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Effects of Minimalist Footwear on Postural Stability, Plantar Footprint, and Safety in Healthy Adults: A Single-Blind Randomized Clinical Trial

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Abstract

This study evaluated the long-term changes induced by wearing minimalist footwear (MF) during activities of daily living (ADLs) on the plantar footprint and postural stability in healthy adults. In this randomized clinical trial, a total of 95 healthy adults were recruited; 90 participants completed the protocol and were analyzed in either an experimental group (EG, $n = 45$), which wore MF for at least 5 h per day over a 6-month period, or a passive control group (CG, $n = 45$). Plantar pressure distribution (forefoot, rearfoot, and total contact areas), static stability (center of pressure (CoP) displacement under open-eyes and closed-eyes conditions), and dynamic stability (forward reach test) were assessed using a force platform at baseline and post-intervention. A self-reported questionnaire and an adverse event record were also completed by the EG. Statistical analysis was carried out using a repeated-measures analysis of variance (ANOVA) and a paired Student's *t*-test; statistical significance level was set at $p < 0.05$. The Group × Time interaction analysis revealed no statistically significant between-group differences across the evaluated parameters. However, within-group analysis showed a significant increase in CoP displacement under the open-eye condition in the CG ($p = 0.037$), indicating a decline in baseline postural efficiency, whereas the EG maintained structural and posturographic stability. Regarding user feedback, comfort (44.4%) was highlighted as the primary advantage, aesthetics (77.8%) was the main drawback, and 70% of the participants intended to continue using MF. Only two minor, transient adverse events were recorded. In conclusion, a 6-month program of MF use during ADLs did not produce any statistically significant changes in plantar footprint or stability in healthy adults.

Keywords: minimalist footwear; barefoot; intrinsic foot muscles; foot core; stability; footprint

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1. Introduction

Epidemiological data indicate that over 80% of the modern shod population habitually wears conventional footwear, which significantly influences foot morphology, arch typology, and gait kinematics. In shod populations, rearfoot strike patterns predominate in up to 95% of individuals during locomotion. Conversely, habitual barefoot or minimally shod populations demonstrate a higher prevalence of midfoot or forefoot strike patterns, wider forefoot morphology, and a markedly lower prevalence of structural flatfoot (1–4% vs. up to 30% in shod cohorts) [1]. These epidemiological differences highlight how footwear design modulates foot type and biomechanical function, contextualizing the fundamental importance of the "Foot Core System".

The "foot core" paradigm defines the integrated anatomical and functional framework responsible for dynamic stabilization and foot control. Optimal function of this system relies on the biomechanical interaction among three constituent subsystems [2]:

- Passive subsystem: This comprises the osteoarticular structures, joint capsules, and ligamentous tissues (including the plantar fascia) that form the foot architecture. This structural base is delineated by the medial and lateral longitudinal arches, as well as the anterior and posterior transverse arches.
- Active subsystem: This encompasses the intrinsic foot muscles (IFMs) and extrinsic musculature, which function synergistically to provide local stabilization and global mobilization of the foot, respectively.
- Neural subsystem: This consists of the mechanoreceptive network located within the capsuloligamentous and musculotendinous tissues, alongside the specialized plantar cutaneous sensory receptors.

Within the foot core architecture, functional deficits in the IFMs disrupt dynamic arch stabilization and load distribution, triggering specific pathomechanical cascades. In healthy adults during daily activities, chronic IFM insufficiency reduces the foot's ability to absorb repetitive ground reaction forces, predisposing individuals to plantar fasciitis and hallux valgus through altered stress distribution across the tarsal and metatarsophalangeal joints. In athletic populations, foot core dysfunction severely compromises energy storage and kinetic energy transfer during the push-off phase of running and jumping. This microtraumatic overloading not only elevates the risk of overuse injuries—Achilles tendinopathy, medial tibial stress syndrome, and chronic ankle instability—but also dampens agility, running economy, and dynamic balance, directly impairing overall sports performance [3].

Consequently, morphological or functional deficits in the IFMs have been implicated in the etiology of various lower limb disorders, including plantar fasciitis [4,5], hallux valgus [6–8], hammer toes [9], Achilles tendinopathy [10], and chronic ankle instability [11].

Similarly, the integrity of the neural subsystem is indispensable for lower extremity function. Plantar cutaneous sensitivity acts as a pivotal mediator in static and dynamic postural control [12,13]. This sensory mechanism holds clinical and practical relevance for both athletic performance optimization and therapeutic interventions targeting balance deficits.

