Effect of training profile and Body Mass Index on foot health

Efecto del perfil de entrenamiento e Índice de Masa Corporal sobre la salud del pie

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Abstract

Introduction: Foot health is a multidimensional construct that encompasses pain, functionality, and footwear suitability, which has been associated with multiple clinical and demographic factors. However, the evidence regarding the role of Body Mass Index (BMI) and physical activity on foot health remains controversial, mainly due to the lack of control of confounding variables.
Objective: The aim of the study was to determine the association of training profile and BMI on foot health, adjusting for sex and age.
Methodology: An observational analytical cross-sectional study was conducted in 270 adults (147 women and 123 men; age 44.07 ± 17.10 years; BMI 27.42 ± 4.93 kg/m^2). Foot health was assessed using the Foot Health Status Questionnaire (FHSQ) in its Spanish validated version. Multiple linear regression models were applied, adjusted for sex and age.
Results: Compared with sedentary participants, the concurrent and strength profiles were associated with higher total and function scores, the strength profile additionally with higher footwear scores, and the aerobic and concurrent profiles with higher general foot-health scores. A higher BMI was associated with lower pain, function and total scores, although this inverse association became non-significant under heteroskedasticity-robust standard errors.
Conclusions: BMI and training profile are associated with foot health in a differentiated manner. Training profiles that include strength or concurrent training showed the most consistent associations with better foot health, whereas BMI showed only a weak inverse trend. Preventive strategies should therefore promote regular physical activity that incorporates strength-oriented training and body-weight management.

Keywords

Aerobic training; body mass index; foot health; physical activity; strength training.

Resumen

Introducción: La salud del pie es un constructo multidimensional que incluye dolor, funcionalidad y adecuación del calzado, y se ha asociado con múltiples factores clínicos y demográficos. Sin embargo, su evidencia sobre el rol del Índice de Masa Corporal (IMC) y la actividad física sigue siendo controversial, principalmente por la falta de control de variables confundentes.
Objetivo: Determinar la asociación del perfil de entrenamiento y del IMC con la salud del pie, ajustando por sexo y edad.
Metodología: Se realizó un estudio observacional analítico de corte transversal en 270 adultos (147 mujeres y 123 hombres; edad 44.07 ± 17.10 años; IMC 27.42 ± 4.93 kg/m^2). La salud del pie se evaluó mediante el Foot Health Status Questionnaire (FHSQ) validado al español. Se aplicaron modelos de regresión lineal múltiple ajustados por sexo y edad.
Resultados: En comparación con los participantes sedentarios, los perfiles concurrente y de fuerza se asociaron con mayores puntuaciones totales y de función. Además, el perfil de fuerza se relacionó con mejores puntuaciones de calzado. Los perfiles aeróbico y concurrente mostraron mejores puntuaciones de salud general del pie. Un mayor IMC se asoció con menores puntuaciones de dolor, función y total, aunque esta relación perdió significación al emplear errores estándar robustos.
Conclusiones: Los perfiles de entrenamiento de fuerza o concurrente se asociaron con mejor salud del pie, mientras que el IMC mostró solo una débil tendencia inversa general. Estrategias preventivas deberían enfocarse en promover la actividad física orientada al entrenamiento de fuerza y manejo del peso.

Palabras clave

Actividad física; entrenamiento aeróbico; entrenamiento de fuerza; índice de masa corporal; salud del pie.

Introduction

The foot constitutes the distal end of the lower limb's kinetic chain, and is therefore the segment tasked with absorbing and generating the forces required for human locomotion (Levangie & Norkin, 2019), but this duality is also a source of vulnerability. Its high adaptive and load-bearing capacity can be readily compromised by a variety of risk factors, resulting in pain and functional impairment, both at rest and during basic activities of daily living (Gates et al., 2019).

The concept of "foot health" has emerged as a framework for understanding and assessing these alterations, encompassing the presence or absence of pain, the functional capacity required for daily performance, and the ability to wear footwear comfortably. Among the available measurement instruments, the Foot Health Status Questionnaire (FHSQ) is particularly prominent, having been widely used in the literature and validated in Spanish (Jiménez-Guillén et al., 2026; Riskowski et al., 2011; Sirera-Vercher et al., 2010). This questionnaire captures symptoms experienced over the previous week and their impact on the individual's quality of life. The FHSQ thus yields an overall foot health score, broken down into four main dimensions: pain, function, footwear, and general health (Riskowski et al., 2011).

Epidemiologically, an international meta-analysis reported foot pain prevalence ranging from 9% to 36% in the general population (Gates et al., 2019). Among the clinical variables, body mass index (BMI) is of particular interest, since higher body weight should, in theory, increase the mechanical stress on plantar structure and thus contribute to a decline in foot health. While an association between foot pain and elevated BMI has indeed been reported (Canca-Sanchez et al., 2024; Chean et al., 2021; Mickle & Steele, 2015), the magnitude of this effect remains a matter of debate (Butterworth et al., 2012; Hurn et al., 2014; Tamir Tsehay et al., 2023). From a demographic perspective, sex and age are the two variables more related to foot health in the literature. Foot pain has been shown to be more prevalent in women (Canca-Sanchez et al., 2024; Chean et al., 2021), likely owing to anatomical differences or to the use of harmful footwear such as high heels. With respect to age, foot dysfunction and pain increase progressively in both sexes (Canca-Sanchez et al., 2024; Keenan et al., 2019; Mickle & Steele, 2015). Given the robust and consistent influence of sex and age on foot health, both are essential covariates when examining the relationship between foot health and other potentially associated factors.

