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Effects of Kinesio Taping on Walking and Dynamic Balance in Individuals with Flat Feet: A Randomized Controlled Clinical Trial

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ABSTRACT

Flatfoot is a common musculoskeletal condition characterized by a collapsed medial longitudinal arch, often leading to altered biomechanics, impaired balance, and an increased risk of injury. Kinesio Taping (KT) has been proposed as a non-invasive intervention to provide arch support. This study investigated the effects of KT on navicular drop, vertical ground reaction force (vGRF) variables during walking, and center of pressure (CoP) parameters during a curve-tracking balance task. Thirty-eight individuals with bilateral flatfoot were randomly assigned to a KT or sham taping group. KT was applied to the medial and transverse arches and along the tibialis posterior muscle. Walking and balance tasks were performed under taped and non-taped conditions, with outcomes measured before and after taping. The results revealed significant main effects for time (pre- vs. post-treatment), group (KT vs. sham), and a group*time interaction for navicular drop ($p < 0.05$ for all). Specifically, navicular drop was reduced by 18.33% following KT application, compared to a 0.85% reduction in the sham condition. However, no significant differences were observed in vGRF or CoP variables for time, group, or their interaction ($p > 0.05$). These findings suggest that while KT may improve static foot posture, its effects do not translate into meaningful changes in gait mechanics or balance control. These findings emphasize the need for therapeutic interventions to be assessed beyond clinical outcomes, with an emphasis on biomechanical evaluations to better understand their functional impact on movement and stability.

Keywords Pes Planus, Taping, Gait, Postural Control, Biomechanics

CITATION LINKS

1- Flatfeet: Biomechanical implications, assessment and .... 2- (ii) Flatfoot deformity: an overview. 3- Flatfoot deformity affected the kinematics of .... 4- Flat foot and associated factors among .... 5- Prevalence and characteristics of .... 6- Biomechanics and pathophysiology of .... 7- Effect of functional fatigue on .... 8- Ground reaction force analysis in .... 9- A comparison of foot kinetic parameters between pronated and .... 10- Biomechanical variations in .... 11- Association between foot type and .... 12- Dynamic postural balance in .... 13- Comparison of dynamic balance between flat feet and .... 14- Effect of flat feet on .... 15- Rehabilitative treatment in flexible flatfoot .... 16- Flatfoot Deformity; Exercise to .... 17- Clinical therapeutic applications of .... 18- Is kinesio taping effective for sport performance and ankle function of .... 19- Does lower limb kinesio taping affect pain, muscle strength, and .... 20- Kinesio Taping relieves pain and improves isokinetic not isometric muscle strength in .... 21- Effectiveness of neuromuscular taping on pronated foot posture and .... 22- To compare the effectiveness of taping and arch support on .... 23- Comparison of the effects of barefoot, kinesio tape, and dynamic tape on .... 24- The effect of Kinesio Taping on balance and .... 25- Effects of Kinesio tape on supporting medial foot arch in runners with .... 26- Does Kinesio taping of tibialis posterior or .... 27- G* Power 3: A flexible statistical power analysis program for .... 28- Measurements used to characterize the foot and .... 29- Effect of using truncated versus total foot length to calculate the .... 30- Reliability and minimal detectable change of .... 31- The effect of ankle kinesio taping on the explosive power of .... 32- Short-term effects of sports taping on navicular height, navicular drop and peak plantar pressure in .... 33- The role of the quadriceps in controlling impulsive forces around .... 34- Gait and muscle activation changes in men with knee osteoarthritis. 35- Relationship between lower limb dynamics and knee joint pain. 36- The effect of six week virtual reality training on .... 37- Statistical power analysis for the behavioral sciences. 38- Effect of gastrocnemius kinesio taping on .... 39- Kinesio taping does not improve ankle functional or performance in people with or .... 40- Effect of foot orthoses on balance among individuals with flatfoot .... 41- The effect of poron layered insole on ....

1. Introduction

Flatfoot, also known as pes planus, is a common musculoskeletal condition characterized by the partial or complete collapse of the medial longitudinal arch (MLA) of the foot. This structural deformity can lead to a wide range of complications, including foot and lower limb pain, muscle fatigue, plantar fasciitis, shin splints, Achilles tendinopathy, and the development of secondary conditions such as hallux valgus[1-3]. These issues not only reduce functional capacity but also negatively impact quality of life and physical activity levels. Given that the foot serves as the primary foundation for locomotion, any structural alteration can disrupt normal biomechanical function, potentially impairing movement and increasing the risk of injury[4-6].

