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Custom-Made Foot Insoles on Dynamic Balance in Children with Flexible Flat Feet: A Community-Based Study

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Abstract

Flexible flat feet in children are common in community and school-aged populations and may be associated with altered lower-limb biomechanics, impaired postural control, and reduced dynamic balance, potentially affecting mobility, participation, and safety in daily activities. Although custom-made foot insoles are widely prescribed, evidence regarding their functional effects on dynamic balance in community-based pediatric settings remains limited. This study aimed to evaluate the effects of custom-made foot insoles on dynamic balance among children with flexible flat feet in a community-based rehabilitation context. A pre–post intervention study was conducted involving 40 children (mean age 10.05 ± 1.04 years). Dynamic balance was assessed using the Balance Beam Test before and after the intervention. Changes in balance performance were analyzed using the Wilcoxon signed-rank test, with effect size calculated using Cohen's d. Dynamic balance scores improved significantly after insole use ($Z = -3.995$, $p < 0.001$), with a large effect size ($d = 0.81$). Greater improvements were observed in children with lower baseline balance. These findings support the potential role of custom-made foot insoles within community-based rehabilitation strategies to enhance functional balance and promote safe participation among children.

Introduction

Flexible flat feet are commonly observed in children and represent one of the most frequently encountered musculoskeletal conditions in pediatric populations. Characterized by the collapse or absence of the medial longitudinal arch during weight-bearing with reconstitution during non–weight-bearing conditions, flexible flat feet are often regarded as a benign developmental variation (Mosca, 2010). Children with flexible flat feet often experience a notable reduction in dynamic balance compared to their peers with normal arch formations. Several studies have reported that children with flexible flat feet show a correlation between foot posture and balance capabilities, indicating a loss of balance compared to controls (Gupta *et al.*, 2023). However, growing evidence suggests that this condition may be associated with altered lower-limb biomechanics, compromised postural control, and impaired balance during functional activities, particularly in school-aged children who are undergoing critical phases of motor development (Li *et al.*, 2025). From a public health perspective, functional impairments in children extend beyond structural or anatomical considerations. Dynamic balance plays a fundamental role in children's ability to perform daily activities such as walking, running, navigating uneven surfaces, and participating safely in school and community environments (Shim and Rose-Woodward, 2019). Impairments in dynamic balance may increase susceptibility to falls, limit participation in physical activities, and

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reduce overall functional independence. At the population level, such functional limitations may contribute to reduced physical activity participation and increased injury risk, highlighting the relevance of balance-related impairments as a public health concern rather than solely a clinical issue.

Children with flexible flat feet may experience altered plantar pressure distribution, delayed proprioceptive feedback, and suboptimal neuromuscular control during dynamic tasks. These biomechanical and sensorimotor alterations can compromise postural strategies required for maintaining stability during movement (Tang, Cheng, Zou, Zho, *et al.*, 2023). Although not all children with flexible flat feet are symptomatic, those with functional impairments may face challenges in maintaining balance during everyday activities, potentially affecting confidence, participation, and safety in school and community settings. Addressing such functional consequences aligns with preventive public health approaches aimed at promoting healthy movement patterns and reducing injury risk during childhood. Custom-made foot insoles are widely prescribed as a conservative intervention to support the medial longitudinal arch, optimize foot alignment, and redistribute plantar loads during standing and walking. In pediatric rehabilitation, foot insoles are commonly utilized to address structural alignment and alleviate discomfort (Evans and Rome, 2011). Previous research has predominantly focused on biomechanical outcomes, such as changes in plantar pressure, joint alignment, or gait parameters, often assessed under controlled laboratory conditions (Tang, Cheng, Zou, Zho, *et al.*, 2023). While these studies provide valuable insights into mechanical effects, they offer limited information regarding functional outcomes that are directly relevant to daily activities and participation in real-world environments. Previous biomechanical studies have demonstrated that custom-made insoles can effectively redistribute plantar pressure and reduce localized loading during stance and gait, providing a mechanical basis for their functional use in pediatric populations (Bus, Ulbrecht and Cavanagh, 2004).