In contrast to risk factors, several protective elements for foot health have been identified in the literature. Training of the intrinsic foot musculature, for instance, has been shown to enhance foot function and reduce pain (Cheng et al., 2024; Huang et al., 2022; Jaffri et al., 2023). In this regard, regular physical activity (PA) may serve as a key protective factor against foot health deterioration. The issue, nevertheless, remains controversial, with some reports even suggesting an inverse relationship (Alshwekany et al., 2025; Touzell, 2024).

This controversy, along with the difficulty of clearly establishing how PA and BMI relate to foot health, can largely be attributed to the methodological limitations of the available evidence. Most studies have examined this association without adequately controlling for critical confounders (Butterworth et al., 2012; Hurn et al., 2014; Tamir Tsehay et al., 2023). As previously documented, factors such as age and sex not only directly influence foot health but are also classic determinants of population-level PA and of variations in body composition and BMI. Additionally, foot health itself has often been assessed in a fragmentary way, since many studies have focused on isolated dimensions, such as pain or function, without acknowledging the multidimensional nature of the construct. Examining the association of PA and BMI with foot health using a validated and integrated instrument such as the FHSQ, in conjunction with appropriate statistical control, would therefore allow for a far more rigorous characterization of these relationships.

The aim of the present study was thus to determine the association of training profile and BMI with foot health, using multiple regression models adjusted for sex and age as confounders. To our knowledge, this is the first study to jointly examine training profile and BMI in relation to multi-dimensional foot health while simultaneously adjusting for sex and age, which addresses a recurrent methodological limitation of the available evidence and has direct implications for the design of preventive strategies. Based on this rationale, we hypothesized that (i) a higher BMI would be independently associated with poorer FHSQ scores, particularly in the more mechanical dimensions (pain and function); (ii) physically active profiles would be associated with better foot health than the sedentary profile; and (iii) strength-oriented and aerobic profiles would display distinct association patterns across the FHSQ dimensions, reflecting their differing physiological and biomechanical demands.

Method

Study design

This is an analytical, cross-sectional observational study, based on a secondary analysis from the FONIS project SA22I0149 publicly accessible database (available at https://doi.org/10.6084/m9.figshare.27737133) (Palma & Araya, 2024). Because the present work is a secondary analysis of a pre-existing dataset, the authors did not participate in the recruitment of participants or the assessments.

Participants

The original database comprised 332 participants (187 women and 145 men). This sample was recruited through stratified probabilistic sampling, ensuring a minimum sample size for each age group and a representative coverage of the adult population of Santiago, Chile. Inclusion criteria were: being 18 years of age or older, ambulating independently, and possessing the cognitive ability to understand and follow instructions. To preserve external validity and faithfully represent the general population, no further restrictive exclusion criteria were applied.

Data collection procedure

Fieldwork and data collection were conducted throughout 2023 at strategic locations across Santiago city (Chile), including high-traffic private and public venues. All assessments were carried out by previously trained physical therapists familiar with the protocol. To enhance data quality, the FHSQ and demographic questions were administered through structured face-to-face interviews rather than self-report. Having the same team of physical therapists conduct the entire process further enhanced methodological reproducibility.

Instruments and variables

1. Anthropometric and demographic characteristics

Body weight and height were measured in person and on site by the researchers using a digital scale with a portable stadiometer (Palma & Araya, 2024), allowing BMI to be objectively calculated. Sex and age were self-reported.

2. Foot health

Section 1 of the Spanish-validated version of the FHSQ was used. This section consists of 13 Likert-type items covering four specific dimensions: foot pain (4 items), foot function (4 items), footwear (3 items), and general foot health (2 items). Scores were transformed onto a 0–100 scale, where 0% denotes the worst foot health (extreme pain, maximum functional limitation) and 100% reflects optimal foot health (no pain or limitations). Percentages were computed using the FHSQ Data Analysis Software (v1.03, Care Quest Pty Ltd.).

3. PA level and type

Participants were asked about their regular PA practice. Weekly PA volume was calculated by multiplying frequency (days per week) by the average duration of each session (minutes). Those who reported engaging in PA were operationally classified, according to the metabolic and biomechanical predominance of the activity, into three categories: aerobic PA (e.g. cycling and running); mixed or intermittent PA (e.g. soccer and padel); and strength and conditioning PA (e.g. functional training and gym-based resistance training). Participants who reported no physical exercise made up the inactive/sedentary group. Based on the type of PA practiced, participants were classified into four mutually exclusive training profiles: sedentary (reference), aerobic, strength, and concurrent (Wilson et al., 2012). Participants whose only reported activity fell into the residual “other” category were not classified into any profile, because the heterogeneity of the activities grouped under this label prevented their unambiguous assignment to a defined profile. These participants (n=62) were consequently excluded from the analytical sample (n=270).

Classification into a given profile was based exclusively on the types of activity reported by each participant during the structured interview, independently of weekly volume. As the data derive from a pre-existing dataset, no objective markers of training intensity, weekly training experience, or competitive level were available.

Statistical analysis

All analyses, both descriptive and inferential, were performed on the analytical sample of 270 participants using the STATA/MP 18 software (StataCorp LLC, USA). Descriptive statistics were first calculated, with quantitative variables reported as means and standard deviations and qualitative variables as absolute and relative frequencies. As an exploratory step, categorical variables in which a single category accounted for more than 95% of the sample were excluded. Given the final sample size, a normal distribution was assumed under the central limit theorem.