From a biomechanical perspective, the MLA plays a fundamental role in load distribution, shock absorption, and energy transfer during walking, running, and other weight-bearing activities. In individuals with flatfoot, collapse of the arch compromises these functions, leading to altered load transmission and abnormal force distribution in the lower extremity[7-10]. Prior studies have demonstrated that individuals with flatfoot exhibit a greater vertical ground reaction force (vGRF) valley during walking, reflecting insufficient load absorption during mid-stance[7]. In addition, reduced ankle joint moment during the push-off phase have been observed, suggesting diminished propulsion efficiency in walking. Furthermore, the foot's decreased stiffness limits its capacity to act as a rigid lever, impairing force transmission and increasing movement inefficiency [10]. In more challenging tasks such as jumping, individuals with flatfoot demonstrate elevated vGRF values, higher loading rates, and prolonged time to stabilization[9]. These biomechanical abnormalities can compromise performance and may contribute to overuse injuries in not only the foot and ankle, but also the knee, hip, and lumbar spine[6, 11].

In addition to gait-related deficits, flatfoot is also associated with impaired postural stability and dynamic balance control. Excessive foot mobility and ligamentous laxity, particularly in the midfoot and rearfoot regions, may alter proprioceptive feedback from plantar mechanoreceptors, thereby compromising neuromuscular coordination[12-14]. Evidence from balance assessments such as the Biodex Stability System has shown increased anteroposterior sway and impaired stability index in individuals with flatfoot[12]. Moreover, reduced reach distances in all directions on the star excursion balance test and shorter single-leg stance durations have been reported[13, 14], further supporting the presence of balance impairments in this population. These findings underscore the importance of evaluating both gait and balance when determining the effectiveness of interventions for individuals with flatfoot.

Conservative management of flatfoot often includes interventions such as orthotic devices, corrective footwear, therapeutic exercises, and taping techniques[1, 15, 16]. Among these options, taping has gained popularity in recent years due to its cost-effectiveness, ease of application, and immediate clinical applicability. Kinesio taping (KT), in particular, is widely used in both sports and rehabilitation settings. Unlike rigid taping methods that limit motion, KT utilizes elastic properties to provide support while allowing functional movement. It has been proposed to alleviate pain, enhance proprioceptive feedback, improve joint stability, and increase muscle strength[17-20].

Several studies have reported that KT may temporarily increase MLA height, reduce discomfort, and improve static balance in individuals with flatfoot[21-26]. Specifically, KT has been shown to improve foot posture index and reduce navicular drop[21,25,26], decrease anteroposterior and mediolateral center of pressure (CoP) variability during walking, and reduce CoP velocity and displacement during static standing[23,24]. Additionally, studies have reported improved activation of the tibialis anterior muscle following KT application[25]. While the taping techniques used in these studies varied slightly, most targeted the medial longitudinal arch, transverse arch, and tibialis posterior region. Despite promising results, the majority of existing research has predominantly focused on static parameters, such as improvements in foot posture and balance during quiet standing. While these outcomes are clinically relevant, they do not fully capture the complexity of human movement. Dynamic tasks such as walking, running, and balance challenges require coordinated multi-joint movement and continuous neuromuscular adaptation. Consequently, it remains unclear whether KT can meaningfully influence biomechanical variables such as vGRF and CoP variables under dynamic, functional conditions.

To address this need, the present randomized controlled trial aimed to evaluate the immediate effects of KT—applied to the foot arches and along the tibialis posterior muscle—on navicular drop, vGRF variables during walking, and CoP measures during a dynamic balance task in individuals with flatfoot. Walking was selected as a representative functional activity due to its critical role in daily mobility. Dynamic balance was assessed using the curve tracking test, a task that challenges real-time postural adjustments by requiring voluntary modulation of the CoP in response to a moving sinusoidal target, thereby providing a functional measure of balance control. By combining clinical (navicular drop) and biomechanical (vGRF and CoP) outcomes, this study aimed to provide a comprehensive evaluation of KT's potential in improving functional performance in individuals with flatfoot. The findings may inform evidence-based clinical practice and contribute to determining whether KT offers meaningful benefits for real-world rehabilitation and injury prevention settings.