Dynamic balance represents a clinically meaningful and functionally relevant outcome, particularly in community-based and school-based contexts. Unlike static measures of foot posture or laboratory-based biomechanical assessments, dynamic balance reflects the integration of sensory, neuromuscular, and musculoskeletal systems during movement (Shim and Rose-Woodward, 2019). Improvements in dynamic balance may translate into enhanced functional mobility, safer participation in physical activities, and reduced risk of falls or injuries among children. Despite its relevance, evidence regarding the effects of custom-made foot insoles on dynamic balance in children with flexible flat feet remains limited and inconsistent, especially within community-based rehabilitation settings (Oerlemans *et al.*, 2023; Chinpeerasathian *et al.*, 2024). Community-based rehabilitation environments introduce contextual factors that are often absent in laboratory or clinical trials, including variability in activity levels, footwear use, compliance, and environmental demands. These factors may influence the functional effectiveness of orthotic interventions and are particularly relevant for public health-oriented research, which seeks to understand intervention outcomes under real-world conditions (Kim *et al.*, 2021). However, studies evaluating orthotic interventions in community settings remain underrepresented in the pediatric literature, resulting in a gap between clinical prescription practices and population-level functional evidence. Recent studies have reported that foot orthoses may improve balance and gait performance in children with flexible flat feet; however, most evidence has been generated under controlled or laboratory-based conditions (Peng *et al.*, 2022). School- and community-based musculoskeletal health promotion programs have been shown to support injury prevention and safe movement participation among children, reinforcing the relevance of functional balance as a public health outcome (Calvo *et al.*, 2025). Custom-made insoles are designed to fit the contours of a child's foot, potentially improving foot biomechanics. Evidence suggests that the use of orthotic devices can effectively manage symptoms associated with flat feet, although the overall effectiveness remains inconclusive.

For instance, a systematic review indicated that while tailored foot orthotics could result in improvements in balance and functionality among children with flatfoot, the evidence was not definitive (Tang, Cheng, Zou, Zhou, *et al.*, 2023; Cockayne *et al.*, 2025).

In addition, studies conducted in the context of public health services affirm the importance of assessing socially meaningful functional outcomes—e.g., children's ability to participate safely in school and community settings—as an indicator of the success of conservative interventions on flat foot problems (Huang, Cheng and Theise, 2013). Furthermore, a recent systematic review shows a heterogeneity of the evidence regarding the functional benefits of pediatric orthoses and emphasizes the need for participation-oriented and outcome-oriented studies in real settings (Chinpeerasathian *et al.*, 2024). Furthermore, children's functional outcomes are influenced by individual characteristics such as age, sex, and nutritional status, commonly reflected by body mass index (BMI). Variations in body composition may affect balance control, neuromuscular performance, and responsiveness to orthotic interventions, suggesting that functional outcomes should be interpreted within a broader biopsychosocial and public health framework (Li *et al.*, 2025). Therefore, this study aimed to evaluate the effects of custom-made foot insoles on dynamic balance among children with flexible flat feet in a community-based rehabilitation context. It was hypothesized that the use of custom-made foot insoles would be associated with a significant improvement in dynamic balance performance. By focusing on functional outcomes within a real-world setting, this study seeks to contribute evidence relevant to both pediatric rehabilitation practice and public health strategies aimed at promoting safe and active participation among children.

Methods

This study employed a community-based pre–post intervention design to evaluate changes in dynamic balance following the use of custom-made foot insoles in children with flexible flat feet. This design was selected to assess within-subject functional changes over time in a real-world rehabilitation context, where randomization and control conditions are often constrained by feasibility and ethical considerations. The study was conducted between March and June 2025 within a community-based rehabilitation program for children with musculoskeletal conditions in Karanganyar, Central Java, Indonesia. A total of 40 children clinically diagnosed with flexible flat feet were enrolled in this study. The participants had a mean age of 10.05 ± 1.04 years, with ages ranging from 8 to 12 years. Eligible participants were children aged between 8 and 12 years who had a clinical diagnosis of flexible flat feet established through physical examination, defined by a collapse of the medial longitudinal arch during weight-bearing that reappeared under non–weight-bearing conditions. All participants were required to be able to understand and follow verbal instructions and to complete balance assessments independently. Children were excluded from the study if they had any neurological or neuromuscular disorders that could affect balance or gait, congenital or structural foot deformities other than flexible flat feet, or a history of lower-limb injury within the six months preceding the study. In addition, children with prior or current use of foot orthoses were not included.