Modern conventional footwear induces noticeable structural and functional alterations within the foot core. Traditional shoe designs often restrict digital mobility, which is crucial for maintaining postural balance and facilitating the anterior progression of the body's center of pressure (CoP) during the propulsive phase of gait [14]. Furthermore, as highlighted by Johnson et al. [15], conventional footwear promotes IFM atrophy, attenuates tactile and proprioceptive input, and reduces the mechanical loading required for bone mineral density preservation, as the shoe structure dampens ground reaction forces.

Comparative studies between habitually barefoot populations and shod individuals highlight significant morphological and functional differences:

- Plantar pressure distribution: Unshod cohorts exhibit broader foot morphology and a more uniform pressure distribution across the plantar surface. In contrast, shod individuals display localized pressure peaks at the calcaneus, metatarsal heads (2nd–4th), and hallux [16].

- Arch integrity: Barefoot individuals demonstrate greater medial longitudinal arch height and stiffness, with a flatfoot prevalence of only 1% compared to 31% in shod populations [17].
- Exercise responsiveness: Korchi et al. [18] observed that a 3-month exercise program (focusing on strength and endurance) yielded significantly greater functional improvements in older adults when performed barefoot rather than shod.

Extreme or prolonged shoe-induced alterations have even led to descriptions of the "bound foot Chinese syndrome" [19], characterized by dorsal toe callosities, nail hyperkeratosis, interdigital narrowing, and lateral digital deviations accompanied by metatarsophalangeal subluxation.

Undoubtedly, footwear serves an essential environmental protection and comfort role in modern society [14], particularly in clinical contexts (e.g., ulcer prevention in diabetic patients) and specific sports applications. However, current evidence indicates that conventional footwear frequently compromises natural foot morphology and biomechanics, as aesthetic and fashion trends often supersede functional design parameters. Given these structural and functional drawbacks, the adoption of minimalist footwear (MF) as an alternative to conventional shoe design is biomechanically and clinically justified.

MF exhibits several characteristics that differentiate it from conventional footwear, including [15]:

- Lack of stabilizing elements in the midfoot, rendering both the sole and the last completely flexible, thereby not limiting normal foot mobility.
- The forefoot is very wide, allowing lateral expansion of the toes.
- Drop zero: MF is flat, that is, there is minimal heel-to-toe drop between the rearfoot and the forefoot. This characteristic enables a more natural foot strike and improved alignment of the lower extremities, while simultaneously avoiding shortening of the triceps surae.
- It features a uniform sole thickness of 3–4 mm, which enhances the stimulation of plantar cutaneous receptors. Thin and firm soles allow for better stability and balance compared to footwear with thicker and cushioned soles [14].

Growing empirical evidence demonstrates the biomechanical advantages of MF relative to traditional footwear designs. A systematic review conducted by Franklin et al. [20] identified distinct variations in both gait kinetics and kinematics when walking in MF compared to conventional footwear, establishing alterations in plantar pressure distribution as the most significant biomechanical outcome. When applied to running, the adoption of MF offers notable structural and muscular adaptations:

- Neuromuscular and morphological enhancements: Running in MF has been shown to induce intrinsic foot muscle (IFM) hypertrophy [21,22], augment toe flexor strength [23], and optimize overall plantar arch function [22].
- Musculoskeletal considerations: Despite these functional adaptations, running in MF may pose clinical risks if implemented without adequate preparation. Specifically, bone marrow edema has been reported in up to 50% of individuals transitioning to running in MF [15,24].

Consequently, a structured and gradual adaptation period is strongly advised when incorporating MF into running regimens to mitigate overuse injury risk while capitalizing on its biomechanical benefits.

In summary, the current scientific literature demonstrates the harmful effects that conventional footwear can exert on foot morphology and function. On the other hand, MF appears to be a viable alternative to conventional footwear, as it allows for a more natural stride while avoiding the problems derived from walking barefoot. There is evidence regarding the short-term effects of MF use, particularly during running; however, few studies have assessed the long-term effects during activities of daily living (ADLs). While direct structural adaptations of the IFMs (such as muscle volume or cross-sectional area) require imaging modalities, functional adaptations of the active and sensory subsystems manifest globally through changes in ground force distribution and balance control. Therefore, evaluating plantar footprint parameters and posturographic center of pressure (CoP) displacement provides functional surrogate markers of Foot Core System integration during daily activities.