2. Method

2.1 Participants

A total of 38 individuals with bilateral flexible flatfoot voluntarily participated in this randomized controlled clinical trial. The required sample size was calculated using G*Power software[27], with a medium effect size (f = 0.25), an alpha level of 0.05, and a power (1 − β) of 0.80. The minimum required sample was 34 participants; however, to account for a potential dropout rate of approximately 10%, the final sample was increased to 38.

Participants were eligible if they met the following inclusion criteria: an arch height ratio (AHR) of less than 0.221[28,29], measured using a reliable custom-made device[30]; age between 18 and 30 years; and a body mass index (BMI) within the normal range (18.5–24 kg/m²). Exclusion criteria included any history of permanent orthopedic, neurological, or rheumatological conditions affecting the lower limbs or low back spine; prior lower limb or lumbar spine surgery; visible deformities other than flatfoot; participation in a physiotherapy program within the past six months; and engagement in vigorous physical activity within 48 hours prior to testing.

Randomization was conducted using block randomization by an independent researcher who was not involved in data collection. Participants were allocated to either the KT or sham taping group. A double-blind design was implemented to ensure that both participants and the assessor remained unaware of group assignments. To maintain blinding, separate laboratory sessions were conducted for each group. All procedures were approved by the Ethics Committee of Tarbiat Modares University and were in accordance with the Declaration of Helsinki. The study was prospectively registered with the Iranian Registry of Clinical Trials. Written informed consent was obtained from all participants prior to enrollment, with the assurance that they could withdraw from the study at any time and for any reason.

2.2 Experimental Procedure

All procedures were conducted at the Research and Treatment Center for Movement Disorders at Tarbiat Modares University. Prior to the main testing session, all participants completed a familiarization session to become accustomed to the gait and balance tasks.

Gait analysis was conducted on a 10-meter walkway equipped with a force platform (Model 9286B, Kistler Co., Winterthur, Switzerland) embedded at the midpoint. To capture natural walking behavior, participants initiated walking five steps before reaching the force plate and continued walking beyond it without altering their pace. Three valid trials were recorded per participant, with vGRF data collected at a sampling rate of 1000 Hz. A trial was considered valid if the entire foot contacted the force plate. Participants maintained a natural walking pace with forward gaze throughout.

Dynamic balance was evaluated using the Curve Tracking Task implemented in Kistler MARS software (v4.0.0.87). Participants stood on a force plate and were instructed to voluntarily shift their CoP to align with a sinusoidal wave moving in the mediolateral direction. The reference curve was displayed on a wall-mounted monitor positioned two meters in front of the participants. Postural control was assessed by measuring the accuracy of CoP tracking relative to the reference curve. Each participant completed three 30-second trials, and the recorded CoP variables were subsequently analyzed.

The order of performing gait and balance tasks was randomized for each participant to minimize potential order effects and ensure unbiased results.

2.3 Taping Procedure

KT was applied by a physiotherapist with prior training in therapeutic taping protocols. The application was based on standardized techniques aimed at supporting the medial longitudinal arch and facilitating activation of the tibialis posterior muscle, which plays a critical role in foot posture [17, 24-26, 31].

Before application, the elastic capacity of the KT was determined to ensure that it remained within its elastic limits. The same brand of KT (ARES Kinesio Tape, South Korea) was used for all participants. To ensure accurate and individualized tape length, the target region of each participant's foot was measured, and the tape was cut accordingly prior to application.

A "Y" strip was anchored at the calcaneus near the origin of the plantar fascia. The tails extended anteriorly along the medial and lateral borders of the foot and ended at the first and fifth metatarsal heads. The tape was stretched to 100% of its elastic capacity to support longitudinal arches.

An "I" strip was placed transversely across the midfoot from the lateral fifth metatarsal to the medial navicular with 50% stretch of its elastic capacity to support the transverse arch.

A final "I" strip was applied along the path of the tibialis posterior muscle, beginning at the lateral posterior surface of the tibia and ending just distal to the medial malleolus, using 35% stretch of its elastic capacity.

Figure 1 illustrates the taping locations. Although shown separately for clarity, in the actual protocol the "Y" strip was applied first, followed by the transverse "I" strip, and finally the strip over the tibialis posterior muscle.

In the sham taping condition, a 10 cm strip of KT was applied with no stretch to the medial ankle region, specifically over the medial malleolus. This neutral placement ensured that participants experienced the tactile sensation of tape without any therapeutic mechanical input, thereby serving as sham condition[32].

Following application, in accordance with previous recommendations[17], participants remained in a resting position for approximately 20 minutes to ensure proper tape adhesion. Gentle rubbing was performed over the tape to warm it and enhance adhesive bonding.