The study protocol was reviewed and approved by the ethical committee of Dr. Moewardi General Hospital (approval no. 2.665/XI/HREC/2024). Written informed consent was obtained from all participants and/or their legal guardians before participation, in accordance with institutional and ethical guidelines. Written informed consent was obtained from the parents or legal guardians of all participants before participation. Assent was obtained from the children when appropriate. The primary outcome measure of this study was dynamic balance, selected as a functional indicator closely related to children's safety, mobility, and participation in daily activities within community and school environments. From a public health perspective, dynamic balance reflects movement competence that is relevant to injury prevention, physical activity engagement, and functional independence at the population level. All participants were provided with custom-made foot insoles fabricated on the basis of individualized foot assessments. The insoles were specifically designed to support the medial longitudinal arch, improve overall foot alignment, and optimize load distribution during standing and walking activities. The

fabrication process involved a comprehensive clinical assessment of the feet in both weight-bearing and non–weight-bearing conditions, followed by individualized shaping of each insole to accurately match the contours of the child's foot. Materials suitable for pediatric orthotic applications were selected to ensure appropriate support, comfort, and safety for use in children.

Participants were instructed to wear the insoles during daily activities and school hours throughout the intervention period. No additional therapeutic exercises or balance training programs were introduced during the study period. The selection of insole materials and design characteristics followed established principles for orthopedic footwear, emphasizing adequate support, comfort, and load distribution for pediatric use (Yick and Tse, 2013). Dynamic balance was assessed using the Balance Beam Test, a functional performance-based tool designed to evaluate postural control during dynamic movement tasks. The test assesses the ability to maintain balance during controlled walking and transitional movements, reflecting neuromuscular coordination and dynamic postural stability in children. The Balance Beam Test has been widely used in pediatric balance assessment and is considered a feasible tool for evaluating dynamic postural control in school-aged children (Bruininks and Bruininks, 2022). The Balance Beam Test has been applied in pediatric populations and has demonstrated feasibility and acceptable test–retest reliability in previous studies, particularly in preschool and school-aged children. Broader evaluations of clinical balance assessment tools in pediatric rehabilitation have also reported good reliability and construct validity for dynamic balance measures, supporting the conceptual use of this class of assessments in functional balance research. However, comprehensive validation data specific to children with flexible flat feet remain limited. This limitation should be considered when interpreting the findings and highlights the need for further validation studies in orthopedic pediatric populations.

Assessments were conducted before the intervention (pre-test) and after the intervention period (post-test). Scores were recorded using an ordinal scoring system, with higher scores indicating better dynamic balance performance. Given the functional focus of the study, dynamic balance was selected as the primary outcome measure to reflect clinically meaningful changes relevant to rehabilitation practice. Body weight and height were measured using standard procedures. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Participants were categorized into BMI groups (underweight, normal, overweight) based on Asia–Pacific classification criteria for descriptive and subgroup analyses. Statistical analyses were performed using SPSS software. Descriptive statistics were calculated for demographic and baseline characteristics. Normality of dynamic balance scores was assessed using the Shapiro–Wilk test. Due to the non-normal distribution of the balance data, the Wilcoxon signed-rank test was used as the primary analysis to compare pre- and post-intervention balance scores. A paired t-test was conducted as a secondary analysis to facilitate comparison with studies reporting parametric outcomes. Effect size was calculated using Cohen's d to quantify the magnitude of change. Subgroup analyses were performed according to BMI categories; these analyses were interpreted cautiously due to unequal group sizes. An analysis of covariance (ANCOVA) was conducted as an exploratory analysis to examine whether post-intervention balance outcomes were influenced by baseline balance scores and demographic variables (age, gender, BMI category). Results of the ANCOVA were interpreted as exploratory and hypothesis-generating. Statistical significance was set at $p < 0.05$.

Results and Discussion

A total of 40 children with flexible flat feet were included in the analysis. Participant demographic and anthropometric characteristics are presented in Table 1. The sample comprised both sexes and included participants classified as underweight, normal weight, and overweight based on BMI criteria.

Changes in dynamic balance scores before and after the intervention are summarized in Table 2. Statistical analysis using the Wilcoxon signed-rank test demonstrated a significant difference between pre-intervention

Table 1. Participant Demographic and Anthropometric Characteristics (n = 40)

Characteristic	n	%
Sex		
Female	26	65.0
Male	14	35.0
Body mass index (BMI) category		
Underweight	28	70.0
Normal weight	10	25.0
Overweight	2	5.0

Table 2. Dynamic Balance Scores Before and After the Intervention (n = 40)

Variable	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	Test	Statistic	p-value
Dynamic balance score	1.60 ± 1.06	2.53 ± 1.41	Wilcoxon signed-rank	Z = −3.995	< 0.001
			Paired t-test	t = −5.127	< 0.001

SD: standard deviation.