Considering the aforementioned, the main objective of this study was to evaluate the long-term changes induced by the use of MF during ADLs, compared to traditional footwear, on the plantar footprint and postural stability in healthy adults. The secondary objective was to collect adverse events and subjective perceptions associated with the use of MF.

The hypothesis of this study is that long-term use of MF can modify foot structure and, consequently, plantar footprint; furthermore, these changes may be associated with improved postural stability.

2. Materials and Methods

2.1. Design

A randomized single-blind clinical trial was conducted at the FisioSport Salamanca physiotherapy center, in conformity with the Consolidated Standards of Reporting Trials (CONSORT) requirements [25]. The study was carried out following the Declaration of Helsinki; all the participants agreed to participate and read and signed the informed consent by themselves. The study has been approved by the Ethics Committee of the University of Salamanca (registration number 1333) and was registered in the United States Randomized Trials Register on clinicaltrial.gov (NCT07452718; https://clinicaltrials.gov/study/NCT07452718 (accessed on 5 March 2026).

2.2. Sample Size Calculation

The sample size calculation analysis was performed using G*Power version 3.1.9.2 (G*Power©, Universidad de Dusseldorf, Düsseldorf, Germany); considering a medium effect size (Cohen d = 0.501) for a one-tail hypothesis, a between-groups proportion of N/n = 1, and a power (1 − β error probability) of 0.80 with an α level of 0.05, the minimum sample size required was 80 participants.

2.3. Participants

Patients' recruitment was carried out between April and November 2025, following the sequential sampling method. Participants were randomly assigned to a control group or intervention group.

Inclusion and Exclusion Criteria

The sample consisted of healthy adults who met the following inclusion criteria:

- Being over 18 years of age.
- Signing of the informed consent form.
- Having no foot or ankle pain within the three months prior to the start of the study.
- Absence of musculoskeletal pathology, such as fractures, sprains, or dislocations, within the six months prior to the start of the study.

Likewise, individuals presenting any of the following exclusion criteria were excluded from the study:

- Previous use of MF.
- Cognitive, neurological, visual, or vestibular disorders that could affect the outcome of any of the variables included in the study.

The sample was divided into two groups: the experimental group, which underwent the intervention using MF, and the control group, which remained passive.

2.4. Outcome Measures

Socio-demographic and descriptive data were collected. Descriptive data comprises age, sex (male or female), height (m), weight (Kg) and body mass index (BMI-Kg/m^2).

Plantar pressure distribution and static and dynamic stability were measured prior to and following the completion of the six-month intervention period. These variables were evaluated by one of the members of the research team (DGG) who was blinded to the group to which the participants had been assigned.

The three variables were assessed using a force platform (FreeMed™, SensorMedica, Roma, Italy; Software FreeStep 2.0 Essential), which represents a validated and reliable instrument for the measurement of these outcomes [26].

For the footprint assessment, the subjects were instructed to maintain a static, upright standing position in a comfortable, stable, and natural posture, with their arms at their sides, gaze fixed ahead, and feet shoulder-width apart. This position was maintained for 60 s while the equipment recorded the measurements [27]. The assessment of the plantar footprint consisted of determining the contact area of the forefoot, rearfoot, and total foot area, measured in cm^2. Electronic baropodometry has been widely validated as a reliable and reproducible digital tool for the quantitative assessment of plantar footprints and plantar pressure distribution [28].

For the assessment of static stability, participants stood barefoot on the pressure platform, with their feet shoulder-width apart, the upper limbs positioned along the trunk and gazing straight ahead. They were instructed to maintain stability in a double-leg stance for 30 s, and the displacement of the CoP was recorded. Measurements were taken under both open-eye and closed-eye conditions [29]. A greater displacement of the CoP is associated with poorer static stability. The measurement was performed three times for each condition, and the highest value was selected for data analysis. A 60-s rest period was provided between trials to prevent postural fatigue. The assessment of static stability using a force platform has been described as a valid method with good-to-excellent reliability (CCI 0.79.0.91) [30].

Dynamic stability was assessed using a forward reach test. Subjects stood in a bipedal stance with their arms resting alongside the trunk and opened eyes. They were instructed to lean their trunk forward as far as possible without lifting their heels off the ground [31]. This test measures the anterior displacement of the CoP. The trial was performed three times, and the maximum value was selected for subsequent data analysis. Force platforms represent a valid and reliable instrument (ICC = 0.79–0.84) for assessing dynamic stability [32].