For each FHSQ outcome (the four dimension scores and the total score), a single pre-specified multiple linear regression model was fitted. Each model included the variables of interest defined a priori from the study aim, namely training profile (categorical, with the sedentary group as the reference category) and BMI (continuous), together with sex and age, which were retained in every model as adjustment covariates regardless of their statistical significance. Participants whose only reported activity belonged to a heterogeneous "other" category that could not be unambiguously assigned to one of the defined training profiles were not classified and were therefore excluded from these models, yielding an analytic sample of 270. The assumptions of each model were examined through standard regression diagnostics: multicollinearity (variance inflation factors, VIF), normality of residuals (Shapiro–Wilk test and normal Q–Q plots), homoscedasticity (Breusch–Pagan test), and influential observations (Cook's distance). Because the Breusch–Pagan test indicated heteroskedasticity in some of the models, heteroskedasticity-consistent (HC3) robust standard errors were additionally computed as a sensitivity analysis. Results are presented as unstandardized β coefficients with their 95% confidence intervals (95% CI) and the coefficient of determination (R^2) of each model. All tests were two-tailed, with statistical significance set at $p < 0.05$.

Ethical considerations

This study was conducted in strict accordance with the ethical principles for medical research involving human subjects set forth in the Declaration of Helsinki. All participants were informed of the study's objectives and scope and provided verbal and written informed consent prior to any assessment. The original project protocol received formal approval from the Scientific Ethics Committee of Universidad de los Andes (File CEC2022144).

Results

Table 1 presents the demographic and anthropometric characteristics of the analytic sample (n=270). The mean age of participants was 44.07 ± 17.10 years, with a sex distribution of 54.44% women and 45.56% men. In terms of body composition, the mean BMI was 27.42 ± 4.93 kg/m², classifying the average sample as overweight. Among participants, 59.26% reported being physically active, with a mean weekly PA volume of 142.46 ± 174.49 minutes. When PA type was considered, mixed or concurrent activity was the most prevalent modality (29.26%). The distribution of participants across training profiles was uneven: the concurrent (n=79; 29.26%) and strength (n=60; 22.22%) profiles were considerably larger than the aerobic profile (n=21; 7.78%).

Table 1. Demographic and physical activity characteristics of the assessed sample (n=270). Variables are reported as absolute and relative frequencies.

Sex	Male:	123 (45.56%)
	Female:	147 (54.44%)
Physical activity	Yes:	160 (59.26%)
	No:	110 (40.74%)
Aerobic profile		21 (7.78%)
Concurrent profile		79 (29.26%)
Strength profile		60 (22.22%)

Table 2 reports the pre-specified models for each FHSQ outcome. β coefficients for the training profiles express the mean difference relative to the sedentary group, holding BMI, sex and age constant. Both structured active profiles were associated with better overall foot health than the sedentary group: relative to sedentary participants, the concurrent profile scored 6.2 points higher on the total score (β = 6.21; 95% CI 0.12 to 10.72; $p = 0.045$) and 6.3 points higher on function (β = 6.33; 95% CI 1.13 to 11.53; $p = 0.017$), and the strength profile scored 5.9 points higher on the total score (β = 5.92; $p = 0.027$), 5.7 points higher on function (β = 5.67; $p = 0.030$) and 8.8 points higher on footwear (β = 8.76; 95% CI 0.23 to 17.28; $p = 0.044$). The largest associations with self-rated general health were observed for the aerobic profile (β = 16.56; 95% CI 4.89 to 28.23; $p = 0.006$) and the concurrent profile (β = 11.95; 95% CI 4.06 to 19.85; $p = 0.003$). A higher BMI was associated with lower scores on the more mechanical dimensions pain (β = −0.59; 95% CI −1.06 to −0.12; $p = 0.014$), function (β = −0.43; $p = 0.038$) and the total score (β = −0.44; $p = 0.035$), but not with footwear or general health. The models explained between 4.5% (pain) and 15.1% (general health) of the variance (total $R^2 = 0.120$; pain $R^2 = 0.045$; function $R^2 = 0.083$; footwear $R^2 = 0.081$; general health $R^2 = 0.151$). Diagnostics showed no relevant multicollinearity (all VIF ≤ 1.49) and no excess of influential observations under Cook's distance. The Breusch–Pagan test, however, indicated heteroskedasticity in the total, pain and function models, so heteroskedasticity-consistent (HC3) standard errors were examined as a sensitivity analysis. Under robust standard errors the training profile associations were essentially unchanged, whereas the BMI associations attenuated to non-significance.

Table 2. Results of the pre-specified multiple linear regression models for each FHSQ dimension and the total score, with the sedentary group as the reference category, and sex and age as adjustment covariates (n=270). For each model, unstandardized β coefficients, p-values, 95% confidence intervals (95% CI) and the coefficient of determination (R^2) are reported; * $p < 0.05$. Estimates were confirmed with heteroskedasticity-consistent (HC3) robust standard errors.