Fig. 1) Kinesio taping applied to the medial longitudinal arch **(a)**, transverse arch **(b)**, and tibialis posterior **(c)**. The tapes are shown separately for better visualization; however, in the actual taping procedure, they were applied in overlapping layers.

2.4 Data Extraction

vGRF variables were extracted from the stance phase of gait[33-35] using Vicon software (Vicon Nexus 2.11.0, VICON Motion Systems Ltd, Oxford, UK) and further analyzed using a custom MATLAB script (MathWorks, Natick, MA) (Figure 2).

1- Heel strike transient (HST): Defined as the initial peak force occurring within the first 5–25 milliseconds of ground contact, typically ranging between 0.5 and 1.25 times body. Values were normalized to body weight.

2- Time to HST: The temporal interval (in milliseconds) from initial foot contact to the occurrence of HST.

3- First peak of vGRF: The maximum vertical force recorded during the loading response phase (early stance), normalized to body weight.

4- vGRF valley: The lowest vertical force value between the first and second peaks, representing mid-stance unloading, normalized to body weight.

5- Second peak of vGRF: The late stance peak force associated with push-off and propulsion, normalized to body weight.

CoP data were processed and analyzed using the MARS[36]. The analysis included the following metrics:

1- Mean absolute error (MAE): The average deviation (in mm) between the actual CoP path and the sinusoidal reference curve across the trial. It is computed as:

$$MAE = \frac{\sum_{i=1}^{n}|x_i - r_i|}{N} \quad (1)$$

where:

xi: Actual CoP position at the i-th point.

ri: Reference curve position at the i-th point.

N: Total number of data points.

2- Standard deviation of absolute error (SD_{AE}): The standard deviation of deviation between the reference curve and the actual COP signal, computed as:

$$SD_{AE} = \sqrt{\frac{\sum_{i=1}^{N}(|x_i - r_i| - MAE)^2}{N-1}} \quad (2)$$

3- Root mean square Error (RMSE): Representing the square root of the mean squared deviations between the reference curve and actual CoP trajectories, computed as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(x_i - r_i)^2}{N}} \quad (3)$$

2.5 Statistical Analyses

All statistical analyses were conducted using SPSS software. For gait and balance assessments, vGRF and CoP variables were averaged across three trials. Prior to hypothesis testing, data distributions were checked for normality using the Shapiro–Wilk test. To assess potential baseline differences between groups, independent samples t-tests were used for variables. For the main analysis, a mixed-model ANOVA was conducted with one within-subject factor (condition: without tape vs. with tape) and one between-subject factor (group: KT vs. sham). Assumptions for ANOVA were verified using Levene's test for equality of error variances and Box's M test for equality of covariance matrices. Statistical significance was set at $p < 0.05$ for all tests. Effect sizes were calculated using partial eta squared (η_p^2) to interpret the magnitude of observed effects. And values of 0.01, 0.06, and 0.14 were interpreted as small, moderate, and large effect sizes, respectively[37].

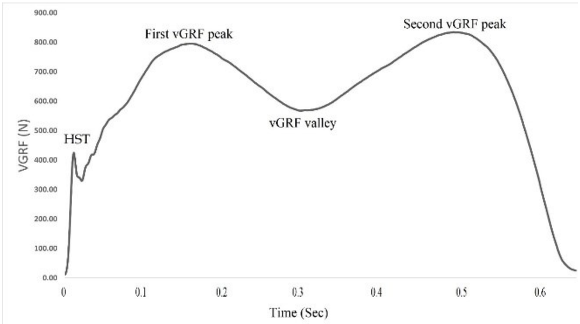

Fig. 2) A vertical ground reaction force (vGRF) curve of a subject, illustrating the heel strike transient (HST), first and second vGRF peaks, and the vGRF valley.

3. Result

All 38 participants (19 in each group) successfully completed the study protocol, and their data were included in the final statistical analyses. The demographic characteristics of both groups are summarized in Table 1. Independent t-tests revealed no statistically significant differences between the KT and sham groups in terms of age, body weight, height, or BMI, indicating that the groups were well-matched at baseline ($p > 0.05$ for all comparisons).

Similarly, no significant between-group differences were observed for any baseline outcome measures, including navicular drop, vGRF, or CoP variables ($p > 0.05$), ensuring that both groups were comparable before the intervention.