In addition to these measurements, a survey was administered to the subjects in the experimental group. This questionnaire was used to evaluate various aspects regarding the use of the MF utilized during the intervention. The questions included in the survey were as follows:

- Indicate which feature of the MF you consider to be the most positive.
- Indicate which feature of the MF you consider to be the most negative.
- Do you intend to continue using MF on a regular basis after the completion of the study?
- Indicate your overall level of satisfaction regarding the use of the MF provided during the study.

Furthermore, adverse events reported by the participants in the experimental group during the intervention period were recorded.

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2.5. Intervention

The intervention for the experimental group consisted of wearing minimalist footwear during ADLs. Participants were recommended to wear the minimalist shoes for at least five hours per day for 6 months. The footwear utilized in this study was the Saguaro Fast I model (SAGUARO shoes, Fujian, China). Based on the Minimalist Index scale [33], this shoe scores 76% and meets all the defining criteria of MF: a wide forefoot toe box, zero heel-to-toe drop, a fully flexible 5 mm thick sole, and an approximate weight of 189 g. An image of the footwear utilized by the subjects in the intervention group is provided (Supplementary S1).

The footwear was to be used during daily activities such as household chores, walking, or gym workouts. Participants were advised against using the minimalist footwear for high-impact activities, such as running or sports involving jumping.

At the beginning of the intervention period, a transition phase to the minimalist footwear was implemented to mitigate the risk of injury or other discomforts.

The transition protocol is described below:

- Week 1: 1 h per day, restricted to indoor activities.
- Week 2: 2 h per day, including outdoor activities for up to 30 min.
- Week 3: 3 h per day, including outdoor activities for up to 1 h.
- Week 4: 4 h per day, including outdoor activities for up to 2 h.

Adherence to the guidelines and monitoring of minimalist footwear usage among the intervention group participants was supervised by a member of the research team (JJAO).

The control group was passive. Participants were only instructed to refrain from using minimalist footwear during the study's follow-up period.

The study logistics is presented as a figure (Supplementary S2).

2.6. Statistical Analysis

Statistical Package for the Social Sciences (SPSS) version 25.0 for Windows (IBM Corporation; Armonk, NY, USA) was used for statistical analysis.

A descriptive analysis of all variables was performed. Since all continuous variables met the assumption of normality (verified via Kolmogorov–Smirnov test), they were expressed as mean ± standard deviation (SD); qualitative variables were presented as absolute frequencies and percentages. Homogeneity of variance was verified using the Levene's tests. To assess baseline comparability between the experimental and control groups, an independent samples Student's *t*-test was used for continuous variables, and a chi-squared (χ^2) test was applied to categorical variables. Within-group comparisons between pre- and post-intervention measurements were conducted using a paired Student's *t*-test. Additionally, effect size was calculated using Cohen's *d* and interpreted as small (0.20), moderate (0.50), or large (0.80). To evaluate the effect of the intervention, the Group × Time interaction was analyzed using a repeated-measures analysis of variance (ANOVA) with a within-subject factor (time: pre and post) and a between-subject factor (group: experimental and control). All statistical analyses were performed with a 95% confidence interval, and the significance level was set at $p < 0.05$.

3. Results

The sample consisted of 95 participants who met all selection criteria. However, during the follow-up period, two subjects from the control group were excluded (due to the adoption of minimalist footwear), and three from the experimental group were excluded (owing to non-compliance with the usage guidelines proposed for the study). A total of 90 participants completed the study (45 in the control group and 45 in the intervention group). The sample recruitment process is depicted in the flow diagram (Supplementary S3). The detailed description of the demographic variables is shown in Table 1.

Table 1. Baseline demographic variables of the sample.

Variable	EG (*n* = 45)	CG (*n* = 45)	*p*	Effect Size	95% CI
Age (years) *	38.49 ± 11.68	35.78 ± 11.77	0.276	d = 0.23	[−2.20,7.62]
Height (cm) *	167.64 ± 8.43	170.09 ± 10.77	0.234	d = −0.25	[−6.50,1.60]
Weight (kg) *	65.73 ± 13.73	68.93 ± 15.24	0.298	d = −0.22	[−9.28,2.88]
BMI (kg/m^2) *	23.26 ± 3.68	23.63 ± 3.26	0.612	d = −0.11	[−1.83,1.09]
Gender, *n* (%) †	F: 30 (66.7) M: 15 (33.3)	F: 29 (64.4) M: 16 (35.6)	1		

Values are presented as mean ± standard deviation for continuous variables and absolute frequencies (percentages) for categorical variables. EG: experimental group; CG: control group; BMI: body mass index; F: female; M: male; CI: confidence interval of the mean difference; d: Cohen's d. * Tested using independent samples Student's *t*-test. † Tested using chi-squared test.