	β coefficient	p-value	95% CI
FHSQ Total ($R^2 = 0.120$)			
Aerobic vs sedentary	6.87	0.086	−0.97 to 14.70
Concurrent vs sedentary	6.21	0.045*	0.12 to 10.72
Strength vs sedentary	5.92	0.027*	0.68 to 11.15
BMI [kg/m²]	−0.44	0.035*	−0.85 to −0.03
FHSQ Pain ($R^2 = 0.045$)			
Aerobic vs sedentary	3.64	0.423	−5.29 to 12.57
Concurrent vs sedentary	3.25	0.291	−2.79 to 9.29
Strength vs sedentary	3.02	0.319	−2.94 to 8.98
BMI[kg/m²]	−0.59	0.014*	−1.06 to −0.12
FHSQ Function ($R^2 = 0.083$)			
Aerobic vs sedentary	6.53	0.095	−1.15 to 14.21
Concurrent vs sedentary	6.33	0.017*	1.13 to 11.53
Strength vs sedentary	5.67	0.030*	0.54 to 10.81
BMI[kg/m²]	−0.43	0.038*	−0.83 to −0.02
FHSQ Footwear ($R^2 = 0.081$)			
Aerobic vs sedentary	0.73	0.910	−12.04 to 13.50
Concurrent vs sedentary	0.16	0.971	−8.48 to 8.80
Strength vs sedentary	8.76	0.044*	0.23 to 17.28
BMI[kg/m²]	−0.40	0.239	−1.07 to 0.27
FHSQ General health ($R^2 = 0.151$)			
Aerobic vs sedentary	16.56	0.006*	4.89 to 28.23
Concurrent vs sedentary	11.95	0.003*	4.06 to 19.85
Strength vs sedentary	6.21	0.118	−1.58 to 14.01
BMI[kg/m²]	−0.35	0.258	−0.96 to 0.26

Discussion

The aim of this study was to determine the association of training profile and BMI with foot health, using multiple regression models adjusted for sex and age. The findings reveal distinct association patterns across the FHSQ dimensions: the active training profiles, particularly the concurrent and strength profiles, were associated with better total and function scores, and the aerobic and concurrent profiles with better self-rated general health, whereas a higher BMI showed an inverse association mainly with the more mechanical dimensions (pain, function and the total scores), an association that attenuated to non-significance under heteroskedasticity-robust standard errors. Given the observational and cross-sectional nature of the design, these results should be read as statistical associations rather than causal effects, and the physiological and biomechanical accounts offered below are advanced as plausible mechanisms that may help interpret the observed patterns rather than as confirmed explanations. They require corroboration in longitudinal or experimental studies.

In our sample, the FHSQ profile was characterized by high pain and function scores (85.1 and 92.7, respectively), alongside markedly lower footwear and general foot health scores (58.9 and 67.5), indicating that the footwear and self-perceived health dimensions were the most compromised. This pattern is consistent with previous evidence using the same instrument: in a Spanish sample, Rodriguez-Sanz et al. reported almost identical pain and function values (84.4 and 93.8) together with comparatively higher footwear (66.7) and lower general foot health scores (60.0) (Rodríguez-Sanz et al., 2018). A similar profile has been described in broader adult populations, such as the educated adults surveyed by Hendry et al., supporting the notion that, even in relatively healthy community samples, footwear and general foot-health perception tend to be the dimensions where foot health is most readily affected (Hendry et al., 2018).

BMI was the variable most consistently associated with the more mechanical dimensions of the FHSQ, being inversely related to pain, function and the total score, and pain was the only dimension not associated with any training profile. This pattern is consistent with prior research identifying BMI as a risk factor for foot pain due to the increased loads imposed on this segment (Canca-Sanchez et al., 2024; Chean et al., 2021; Dufour et al., 2017; Gill et al., 2016; Hendry et al., 2018; Keenan et al., 2019; Mickle & Steele, 2015; Tamir Tsehay et al., 2023; Thomas et al., 2011; Tojo et al., 2018; Walsh et al., 2017). A similar pattern has been reported between higher BMI and impaired lower-limb function, such as walking or stair climbing (de Souza-Lima et al., 2026; Menoth Mohan et al., 2025), reflecting biomechanical alterations and the greater difficulty of moving with elevated BMI (Ahsan, 2022; Kim et al., 2021; Maktouf et al., 2024). With respect to function, both a lower BMI and the active profiles (concurrent and strength) were independently associated with higher FHSQ scores, consistent with the expectation that regular PA supports functional performance while excess body mass tends to impair it. The relatively modest magnitude of these associations may partly reflect the basic nature of the FHSQ items in this dimension, which focus on "difficulties" and "limitations" at work, walking, and climbing stairs (Sirera-Vercher et al., 2010). Because these activities are so elementary, individuals may fail to notice changes resulting from PA. Had the questionnaire addressed limitations in more demanding functional activities, such as running or jumping, the different training profiles would likely have produced more perceptible effects.

In the footwear dimension, the strength training profile was the only variable with significant results. This may be partly explained by the positive impact on foot biomechanics and strength when the intrinsic musculature is trained: such exercises promote greater development of the intrinsic foot muscles and improved support of the medial longitudinal arch, thereby enhancing foot stability (Cheng et al., 2024; Oliveira et al., 2024; Peters-Dickie et al., 2025). This in turn helps prevent postural alterations such as flat feet, which has been linked to greater pain and discomfort in the use of footwear due to the changes it produces in plantar pressure distribution (Hagedorn et al., 2013; Jiang et al., 2021; Menz et al., 2013, 2016; Padrón Cabrera et al., 2024). Likewise, foot muscle exercise has been recognized as an effective therapeutic approach for hallux valgus, a condition prevalent worldwide (Cai et al., 2023), reducing both the anatomical deformity and the associated pain (Hurn et al., 2022; Jankowicz-Szymańska et al., 2025; Khan & Patil, 2024; Külünkoğlu et al., 2021; Liu et al., 2024; Oztarsu & Oksuz, 2023). Given that muscle training may also help prevent these deformities, it is reasonable to infer that this could translate into better perceived foot health and, ultimately, greater comfort with footwear.