The results of the mixed ANOVA are presented in Table 2. A significant main effect of group, condition, and a group*condition interaction was observed for navicular drop ($p < 0.05$). As there were no significant baseline differences between groups, the observed changes were attributed to post-intervention effects (Figure 3). Specifically, navicular drop decreased from 1.20 ± 0.18 cm to 0.98 ± 0.11 cm in the KT group, indicating a 18.33% reduction. In contrast, the sham group showed only a slight reduction, from 1.18 ± 0.15cm to 1.17 ± 0.15 cm (0.85%). These findings confirm that KT produced a significant immediate reduction in navicular drop compared to sham taping.

For vGRF and CoP variables, no significant main effects of group or condition, nor any significant interactions, were observed ($p > 0.05$). This suggests that neither the application of taping (KT vs. sham) nor the condition (with or without taping) had a measurable impact on these variables.

Table 1) Demographic data, mean (SD) of participants

Variables	KT group (N=19)	Sham group (N=19)	p-value
Age	24.68 (3.31)	25.10 (3.55)	0.731
Weight (kg)	58.47 (7.73)	58.58 (6.73)	0.668
Height (m)	1.61 (0.05)	1.62 (0.06)	0.998
BMI	22.49 (2.16)	22.15 (1.72)	0.161

Table 2) Descriptive statistics, mean (SD), and mixed ANOVA results, p-value (partial eta squared), for group (KT vs. Sham), condition (with vs. without tape), and interaction effects

Variables	Before Taping		After taping		Group effect	Condition effect	Interaction effect
	KT	ST	KT	ST			
Navicular drop (cm)	1.20 (0.18)	1.18 (0.15)	0.98 (0.11)	1.17 (0.15)	0.019* (0.072)	< 0.001* (0.554)	< 0.001* (0.507)
Walking variables							
HST (%BW)	0.48 (0.08)	0.48 (0.05)	0.49 (0.08)	0.49 (0.08)	0.960 (< 0.001)	0.687 (0.009)	0.992 (< 0.001)
1st vGRF peak (%BW)	1.12 (0.04)	1.14 (0.06)	1.12 (0.04)	1.14 (0.05)	0.186 (0.039)	0.668 (0.004)	0.846 (0.001)
2nd vGRF peak (%BW)	0.88 (0.09)	0.89 (0.09)	0.88 (0.10)	0.87 (0.18)	0.926 (< 0.001)	0.630 (0.005)	0.619 (0.006)
vGRF minimum (%BW)	0.70 (0.09)	0.89 (0.11)	0.70 (0.08)	0.83 (0.11)	0.600 (0.006)	0.696 (0.003)	0.637 (0.005)
Time to HST (s)	0.33 (0.01)	0.38 (0.01)	0.36 (0.01)	0.48 (0.02)	0.301 (0.059)	0.105 (0.139)	0.452 (0.032)
Time to 1st vGRF peak (s)	0.74 (0.05)	0.67 (0.01)	0.74 (0.05)	0.69 (0.01)	0.096 (0.060)	0.407 (0.015)	0.342 (0.020)
Curve tracking variables							
Mean absolute error (mm)	72.14 (14.33)	77.75 (10.68)	72.23 (15.08)	80.74 (12.69)	0.083 (0.073)	0.288 (0.028)	0.314 (0.025)
SD of absolute error (mm)	44.77 (8.58)	49.29 (5.37)	45.07 (9.90)	50.12 (8.34)	0.065 (0.083)	0.429 (0.016)	0.707 (0.004)
RMSE (mm)	84.97 (16.55)	93.10 (12.09)	85.20 (17.85)	95.11 (14.96)	0.063 (0.089)	0.420 (0.016)	0.521 (0.010)

HST: Heel Strike Transient; vGRF: Vertical Ground Reaction Force; SD: Standard Deviation; RMSE: Root Mean Square Error.

*Significant difference

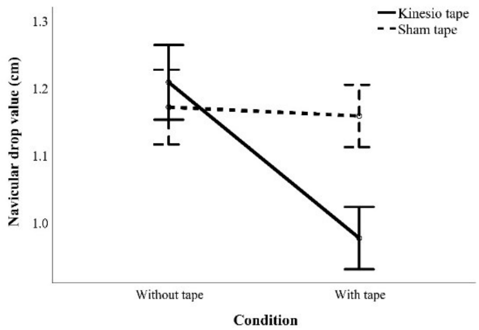

Fig. 3) Navicular drop values decreased following kinesiology tape application, whereas values remained constant in the sham tape condition.