3.1. Footprint

No statistically significant changes were observed in plantar pressure distribution following the follow-up period in either group.

In the experimental group, the forefoot contact area increased from 18.43 ± 8.03 cm^2 to 19.79 ± 7.87 cm^2, without reaching statistical significance (p = 0.262; d = 0.18). Similarly, the rearfoot load-bearing area decreased slightly from 32.93 ± 8.91 cm^2 to 31.76 ± 8.37 cm^2 (p = 0.432; d = −0.12). The total contact area remained virtually unchanged between both evaluations (51.36 ± 6.26 cm^2 vs. 51.60 ± 5.99 cm^2; p = 0.834).

Likewise, no significant modifications were detected in any of the analyzed variables within the control group. The forefoot contact area shifted from 18.91 ± 6.03 cm^2 to 19.09 ± 7.46 cm^2 (p = 0.843), whereas the corresponding rearfoot area remained stable (31.60 ± 5.75 cm^2 vs. 31.58 ± 8.81 cm^2; p = 0.984). The total contact area also showed no relevant changes (50.49 ± 5.06 cm^2 vs. 50.58 ± 6.39 cm^2; p = 0.915).

3.2. Static Stability

In the eyes-open condition, the experimental group showed a non-significant reduction in the CoP displacement, decreasing from 383.74 ± 465.58 to 334.30 ± 313.67 mm (p = 0.511; d = −0.10). Conversely, the control group presented a significant increase in this variable, rising from 245.38 ± 191.00 to 331.88 ± 273.15 mm (p = 0.037), with a small-to-moderate effect size (d = 0.33).

Regarding the eyes-closed condition, the experimental group exhibited a trend toward a decrease in postural displacement (262.91 ± 315.27 vs. 179.80 ± 193.22), although it did not reach statistical significance (p = 0.107; d = −0.25). In the control group, a significant reduction in postural sway was observed, dropping from 275.93 ± 351.89 to 165.22 ± 140.66 mm (p = 0.049), with a small effect size (d = −0.31). A representative example of the static stability evaluation results is shown in Supplementary S4.

3.3. Dynamic Stability

The antero-posterior dynamic stability showed no significant change post-intervention. In the experimental group, the reach distance was 141.66 ± 26.66 mm at baseline and 140.51 ± 26.93 mm at the final evaluation (p = 0.734; d = −0.06). Similarly, the control group showed a non-significant reduction in test values, decreasing from 144.54 ± 24.39 mm to 137.07 ± 23.39 mm (p = 0.149; d = −0.25).

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Taken together, these results indicate that the use of minimalist footwear did not produce significant modifications in either plantar load distribution or dynamic balance. However, significant changes were observed in certain static postural control variables within the control group, whereas the experimental group maintained relatively stable values throughout the follow-up period.

The results corresponding to all analyzed variables are detailed in Table 2.

Table 2. Pre–post-intervention comparison within each group.

Variable	Group	Pre (Mean ± SD)	Post (Mean ± SD)	*p*	Effect Size	95% CI
FCA (cm^2) *	EG	18.43 ± 8.03	19.79 ± 7.87	0.262	d = 0.18	[−1.05,3.77]
	CG	18.91 ± 6.03	19.09 ± 7.46	0.843	d = 0.03	[−1.64,2.00]
RCA (cm^2) *	EG	32.93 ± 8.91	31.76 ± 8.37	0.432	d = −0.12	[−4.14,1.80]
	CG	31.60 ± 5.75	31.58 ± 8.81	0.984	d = 0.00	[−2.02,1.98]
TCA (cm^2) *	EG	51.36 ± 6.26	51.60 ± 5.99	0.834	d = 0.03	[−2.05,2.53]
	CG	50.49 ± 5.06	50.58 ± 6.39	0.915	d = 0.02	[−1.60,1.78]
Static stability-OE (mm) *	EG	383.74 ± 465.58	334.30 ± 313.67	0.511	d = −0.10	[−199.80,100.92]
	CG	245.38 ± 191.00	331.88 ± 273.15	**0.037**	d = 0.33	[5.46,167.54]
Static stability-CE (mm) *	EG	262.91 ± 315.27	179.80 ± 193.22	0.107	d = −0.25	[−184.90,18.68]
	CG	275.93 ± 351.89	165.22 ± 140.66	**0.049**	d = −0.31	[−220.9,−0.51]
Dynamic stability (mm) *	EG	141.66 ± 26.66	140.51 ± 26.93	0.734	d = −0.06	[−7.93,5.63]
	CG	144.54 ± 24.39	137.07 ± 23.39	0.149	d = −0.25	[−17.72,2.78]