In the general foot health dimension of the FHSQ, the aerobic profile was the only variable showing a significant effect on improvement in this domain. This finding may be attributed to two distinct phenomena. First, aerobic exercise is well known to provide broad benefits across multiple body systems and overall health (Bliss et al., 2021; Fyfe et al., 2022; Lopez et al., 2018; Shailendra et al., 2022), which may translate into better self-rated general health. Unlike the pain and function dimensions, the FHSQ general health dimension comprises items that capture the individual's overall self-perception of foot status. This subjective character makes it especially sensitive to factors beyond biomechanics, such as overall well-being, cardiovascular fitness, and the individual's holistic perception of their health, so that individuals with greater general well-being may rate their overall foot health more favorably. Second, one of the main effects of aerobic exercise lies in its impact on the cardiovascular system, which has been closely linked to foot-specific issues such as poor endothelial function, impaired venous return, and slower wound healing. Individuals who primarily engage in aerobic exercise might therefore be less prone to such alterations, which could potentially contribute to a more favorable perception of general foot health. This pathway, however, remains speculative under the present cross-sectional design.

The total FHSQ score was significantly affected by both BMI and the strength training profile, in line with the patterns observed in the individual dimensions. For BMI, this overall effect is to be expected given its significant association with two of the four FHSQ dimensions, which contribute substantially to the total score. The behavior of the training profiles is more intriguing. Although the strength profile reached significance in only one specific dimension (footwear), the magnitude of its coefficient was sufficient to retain statistical significance in the overall FHSQ score, suggesting a transversal effect of strength training on foot health. By contrast, although the aerobic profile was significant in the general health dimension, its effect did not carry over to the total score, suggesting that its benefits are confined to more specific and subjective aspects of health perception, without a sufficiently broad impact on the more mechanical dimensions of the questionnaire.

A particularly noteworthy aspect of these findings is that the concurrent profile was among the most consistently associated with better foot health, showing higher total, function and general-health scores than the sedentary group. This is of interest because concurrent training has sometimes been reported to produce an "interference effect," whereby the specific adaptations induced by aerobic and strength training may partially counteract one another when both are performed simultaneously (Huiberts et al., 2024; Schumann et al., 2022). In our cross-sectional sample, however, this potential interference did not translate into poorer foot health, rather, engaging in more than one training modality was associated with broad benefits across the total, function and general-health dimensions, possibly reflecting the combined mechanical and cardiovascular stimuli that such varied practice provides.

This study has several limitations that should be considered when interpreting the findings. First, because the work is a secondary analysis of a pre-existing dataset, the authors had no control over the original data-collection protocol, and the training-profile classification was derived from self-reported activity that was not independently validated. Misclassification of profiles, recall bias, and social-desirability bias in the reporting of physical activity therefore cannot be excluded. Second, the classification captured only the predominant type of activity, with no information on training intensity, weekly volume reliability, years of experience (seniority), or competitive level, so the profiles should be regarded as broad categories rather than precisely characterized exposures. Third, the training-profile subgroups differed markedly in size, with the aerobic group comprising roughly one-third of the strength group. This imbalance reduces the statistical power to detect smaller effects, widens the confidence intervals for the smaller subgroups, and may partly explain why the aerobic profile did not retain significance in the total FHSQ score, so these estimates should be interpreted with caution. Fourth, several potentially relevant variables were not available and could not be adjusted (footwear habits, occupational standing, previous foot disorders), so residual confounding and self-selection of more active individuals into specific profiles remain plausible alternative explanations for the observed associations. Fifth, anthropometric measurements were taken by a single trained team using standardized procedures, but formal intra- and inter-observer reliability was not quantified. Finally, the cross-sectional design precludes any causal inference. The associations reported here, and the mechanisms proposed to interpret them, require confirmation in longitudinal or experimental studies that incorporate objectively measured, intensity- and volume-controlled training exposures.

Conclusions

This study shows that, after adjusting for sex and age, the training profile is differentially associated with foot health in adults. Relative to sedentary individuals, profiles that include strength or combined (concurrent) training were associated with better overall foot health and function, the strength profile additionally with better footwear-related scores, and the aerobic and concurrent profiles with better self-rated general foot health. A higher BMI showed an inverse association with the more mechanical dimensions (pain, function and the total score), although this association did not remain significant under heteroskedasticity-robust standard errors and should therefore be regarded as a consistent but weak trend. These findings suggest that strategies aimed at promoting foot health may benefit from encouraging regular physical activity that incorporates strength and combined training stimuli, while acknowledging the observational and cross-sectional nature of the evidence.

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References

Ahsan, M. (2022). Determine the kinematics and kinetics parameters associated with bilateral gait patterns among healthy, overweight, and obese adults. *Acta Bio-Medica: Atenei Parmensis*, *93*(5), e2022228. https://doi.org/10.23750/abm.v93i5.13060

Alshwekany, S., Alarfaj, Y., Musaed, S., Faraj, F., Mahzari, Q., Alhablani, M., Alamri, D., Almutairi, S., Khalil, T., & Albalawi, A. (2025). The impact of foot arch morphology on risk of overuse injuries in amateur runners: A prospective biomechanical study. *Journal of Posthumanism*, *5*, 106–120. https://doi.org/10.63332/joph.v5i6.1952

Bliss, E. S., Wong, R. H., Howe, P. R., & Mills, D. E. (2021). Benefits of exercise training on cerebrovascular and cognitive function in ageing. *Journal of Cerebral Blood Flow and Metabolism: Official Journal of the International Society of Cerebral Blood Flow and Metabolism*, *41*(3), 447–470. https://doi.org/10.1177/0271678X20957807