Table 3. Changes in Dynamic Balance Scores by BMI Category

BMI category	n	Statistical test	Statistic	p-value
Underweight	28	Wilcoxon signed-rank	—	< 0.001
Normal weight	10	Wilcoxon signed-rank	—	0.102
Overweight	2	Wilcoxon signed-rank	—	0.317

BMI: body mass index.
Note: Subgroup analyses were conducted using non-parametric tests due to small and unequal group sizes.

Table 4. Exploratory ANCOVA for Post-Intervention Dynamic Balance Score

Source	df	F	p-value
Baseline balance score	1	—	< 0.001
Age	1	—	> 0.05
Sex	1	—	> 0.05
BMI category	2	—	> 0.05
Model R^2	—	—	0.401

ANCOVA: analysis of covariance; BMI: body mass index.
Baseline balance score was included as a covariate. F values are not presented for non-significant covariates.

and post-intervention dynamic balance scores. Secondary analysis using a paired t-test yielded consistent results. The magnitude of change was quantified using effect size analysis.

Results of subgroup analyses according to BMI category are shown in Table 3. A statistically significant change in dynamic balance scores was observed in one BMI subgroup, while changes in the other BMI categories did not reach statistical significance.

Results of the exploratory analysis of covariance are presented in Table 4. Baseline dynamic balance score was identified as a significant covariate associated with post-intervention balance outcomes. Age, sex, and BMI category were not statistically significant covariates in the model.

The ANCOVA model was statistically significant ($R^2 = 0.401$). Baseline balance score was a significant predictor of post-intervention

balance ($p < 0.001$), whereas age, gender, and BMI category were not significant predictors. This community-based pre–post intervention study demonstrated that the use of custom-made foot insoles was associated with a significant improvement in dynamic balance among children with flexible flat feet. The observed increase in balance scores, accompanied by a large effect size, suggests that the intervention yielded not only statistically significant but also functionally meaningful improvements. These findings are consistent with previous evidence indicating that orthotic interventions can influence functional performance beyond structural correction alone (Chinpeerasathian *et al.*, 2024).

Baseline balance score emerged as a significant predictor of post-intervention balance outcomes, indicating that children with lower initial balance performance may derive greater benefit from orthotic intervention. This observation aligns with rehabilitation principles, suggesting that interventions targeting functional deficits tend to yield more pronounced effects among individuals with greater baseline impairment (Oerlemans *et al.*, 2023). Previous studies examining the effects of foot orthoses in children with flexible flat feet have primarily focused on biomechanical parameters, such as plantar pressure redistribution and lower-limb alignment (Tang, Cheng, Zou, Zho, *et al.*, 2023). While these outcomes provide important mechanistic insights, they do not fully capture functional performance during daily activities. The present study extends existing literature by demonstrating improvements in dynamic balance, a functional outcome closely related to participation and movement safety in children (Shim and Rose-Woodward, 2019).

Systematic reviews have reported mixed evidence regarding the functional benefits of orthotic interventions in pediatric flat feet, largely due to heterogeneity in study designs, outcome measures, and participant characteristics (Chinpeerasathian *et al.*, 2024). By situating the intervention within a community-based context and employing a functional balance assessment, this study addresses an important gap between controlled clinical research and real-world rehabilitation practice. From a functional perspective, the observed improvement in dynamic balance may be attributed to enhanced foot stability, optimized load distribution, and improved plantar sensory input facilitated by custom-made foot insoles (Tang, Cheng, Zou, Zho, *et al.*, 2023). Adequate support of the medial longitudinal arch may promote more efficient neuromuscular responses, thereby supporting balance control during walking and transitional movements. Improvements in dynamic balance may also be related to changes in plantar pressure distribution facilitated by insole use, as supported by evidence showing optimized load redistribution following custom insole intervention (Elgohary *et al.*, 2024). Postural stability in children is influenced by neuromuscular coordination and sensory integration, and deficits in these systems have been shown to affect balance performance in pediatric populations with movement disorders (Szopa and Domagalska-Szopa, 2024).

Dynamic balance is a key determinant of safe participation in physical activities among children. Improvements in balance performance may therefore have broader implications for injury prevention, physical activity engagement, and confidence during school and community participation (Alsaafin *et al.*, 2023). From a public health standpoint, even modest functional improvements at the individual level may yield meaningful benefits when considered across pediatric populations, particularly given the high prevalence of flexible flat feet (Mosca, 2010). A systematic review highlighted that flatfoot is linked to balance disorders, affecting physical performance in activities requiring stability (Eren-Zengin *et al.*, 2025).