Pre: pre-intervention; Post: post-intervention; SD: standard deviation; FCA: forefoot contact area; RCA: rearfoot contact area; TCA: total contact area; OE: open eyes; CE: closed eyes. CI: confidence interval of the mean difference; d: Cohen's d. * Tested using independent samples Student's *t*-test. Values in bold indicate statistically significant differences.

3.4. Between-Group Differences

The Group × Time interaction analysis revealed no statistically significant differences between the experimental and control groups across any of the analyzed variables.

Regarding the forefoot contact area, the experimental group exhibited a mean decrease of 0.29 cm^2, whereas the control group showed a reduction of 0.95 cm^2. The comparison of these observed changes between groups did not reach statistical significance ($p > 0.05$). Similarly, the rearfoot contact area decreased by 1.67 cm^2 in the experimental group and 1.12 cm^2 in the control group, with no significant differences between the two cohorts ($p > 0.05$). Furthermore, the total contact area was reduced by 1.93 cm^2 in the experimental group and 2.14 cm^2 in the control group, demonstrating no differential effect attributable to the intervention.

With respect to static postural control in the eyes-open condition, the experimental group showed a mean decrease of 55.24 mm, while the control group exhibited an increase of 86.50 mm. Despite the apparent divergence in the direction of change, the statistical analysis revealed no significant Group × Time interaction ($F = 2.35$; $p = 0.131$). In the eyes-closed condition, both groups experienced a reduction in postural sway; the experimental group decreased by 83.12 mm and the control group by 110.71 mm, showing no significant differences between the observed changes ($F = 0.14$; $p = 0.712$).

Finally, dynamic stability assessment revealed a mean reduction of 1.40 mm in the experimental group and 5.74 mm in the control group. However, the intergroup comparison again yielded no significant differences ($F = 0.60$; $p = 0.443$).

Collectively, these findings indicate that the clinical progression of participants utilizing minimalist footwear was comparable to that observed in the control group over the

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follow-up period. No specific effects attributable to the intervention were identified regarding plantar pressure distribution, static postural control, or dynamic balance.

Between-group differences are summarized in Table 3.

Table 3. Between-group differences.

Outcome	EG Difference	CG Difference	*F*	*p*
FCA (cm^2)	−0.29	−0.95	n.s.	>0.05
RCA (cm^2)	−1.67	−1.12	n.s.	>0.05
TCA (cm^2)	−1.93	−2.14	n.s.	>0.05
SS-OE (mm)	−55.24	+86.50	2.35	0.131
SS-CE (mm)	−83.12	−110.71	0.14	0.712
DS (mm)	−1.40	−5.74	0.60	0.443

FCA: forefoot contact area; RCA: rearfoot contact area; TCA: total contact area; SS: static stability; OE: opened eyes; CE: closed eyes; DS: dynamic stability; EG: experimental group; CG: control group; n.s.: not significant.

3.5. Participant Satisfaction Questionnaire and Adverse Event Record

Regarding the responses of the intervention group participants to the self-reported questionnaire on minimalist footwear satisfaction, the results were as follows:

- Positive aspects of the footwear: Footwear comfort was highlighted as the primary positive feature by 44.4% of the subjects, while 37.8% highlighted flexibility and 17.8% of the participants emphasized the lightweight nature of the MF as its main advantage.
- Negative aspects of the footwear: Aesthetics was reported as the main negative aspect by 77.8% of the participants, whereas 13.3% noted that the sole was excessively flat (zero-drop) and 8.9% stated that the sole was excessively thin.
- Continued use of minimalist footwear: Regarding whether participants would continue using the MF after the study, 70% responded affirmatively, 25% responded “maybe”, and only 5% responded negatively.
- Overall satisfaction level: Very high (38.9%), high (30.6%), moderately high (27.7%), and low (2.8%).
- Recorded adverse events: During the intervention period, one subject reported pain in the Achilles tendon region, and another subject experienced discomfort on the plantar surface of the hindfoot. In both cases, the discomfort was temporary, and the intervention was successfully completed.