4. Discussion

This study aimed to evaluate the immediate effects of KT on navicular drop, vGRF, and CoP variables in individuals with flat feet. The results demonstrated that KT significantly reduced navicular drop compared to the sham condition, indicating that KT exerts a measurable structural influence on the medial longitudinal arch. This finding aligns with earlier reports that have highlighted KT's potential to support foot posture and enhance static balance by mechanically lifting the arch and reducing excessive pronation[21-26]. However, this structural improvement did not translate into significant changes in dynamic performance measures. KT application failed to induce notable modifications in vGRF parameters or CoP variables during walking and dynamic balance tasks. These results imply that although KT may offer benefits for static foot alignment, its mechanical effect may be insufficient to influence dynamic biomechanical behavior during functional activities such as gait and postural control.

The observed discrepancy between the improvement in static structure (navicular drop) and the lack of change in dynamic variables (vGRF and CoP) highlights a key distinction between structural and functional assessments in biomechanics. While navicular drop is a clinically useful indicator of arch integrity, it reflects only a static characteristic and does not fully account for the complex, multi-joint, and neuromuscular coordination required during dynamic movement. Gait and balance tasks involve continuous adjustments and proprioceptive feedback that go beyond the localized effects of a taping intervention.

This interpretation is supported by earlier investigations that reported minimal or no significant effects of KT on neuromuscular activity and biomechanical output during functional activities. For instance, one study found that KT did not improve functional outcomes in individuals with ankle sprains during dynamic activities, and another observed no enhancement in jumping performance following KT application[38, 39]. A potential explanation for these findings is that the body utilizes compensatory mechanisms to preserve stability and movement efficiency, potentially offsetting the localized effects of KT on a single anatomical region. Furthermore, the mechanical properties of KT may limit its capacity to provide sustained support under dynamic loading conditions. Unlike rigid devices such as custom orthoses or arch-support insoles, which have been shown to positively affect vGRF and balance[40, 41], KT's flexible and stretchable nature may be insufficient to maintain medial longitudinal arch elevation throughout the entire stance phase of gait.

These results underscore the importance of incorporating both clinical and biomechanical outcomes when evaluating the effectiveness of an intervention. While the observed reduction in navicular drop indicates a potential clinical benefit, the absence of improvements in gait and balance performance suggests that KT alone may be inadequate for addressing functional deficits in individuals with flatfoot.

Despite the valuable insights offered by this study, several limitations should be acknowledged. First, lower limb kinematic data were not collected, which could have provided a more detailed understanding of compensatory movement strategies and joint interactions. Second, although the taping protocol was based on previous literature[17,24-26,31], variations in tape tension and application technique may have influenced the outcomes. These differences can serve as a foundation for future research exploring their impact on therapeutic effectiveness. Additionally, this study focused on the short-term, immediate effects of KT; long-term clinical aspects such as pain, fatigue, or muscle cramping were not examined but could offer further insight into KT's utility in real-world settings. Finally, exploring the combination of KT with other interventions, such as exercise therapy or orthotic support, could help determine whether KT has additive or synergistic effects when integrated into a broader rehabilitation program.

5. Conclusion

This randomized controlled trial provides new evidence regarding the immediate biomechanical effects of KT in individuals with flat feet. Although KT significantly reduced navicular drop—indicating a temporary improvement in medial longitudinal arch support—no significant changes were observed in vGRF or CoP variables during walking and dynamic balance tasks. These findings suggest that while KT may enhance static foot posture, it does not translate into measurable improvements in dynamic functional performance.

The study emphasizes the importance of incorporating both clinical and biomechanical outcome measures when evaluating therapeutic interventions. Clinicians should be cautious in interpreting improvements in static indicators, such as navicular drop, as evidence of functional gains. Overall, KT may be a useful short-term adjunct for arch support, but it is unlikely to address the more complex motor control and load management challenges associated with flatfoot during dynamic activities.

Highlights:

- KT application significantly reduced navicular drop, indicating improved static medial arch support.
- No significant effects were observed on vGRF or CoP variables, suggesting limited impact on gait kinetics and balance.
- KT may be a useful adjunct for static posture correction but should not be relied upon as a standalone intervention for improving dynamic function in individuals with flat feet.

Ethical Statement

The content of this manuscript is original, based on the authors' research, and has not been published or submitted elsewhere, either in Iranian or international journals.

Conflict of interest

The authors declared that they have no conflicts of interest to this work.

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