Some studies have shown that specific exercises combined with the use of orthotic interventions may enhance dynamic balance (Erten, Tarakçı and Çaçan, 2023). Consistent with the selection of dynamic balance as the primary outcome measure, the observed functional improvements have relevance beyond individual clinical gains and reflect broader public health priorities. Dynamic balance represents a key component of movement competence that supports children's safety, physical activity participation, and

injury prevention in school and community settings, making it a meaningful indicator for evaluating population-oriented rehabilitation interventions. From a public health perspective, the findings of this study underscore the potential role of custom-made foot insoles as part of community-based rehabilitation strategies aimed at promoting functional health in children. Flexible flat feet are prevalent in pediatric populations, and even modest functional impairments, when present at the population level, may contribute to reduced physical activity participation and increased injury risk. Interventions that improve functional balance may therefore support broader public health goals related to child safety, physical activity promotion, and healthy motor development. In community-based rehabilitation and school health settings, interventions must be feasible, acceptable, and capable of producing meaningful functional benefits without requiring extensive resources. Custom-made foot insoles represent a relatively accessible intervention that can be integrated into daily routines. The present findings support their potential role as part of community-based rehabilitation strategies aimed at promoting functional mobility and preventive musculoskeletal health in children (Kim *et al.*, 2021). Evidence from public health studies indicates that knowledge-based approaches alone may be insufficient to prevent musculoskeletal disorders in children, highlighting the need for functional and biomechanical interventions within community-based health promotion programs (Lubis, Khamidah and Yuliadarwati, 2023). The effectiveness of movement-based health promotion programs in schools underscores the importance of addressing underlying biomechanical limitations, such as flexible flat feet, that may restrict children's optimal participation in physical activities (Nurharsono *et al.*, 2023).

Furthermore, the association between baseline balance performance and post-intervention outcomes highlights the importance of functional screening within community settings. Incorporating simple balance assessments into school or community health programs may help identify children who could benefit from early orthotic intervention, thereby supporting preventive approaches to musculoskeletal health. Such strategies align with public health frameworks that emphasize early identification and intervention to mitigate long-term functional consequences. The practical implication is that when this effectiveness is confirmed through controlled studies, custom insoles can be an inexpensive prevention strategy and easily integrated into school health programs or child rehabilitation, with large-scale potential to increase physical participation and reduce minor balance-related injuries. In addition, recent technological developments such as digital foot scanning and customized insole fabrication may further enhance the feasibility and scalability of orthotic interventions within community-based rehabilitation programs. The integration of orthotic interventions into community-based rehabilitation programs aligns with international public health frameworks that emphasize functional participation, accessibility, and early intervention in child health services (World Health Organization, 2023).

Subgroup analyses suggested that improvements in dynamic balance were more pronounced in children classified as underweight, although these findings should be interpreted cautiously due to unequal group sizes. This observation highlights the potential interaction between nutritional status, musculoskeletal function, and balance performance in children (Li *et al.*, 2025). From a public health perspective, this underscores the importance of considering nutritional and growth-related factors when interpreting functional outcomes and planning rehabilitation interventions. Several limitations should be acknowledged. The absence of a control group limits the ability to establish causal relationships between insole use and balance improvement. The relatively small sample size and unequal distribution across BMI categories may have reduced the statistical power of subgroup analyses. Additionally, the short follow-up period precluded assessment of long-term adaptation or sustainability of balance improvements. These limitations are common in community-based intervention

studies, where randomized designs and extended follow-up may be constrained by practical considerations. Future research should employ randomized controlled designs with appropriate comparison groups to strengthen causal inference. Longer follow-up periods are recommended to evaluate the durability of functional improvements and their potential impact on participation and injury risk. Incorporating objective balance assessment tools and monitoring adherence to insole use may further enhance understanding of the effectiveness of orthotic interventions in real-world pediatric settings.

Conclusion

This community-based study demonstrated that the use of custom-made foot insoles was associated with a significant and clinically meaningful improvement in dynamic balance among children with flexible flat feet. By focusing on functional outcomes relevant to daily activities, these findings support the potential integration of individualized orthotic interventions into community-based rehabilitation strategies aimed at enhancing safe participation, functional mobility, and preventive musculoskeletal health in children.

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