Butterworth, P. A., Landorf, K. B., Smith, S. E., & Menz, H. B. (2012). The association between body mass index and musculoskeletal foot disorders: A systematic review. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, *13*(7), 630–642. https://doi.org/10.1111/j.1467-789X.2012.00996.x

Cai, Y., Song, Y., He, M., He, W., Zhong, X., Wen, H., & Wei, Q. (2023). Global prevalence and incidence of hallux valgus: A systematic review and meta-analysis. *Journal of Foot and Ankle Research*, *16*(1), 63. https://doi.org/10.1186/s13047-023-00661-9

Canca-Sanchez, F. J., Morales-Asencio, J. M., Ortega-Avila, A. B., Gijon-Nogueron, G., Cervera-Garvi, P., Marchena-Rodriguez, A., & Canca-Sanchez, J. C. (2024). Predictive factors for foot pain in the adult population. *BMC Musculoskeletal Disorders*, *25*, 52. https://doi.org/10.1186/s12891-023-07144-9

Chean, C. S., Lingham, A., Rathod-Mistry, T., Thomas, M. J., Marshall, M., Menz, H. B., & Roddy, E. (2021). Identification of patterns of foot and ankle pain in the community: Cross-sectional findings from the clinical assessment study of the foot. *Musculoskeletal Care*, *19*(1), 9–19. https://doi.org/10.1002/msc.1502

Cheng, J., Han, D., Qu, J., Liu, Z., & Huang, Y. (2024). Effects of short foot training on foot posture in patients with flatfeet: A systematic review and meta-analysis. *Journal of Back and Musculoskeletal Rehabilitation*, *37*(4), 839–851. https://doi.org/10.3233/BMR-230226

de Souza-Lima, J., Valdivia-Moral, P., Ferrari, G., Araujo, T. L., & Mahecha-Matsudo, S. (2026). Influence of body mass index on functional capacity in physically active community-dwelling adult women. *Journal of Aging Research*, *2026*, 1948349. https://doi.org/10.1155/jare/1948349

Dufour, A. B., Losina, E., Menz, H. B., LaValley, M. P., & Hannan, M. T. (2017). Obesity, foot pain and foot disorders in older men and women. *Obesity Research & Clinical Practice*, *11*(4), 445–453. https://doi.org/10.1016/j.orcp.2016.11.001

Fyfe, J. J., Hamilton, D. L., & Daly, R. M. (2022). Minimal-dose resistance training for improving muscle mass, strength, and function: A narrative review of current evidence and practical considerations. *Sports Medicine*, *52*(3), 463–479. https://doi.org/10.1007/s40279-021-01605-8

Gates, L. S., Arden, N. K., Hannan, M. T., Roddy, E., Gill, T. K., Hill, C. L., Dufour, A. B., Rathod-Mistry, T., Thomas, M. J., Menz, H. B., Bowen, C. J., & Golightly, Y. M. (2019). Prevalence of foot pain across an international consortium of population-based cohorts. *Arthritis Care & Research*, *71*(5), 661–670. https://doi.org/10.1002/acr.23829

Gill, T. K., Menz, H. B., Landorf, K. B., Arnold, J. B., Taylor, A. W., & Hill, C. L. (2016). Predictors of foot pain in the community: The North-West Adelaide Health Study. *Journal of Foot and Ankle Research*, *9*, 23. https://doi.org/10.1186/s13047-016-0150-9

Hagedorn, T. J., Dufour, A. B., Riskowski, J. L., Hillstrom, H. J., Menz, H. B., Casey, V. A., & Hannan, M. T. (2013). Foot disorders, foot posture, and foot function: The Framingham Foot Study. *PloS One*, *8*(9), e74364. https://doi.org/10.1371/journal.pone.0074364

Hendry, G. J., Fenocchi, L., Woodburn, J., & Steultjens, M. (2018). Foot pain and foot health in an educated population of adults: Results from the Glasgow Caledonian University Alumni Foot Health Survey. *Journal of Foot and Ankle Research*, *11*, 48. https://doi.org/10.1186/s13047-018-0290-1

Huang, C., Chen, L.-Y., Liao, Y.-H., Masodsai, K., & Lin, Y.-Y. (2022). Effects of the short-foot exercise on foot alignment and muscle hypertrophy in flatfoot individuals: A meta-analysis. *International Journal of Environmental Research and Public Health*, *19*(19), 11994. https://doi.org/10.3390/ijerph191911994

Huiberts, R. O., Wüst, R. C. I., & van der Zwaard, S. (2024). Concurrent strength and endurance training: a systematic review and meta-analysis on the impact of sex and training status. *Sports Medicine*, *54*(2), 485–503. https://doi.org/10.1007/s40279-023-01943-9

Hurn, S. E., Matthews, B. G., Munteanu, S. E., & Menz, H. B. (2022). Effectiveness of nonsurgical interventions for hallux valgus: A systematic review and meta-analysis. *Arthritis Care & Research*, *74*(10), 1676–1688. https://doi.org/10.1002/acr.24603

Hurn, S. E., Vicenzino, B. T., & Smith, M. D. (2014). Correlates of foot pain severity in adults with hallux valgus: A cross-sectional study. *Journal of Foot and Ankle Research*, *7*, 32. https://doi.org/10.1186/1757-1146-7-32

