; ** Wilcoxon signed-rank test. P value < 0.05 are considered as statistically significant

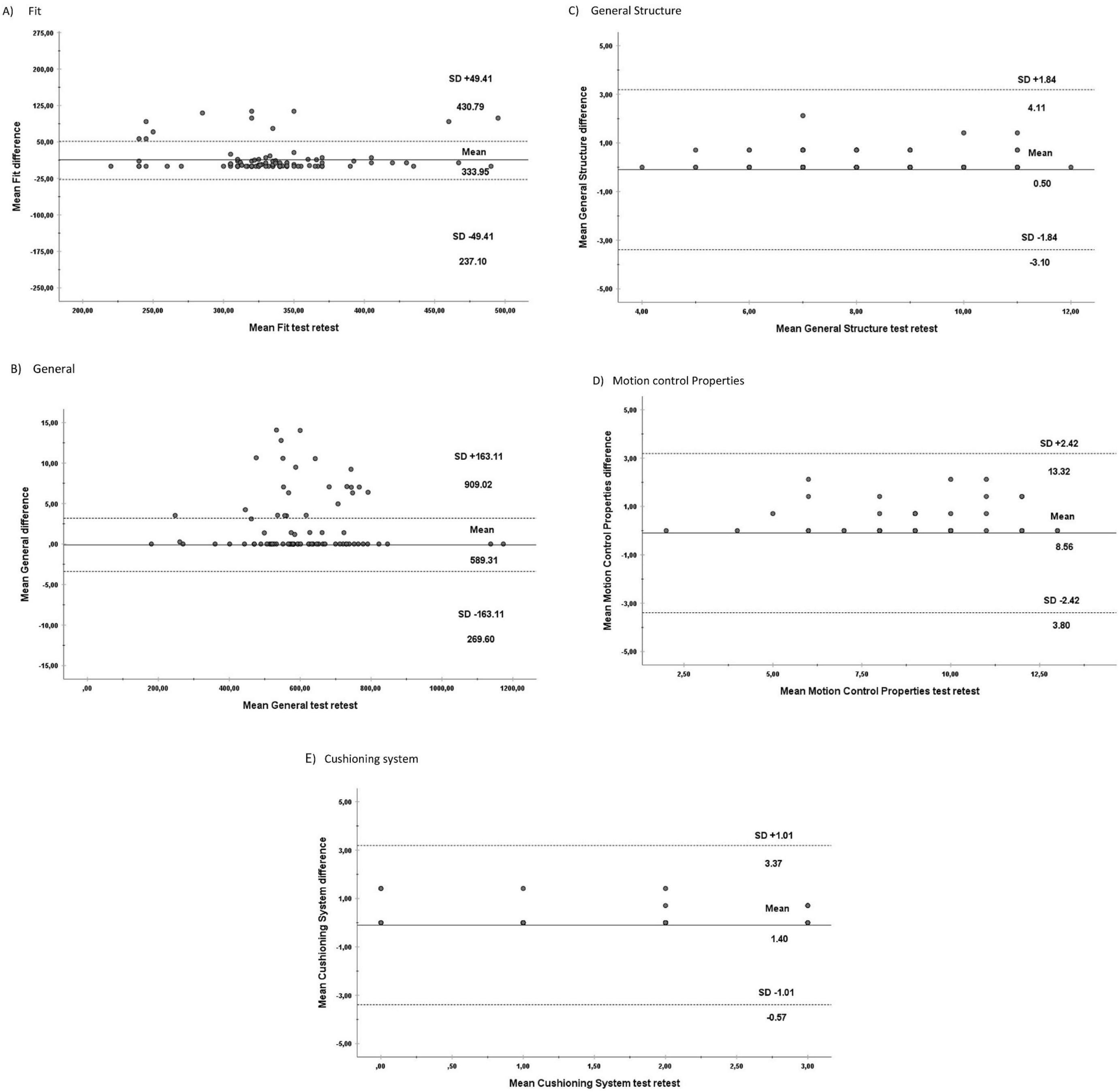

Fig. 1. Bland–Altman plot showing the agreement between test and retest for the individual subscales and the total score. Dimensions: A) Fit, B) General, C) General Structure, D) Motion control Properties, E) Cushioning system. A) Fit.

motion control properties and cushioning system.

Inappropriately sized footwear is one of the mains falls in older people and development of different foot disorders [28,29]. The research performed by O'Rourke and cols observed that there was a difference measure between the shoe length and the foot length of 18.6 mm. This difference in measurements caused an inadequate fit of the footwear being a risk of falling [30]. Inadequate shoe fit may increase risks in Parkinson disease patients decreasing the foot health and quality of life [31,32]. In our research, we obtained high reliability in the fit domain, being appropriate to avoid diseases in subject perform the footwear assessment tool.

For the general features domain our research demonstrates an excellent reliability. The footwear weight has an influence in the gait patterns runners decreasing the jump height affecting in the performance and training [33]. Lin Wang and cols conducted a research using the same running shoes but with different weights for all participants and concluded that heavier running shoes decreased calf muscle contribution and was significantly different during the braking phase [34].

Stable footwear is an important factor with influence in the kinematic and kinetic alterations in the lower limb muscle function [35]. Heel height variation, as heelless shoes, unstable shoes and running shoes, increase blood flow and venous return in lower limb [36–38]. In the general structure domain, the heel height item showed no statistical difference in the results and has an important clinical relevance.

The use of footwear with stiffness heel counter produces a great motion control, affecting in the rearfoot motion, and frontal and sagittal plane stability is important in the motion control through the midfoot.

Motion control running shoes avoid the injury risk decreasing the fatigue caused by an increase in kinematic loading in the initial contact phase period in pronated runners [39]. On the other hand, Holowka et cols. related a comparative between barefoot and conventional modern footwear people concluding who wear barefoot has a longitudinal arch stiffness both in standing position and dynamic and an increase in the cross-sectional area of intrinsic muscle compared to people who wear conventional shoes [40] Regarding to our findings the motion control properties domain showed no systematic differences.

Nowadays, different kind of shoe lacing exists in numerous footwears. Hadi Rahemi et cols. concluded in their research that a shoe lacing closure technical has an effect in the plantar thermal response being the self-adjusted lace closure not appropriate with subjects with metabolic disorders as plantar ulcers [41]. In our study, the motion control properties domain results can be related to the footwear tool showing a Cronbach's α of 0.951.

Previous research performed by Navarro Flores et al. evaluated the repeatability and reliability of a diabetic foot self-care questionnaire in Arabic subjects and concluded that the questionnaire in Arabic language was considered strong and valid in that language [42]. Otherwise, Martínez Jiménez et al. concluded that the rheumatoid arthritis foot disease activity index questionnaire in Spanish subjects was valid and strong in Spanish population [43]. In order to our research, the tool for the assessment European footwear is a suitable repeatability and reliability footwear tool that can be used in Spanish language subjects.

In our research, the footwear assessment tool participants were young adult (33.021 ± 18.902) but no older adult, influencing in the type of footwear the used to wear. Another limitation of our research was the item forefoot height that shown systematic differences. This limitation could be influenced by the age of the participants.

5. Conclusions

The tool for the assessment European footwear is a suitable repeatability and reliability footwear tool that can be used in Spanish patients and can be advice in the proper choice of footwear based on the respective five dimensions such fit, general features, general structure, motion control properties and cushioning system.

Declaration of competing Interest

The authors have declared no conflict of interest.

Acknowledgements

No fundings were used in the research.

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