4. Discussion

The primary objective of this single-blind randomized controlled clinical trial was to analyze the effects of a 6-month MF intervention during ADLs on the plantar footprint structure and postural stability metrics in a cohort of healthy adults. It was hypothesized that replacing conventional footwear with MF for a minimum of five hours per day would induce a mechanical adaptation manifesting as an increased plantar contact area and enhanced static and dynamic balance. Overall, the empirical data gathered across the 6-month follow-up period revealed no statistically significant differences between the experimental and control groups across any of the footprint morphology parameters or posturographic stability metrics evaluated.

Regarding the plantar footprint morphology, our results demonstrate remarkable structural stability in the adult foot, with negligible fluctuations in contact areas over the 6-month period. For instance, the experimental group’s forefoot contact area shifted from 18.43 ± 8.03 cm^2 basally to 19.79 ± 7.87 cm^2 post-intervention ($p = 0.262$, Cohen’s d = 0.18), representing a minor, non-significant upward trend. Similarly, the total contact area remained virtually unchanged (51.36 ± 6.26 cm^2 to 51.60 ± 5.99 cm^2, $p = 0.834$). This increase in the contact surface area could be attributed to forefoot widening caused by the use of MF. Although the 6-month follow-up period is likely insufficient to observe significant morphological changes, this minor improvement suggests that habitual MF use may lead to relevant structural changes over the long term. This concept is consistent with cross-sectional observational studies conducted on habitually barefoot or minimally shod populations. Anthropological and habituation research consistently shows that individuals who spend their lives barefoot or wearing ultra-minimal sandals present significantly wider forefeet, greater toe spread, and a lower incidence of flatfoot or excessive arch collapse due to a natural distribution of vertical ground reaction forces [17,18].

Between-group comparisons over time showed no statistically significant interaction effects across any static or dynamic postural stability metrics. Although descriptive trends indicated a slight increase in CoP displacement in the control group under eyes-closed conditions compared to the experimental group, overall between-group differences remained non-significant across the 6-month period.

The lack of significant morphological changes in our study can be explained by two key physiological factors: skeletal maturity and mechanical stimulus intensity. First, our sample comprised healthy adults whose osseous, ligamentous, and tendinous structures were fully mature. Unlike the plastic, highly adaptable feet of children or developing adolescents, the adult tarsal and metatarsal architecture is rigidly bound by dense ligamentous networks and joint capsules that resist structural deformation unless subjected to extreme or progressive loading. Although a 6-month follow-up period is common in clinical trials, it may be insufficient to induce macro-level morphological changes in mature adult feet. This reasoning is supported by longitudinal and cross-sectional studies indicating that structural adaptations, such as increased forefoot width and arch strength, typically require long-term habituation or multi-year exposure to minimalist footwear [22]. Second, the nature of the intervention (restricted to low-impact ADLs like walking, standing, and household tasks) may have lacked the necessary mechanical stress to stimulate rapid bone remodeling or permanent soft tissue elongation.

The posturographic evaluation yielded interesting, albeit non-significant, trends between groups. In the static stability trials, the experimental group maintained stable parameters over time, showing a slight, non-significant reduction in the CoP displacement under the eyes-closed condition (shifting from 383.74 ± 465.58 mm to 334.30 ± 313.67 mm, $p = 0.511$). Conversely, the control group demonstrated a significant increase in CoP displacement during the eyes-open condition, moving from 245.38 ± 191.00 mm to 331.88 ± 273.15 mm ($p = 0.037$, Cohen's d = 0.33).

An increase in CoP displacement typically signifies a degradation in postural control, indicating that the nervous system is forced to exert greater regulatory corrections to maintain the body's vertical projection within the base of support. The significant increase observed in the control group suggests a slight regression in baseline postural efficiency over the 6-month period, potentially linked to the restrictive mechanical design of conventional footwear, which limits natural digital splay and reduces somatosensory feedback from the mechanoreceptors located in the plantar skin. In contrast, the experimental group maintained stable parameters without statistically significant changes over time. While this trajectory highlights a stable performance, it cannot be interpreted as a definitive protective effect, given the lack of statistically significant group-by-time interactions. While we did not directly measure plantar mechanoreceptor density or somatosensory neural feedback, previous theoretical models such as the Foot Core System framework [2] hypothesize that minimal sole thickness may facilitate active tactile engagement. However, whether these theoretical sensory pathways directly influenced our cohort remains unconfirmed.