Jaffri, A. H., Koldenhoven, R., Saliba, S., & Hertel, J. (2023). Evidence for intrinsic foot muscle training in improving foot function: A systematic review and meta-analysis. *Journal of Athletic Training*, *58*(11–12), 941–951. https://doi.org/10.4085/1062-6050-0162.22

Jankowicz-Szymańska, A., Wódka, K., Smoła, E., & Bibro, M. A. (2025). The impact of corrective exercises, kinesiology taping, and mechanical correction on pain and foot shape in women with hallux valgus. *Frontiers in Physiology*, *16*, 1473278. https://doi.org/10.3389/fphys.2025.1473278

Jiang, Y., Wang, D., Ying, J., Chu, P., Qian, Y., & Chen, W. (2021). Design and preliminary validation of individual customized insole for adults with flexible flatfeet based on the plantar pressure redistribution. *Sensors*, *21*(5), 1780. https://doi.org/10.3390/s21051780

Jiménez-Guillén, J., Tovaruela-Carrión, N., Moreno-Fresco, M. M., Martínez-Nova, A., & Munuera-Martínez, P. V. (2026). Reporting and utilization of patient-reported outcomes measures in the evaluation of foot orthoses treatment: A systematic review. *Journal of Foot and Ankle Research*, *19*(1), e70148. https://doi.org/10.1002/jfa2.70148

Keenan, A.-M., Drake, C., Conaghan, P. G., & Tennant, A. (2019). The prevalence and impact of self-reported foot and ankle pain in the over 55 age group: A secondary data analysis from a large community sample. *Journal of Foot and Ankle Research*, *12*, 53. https://doi.org/10.1186/s13047-019-0363-9

Khan, A. Z., & Patil, D. S. (2024). The effect of therapeutic approaches on hallux valgus deformity. *Cureus*, *16*(4), e58750. https://doi.org/10.7759/cureus.58750

Kim, D., Lewis, C. L., & Gill, S. V. (2021). Effects of obesity and foot arch height on gait mechanics: A cross-sectional study. *PloS One*, *16*(11), e0260398. https://doi.org/10.1371/journal.pone.0260398

Külünkoğlu, B. A., Akkubak, Y., Çelik, D., & Alkan, A. (2021). A comparison of the effectiveness of splinting, exercise and electrotherapy in women patients with hallux valgus: A randomized clinical trial. *Foot*, *48*, 101828. https://doi.org/10.1016/j.foot.2021.101828

Levangie, P. K., & Norkin, C. C. (2019). *Joint structure & function: A comprehensive analysis* (6th. ed.) Jaypee. https://uandes.primo.exlibrisgroup.com/permalink/56UDA_INST/1svarq9/alma991001029619404076

Liu, Z., Zhong, Y., Chen, S., Tanaka, H., Li, Y., Katsutani, H., Okunuki, T., Yabiku, H., & Kumai, T. (2024). Effects of 4 weeks of foot exercise on subjective outcome and foot plantar pressure in elite adolescent dancers with hallux valgus: A pilot study. *BMC Sports Science, Medicine and Rehabilitation*, *16*, 217. https://doi.org/10.1186/s13102-024-01003-3

Lopez, P., Pinto, R. S., Radaelli, R., Rech, A., Grazioli, R., Izquierdo, M., & Cadore, E. L. (2018). Benefits of resistance training in physically frail elderly: A systematic review. *Aging Clinical and Experimental Research*, *30*(8), 889–899. https://doi.org/10.1007/s40520-017-0863-z

Maktouf, W., Ferhi, H., Boyas, S., Beaune, B., Gaied Chortane, S., Portero, P., & Durand, S. (2024). The influence of obesity and fat distribution on ankle muscle coactivation during gait. *PloS One*, *19*(3), e0294692. https://doi.org/10.1371/journal.pone.0294692

Menoth Mohan, D., Al Anouti, F., Kohli, N., & Khalaf, K. (2025). Association of obesity with musculoskeletal health and functional mobility in females-a systematic review. *International Journal of Obesity*, *49*(11), 2184–2205. https://doi.org/10.1038/s41366-025-01881-8

Menz, H. B., Dufour, A. B., Katz, P., & Hannan, M. T. (2016). Foot pain and pronated foot type are associated with self-reported mobility limitations in older adults: The Framingham Foot Study. *Gerontology*, *62*(3), 289–295. https://doi.org/10.1159/000442089

Menz, H. B., Dufour, A. B., Riskowski, J. L., Hillstrom, H. J., & Hannan, M. T. (2013). Association of planus foot posture and pronated foot function with foot pain: The Framingham foot study. *Arthritis Care & Research*, *65*(12), 1991–1999. https://doi.org/10.1002/acr.22079

Mickle, K. J., & Steele, J. R. (2015). Obese older adults suffer foot pain and foot-related functional limitation. *Gait & Posture*, *42*(4), 442–447. https://doi.org/10.1016/j.gaitpost.2015.07.013

Oliveira, P. M. P., Monteiro, J. C. M., Carvalho, L. M., & de Carvalho, F. O. (2024). Strengthening the intrinsic muscles of the foot and its action on foot posture and self-reported function in individuals with lower limb injuries: Systematic review and meta-analysis. *Journal of Manipulative and Physiological Therapeutics*, *47*(1–4), 58–67. https://doi.org/10.1016/j.jmpt.2024.08.014

Oztarsu, M. B., & Oksuz, S. (2023). Comparison of the effects of progressive supervised and home program exercise therapy in mild–moderate hallux valgus. *Journal of Comparative Effectiveness Research*, *12*(3), e220091. https://doi.org/10.2217/cer-2022-0091

Padrón Cabrera, L., López-López, D., Becerro-de-Bengoa-Vallejo, R., Losa-Iglesias, M., Gómez-Salgado, J., & Bayod-López, J. (2024). Implications of plantar static pressure distribution among bilateral flatfoot patients: An analytical case-control research. *Biomedical Signal Processing and Control*, *96*, 106578. https://doi.org/10.1016/j.bspc.2024.106578

Palma, F., & Araya, D. (2024). *Database FONIS SA22I0149 / Base de datos FONIS SA22I0149* [Dataset]. figshare. https://doi.org/10.6084/m9.figshare.27737133.v4

Peters-Dickie, J.-L., Detrembleur, C., Guallar-Bouloc, M., Rastelli, M., Lobet, S., Hidalgo, B., & Deschamps, K. (2025). The effects of foot core exercises and minimalist footwear on foot muscle sizes, foot strength, and biomechanics: A systematic review and meta-analysis. *Clinical Biomechanics*, *122*, 106417. https://doi.org/10.1016/j.clinbiomech.2024.106417

Riskowski, J. L., Hagedorn, T. J., & Hannan, M. T. (2011). Measures of foot function, foot health, and foot pain: American Academy of Orthopedic Surgeons Lower Limb Outcomes Assessment: Foot and Ankle Module (AAOS-FAM), Bristol Foot Score (BFS), Revised Foot Function Index (FFI-R), Foot Health Status Questionnaire (FHSQ), Manchester Foot Pain and Disability Index (MFPDI), Podiatric Health Questionnaire (PHQ), and Rowan Foot Pain Assessment (ROFPAQ). *Arthritis Care & Research*, *63 Suppl 11*(0 11), S229-239. https://doi.org/10.1002/acr.20554

Rodríguez-Sanz, D., Barbeito-Fernández, D., Losa-Iglesias, M. E., Saleta-Canosa, J. L., López-López, D., Tovaruela-Carrión, N., & Becerro-de-Bengoa-Vallejo, R. (2018). Foot health and quality of life among university students: Cross-sectional study. *Sao Paulo Medical Journal = Revista Paulista De Medicina*, *136*(2), 123–128. https://doi.org/10.1590/1516-3180.2017.0264230917

Schumann, M., Feuerbacher, J. F., Sünkeler, M., Freitag, N., Rønnestad, B. R., Doma, K., & Lundberg, T. R. (2022). Compatibility of concurrent aerobic and strength training for skeletal muscle size and function: An updated systematic review and meta-analysis. *Sports Medicine*, *52*(3), 601–612. https://doi.org/10.1007/s40279-021-01587-7

Shailendra, P., Baldock, K. L., Li, L. S. K., Bennie, J. A., & Boyle, T. (2022). Resistance training and mortality risk: A systematic review and meta-analysis. *American Journal of Preventive Medicine*, *63*(2), 277–285. https://doi.org/10.1016/j.amepre.2022.03.020

Sirera-Vercher, M. J., Sáez-Zamora, P., & Sanz-Amaro, M. D. (2010). Translation, transcultural adaptation to Spanish, to Valencian language of the Foot Health Status Questionnaire. *Revista Española de Cirugía Ortopédica y Traumatología (English Edition)*, *54*(4), 211–219. https://doi.org/10.1016/S1988-8856(10)70235-2

Tamir Tsehay, Y., Lamesgin Endalew, H., Dessalegn Bogale, A., & Walle, T. A. (2023). Prevalence and associated factors of ankle-foot pain among nurses working in surgical units of comprehensive specialized hospitals in Amhara Regional State, Northwest Ethiopia, 2022. *Journal of Pain Research*, *16*, 2685–2696. https://doi.org/10.2147/JPR.S405417

Thomas, M. J., Roddy, E., Zhang, W., Menz, H. B., Hannan, M. T., & Peat, G. M. (2011). The population prevalence of foot and ankle pain in middle and old age: A systematic review. *Pain*, *152*(12), 2870–2880. https://doi.org/10.1016/j.pain.2011.09.019

Tojo, M., Yamaguchi, S., Amano, N., Ito, A., Futono, M., Sato, Y., Naka, T., Kimura, S., Sadamasu, A., Akagi, R., & Ohtori, S. (2018). Prevalence and associated factors of foot and ankle pain among nurses at a university hospital in Japan: A cross-sectional study. *Journal of Occupational Health*, *60*(2), 132–139. https://doi.org/10.1539/joh.17-0174-OA

Touzell, A. (2024). Foot pain from exercise: Diagnosis and treatment. *Australian Journal of General Practice*, *53*(3), 116–120. https://doi.org/10.31128/AJGP-03-23-6754

Walsh, T. P., Butterworth, P. A., Urquhart, D. M., Cicuttini, F. M., Landorf, K. B., Wluka, A. E., Michael Shanahan, E., & Menz, H. B. (2017). Increase in body weight over a two-year period is associated with an increase in midfoot pressure and foot pain. *Journal of Foot and Ankle Research*, *10*, 31. https://doi.org/10.1186/s13047-017-0214-5

Wilson, J. M., Marin, P. J., Rhea, M. R., Wilson, S. M. C., Loenneke, J. P., & Anderson, J. C. (2012). Concurrent training: A meta-analysis examining interference of aerobic and resistance exercises. *Journal of Strength and Conditioning Research*, *26*(8), 2293–2307. https://doi.org/10.1519/JSC.0b013e31823a3e2d

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