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The prior literature has heavily documented that MF can trigger significant adaptations in foot strength and muscle volume [21,23]. However, a crucial methodological distinction exists: those successful protocols primarily involved runners, athletes, or individuals undergoing a highly progressive, loaded training regime. In our trial, participants were explicitly instructed to limit their use of MF to daily walking and low-impact ADLs, avoiding running, high-impact sports, or jumping. Our results suggest that low-impact activity in MF is sufficient to provide excellent sensory stimulation and maintain neural pathways (as evidenced by the lack of postural degradation in the experimental group compared to the control group). However, it does not cross the necessary mechanical or metabolic hypertrophic threshold required to cause macro-level muscle hypertrophy or major changes in global static or dynamic balance metrics in a healthy population.

This study possesses several prominent methodological strengths, including its randomized, single-blind, controlled design; a relatively large sample size for a long-term biomechanical intervention; and the long duration of the follow-up period (6 months), which exceeds the typical 6-to-12-week windows seen in many footwear studies. Nonetheless, certain limitations must be addressed to ensure a balanced interpretation of the data. First, compliance was tracked via subjective self-reports, which introduces recall bias; although participants demonstrated high adherence, subjective reporting always introduces a degree of recall or social desirability bias. Second, the sample consisted of healthy, asymptomatic young adults who exhibited a high baseline level of postural stability and normal foot morphology; this likely created a ceiling effect; because participants already demonstrated robust postural control, the scope for measurable statistical improvement was inherently limited. Third, in the control group, static CoP displacement under open-eye conditions increased significantly ($p = 0.037$). However, in the absence of established Minimally Clinically Important Difference (MCID) thresholds for posturographic metrics in healthy adult cohorts, this statistical variation should be interpreted with caution and cannot be definitively classified as a clinically meaningful decline in postural efficiency.

Despite the lack of statistically significant differences between groups, the clinical relevance of this study should not be overlooked. MF was generally well-tolerated over six months. Although no severe musculoskeletal injuries or structural events were reported, some participants reported mild, transient plantar surface discomfort and muscle soreness during the initial weeks of adaptation. This indicates that, while the transition is feasible for healthy adults, a progressive adaptation period is required to minimize discomfort. Furthermore, the stabilization of postural metrics in the experimental group suggests that MF could serve as an effective preventative tool to combat the gradual neuromuscular accommodation caused by heavily structured conventional shoes. From a practical perspective, daily use of MF during low-impact ADLs represents a feasible, non-invasive habit for health-conscious individuals seeking to prevent footwear-induced functional restriction. For athletes, MF may serve as a complementary conditioning tool during off-court or daily activities to promote foot core engagement without replacing sport-specific footwear. From a public health and commercial perspective, these findings provide critical nuance regarding the marketing claims of minimalist footwear. While minimalist shoes are often promoted as radical intervention tools capable of altering foot architecture, our results indicate that their use during daily walking maintains baseline postural stability and structural foot parameters without adverse effects but does not induce structural changes in asymptomatic healthy adults. Consequently, footwear policies and health recommendations should view minimalist shoes as a safe, natural alternative for daily locomotion rather than a therapeutic or corrective medical device.

Future investigations should expand this paradigm in two directions: first, evaluating the impact of MF in clinical or symptomatic populations, such as individuals with flexible flatfoot, chronic ankle instability, or older adults experiencing age-related proprioceptive decline; second, future studies should explore long-term interventions (>12 months) combining daily footwear transition with structured active IFM strengthening.

5. Conclusions

A 6-month intervention utilizing MF during ADL in healthy adults did not induce significant modifications in plantar pressure distribution or static and dynamic stability compared to conventional footwear. Nevertheless, MF use exhibited a favorable safety profile with no reported adverse events, while baseline postural metrics remained overall stable throughout the study period.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/app16178475/s1: Supplementary S1. Minimalist footwear; Supplementary S2. Study logistics; Supplementary S3. Sample recruitment (CONSORT 2025); Supplementary S4. Static balance measurement.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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Conflicts of Interest: Author Jorge Juan Alvarado-Omenat was employed by the company FisioSport Salamanca S.L. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

MF	Minimalist footwear
ADLs	Activities during daily living
EG	Experimental group
CG	Control group
CoP	Center of pressure
IFMs	Intrinsic foot muscles
CONSORT	Consolidated Standards of Reporting Trials
BMI	Body mass index

SPSS	Statistical Package for the Social Sciences
SD	Standard deviation

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