Research Article

BIOMEDICAL Journal of Scientific & Technical Research

ISSN: 2574 -1241

DOI: 10.26717/BJSTR.2023.54.008504

Acute Effects of Athletic Taping Techniques on Calcaneus Frontal Motion in Young Female Adults with Flexible Flatfoot

Lin Wang*

Associate Professor, School of Kinesiology, Shanghai University of Sport, China

***Corresponding author:** Lin Wang, Associate Professor, School of Kinesiology, Shanghai University of Sport, Shanghai, China

ARTICLE INFO

Received: December 01, 2023

Published: December 13, 2023

Citation: Lin Wang. Acute Effects of Athletic Taping Techniques on Calcaneus Frontal Motion in Young Female Adults with Flexible Flatfoot. Biomed J Sci & Tech Res 54(1)-2023. BJSTR. MS.ID.008504.

ABSTRACT

Objective: This study aimed to explore the acute effects of athletic taping techniques on calcaneus motion during walking in young female adults with Flexible Flatfoot (FFT).

Methods: Twenty young female adults with FFT were randomly assigned to Augmented Low Dye (ALD) and Modified Low Dye (MLD) taping groups. The calcaneus frontal motion was measured by Resting Calcaneus Stance Position (RCSP), peak calcaneus eversion, peak calcaneus inversion and calcaneus frontal range of motion (frontal ROM). An electronic protractor was used to measure RCSP, and STT-IWS 3D IMU system was applied to calcaneus frontal motion. The measurements were collected at baseline, post-taping and after 20 minutes of walking.

Results: Compared with baseline, the RCSP values significantly increased after 20 minutes of walking with ALD ($p = 0.004$). After 20 minutes of walking, ALD taping performed higher peak calcaneus version ($p = 0.02$) and frontal ROM ($p = 0.003$) compared to post-taping. MLD taping exhibited higher peak calcaneus inversion ($p = 0.001$) and frontal ROM ($p = 0.002$) after 20 minutes of walking than post-taping.

Conclusions: This study indicated that acute effects of AT on calcaneus frontal motion were limited in young female adults with FFT. ALD taping exhibited higher RCSP on walking time compared to MLD taping. Caution should be taken when using AT to address calcaneus frontal motion in young female adults with FFT in clinical practice. Furthermore, when addressing midfoot issues, clinicians should consider the influence of hindfoot deformity severity in the prescription for FFT. Therefore, future studies could focus on orthoses or other taping techniques as prescription basis for calcaneus eversion correction in young women with FFT in clinical practice.

Keywords: Athletic Tape; Flexible Flatfoot; Calcaneus Frontal Motion; Resting Calcaneus Stance Position

Abbreviations: FFT: Flexible Flatfoot; MLD: Modified Low Dye; ALD: Augmented Low Dye; RSCP: Resting Calcaneus Stance Position; PFPS: Patellofemoral Pain Syndrome; AT: Athletic Taping; NDD: Navicular Drop Distance

Introduction

Flexible flatfoot (FFT) is a common foot arch deformity, primarily caused by ankle medial collateral ligament relaxation or intrinsic muscle weakness, resulting in navicular drop and calcaneus eversion during stance and gait [1,2]. Excessive rearfoot eversion in FFT poses a risk for conditions such as increased tibial internal rotation 40, potentially linked to issues like medial tibial stress syndrome and Patellofemoral Pain Syndrome (PFPS) [3-6]. Epidemiological data indicated an incidence of FFT in young female adults in America and India is over 10.3%, which was higher than that in male populations [7,8]. Several studies have found significant differences in calcaneus frontal motion between normal foot and FFT, characterized by greater Resting Calcaneus Stance Position (RCSP) and peak calcaneus eversion during gait and running [9-11]. The clinical conservative treatments for controlling calcaneus eversion include Athletic Taping (AT) and foot–ankle orthoses [12-16]. In a meta-analysis, AT has proven more

effective than foot orthoses in controlling calcaneus eversion in FFT, characterized by its simplicity [17]. In AT techniques, both augmented low dye (ALD) and Modified Low Dye (MLD) taping techniques are derived from the low dye technique. They start from the fifth metatarsophalangeal joint, pass through the heel to the first metatarsal to establish an anchor band, and transversal tapes are then applied from the lateral anchor to the medial [18].

ALD, an extension of low dye, includes three bands supporting the medial longitudinal arch and two calcaneal stabilization belts, enhancing foot arch lifting [19,20]. In MLD taping, the forefoot is manually everted. The first metatarsophalangeal joint is flexed, exerting a pulling force on the lateral calcaneal to maintain the subtalar joint in neutral position [21]. Previous studies have investigated the acute effects of AT on calcaneus frontal motion during gait, showing conflicting results regarding RCSP values after taping and acute walking in FFT [22,23]. While AT has been found to maintain arch deformity in FFT within a 20-minute exercise protocol, its effects on calcaneus frontal motion after this duration remain unknown [2,4,24-26]. In terms of AT techniques, MLD taping has been associated with increased peak calcaneus eversion 5 and ALD has been applied to improve midfoot deformity in FFT widely, although its effects on calcaneus frontal motion remain unclear [27-29]. The limited current studies are insufficient to support a positive influence of ALD and MLD techniques on calcaneus frontal motion in FFT after a 20-minute walk [22,25,30]. Therefore, this study aimed to investigate the effects of ALD and MLD taping techniques on calcaneus frontal motion in young female adults with FFT after 20 minutes of walking. We hypothesized that AT techniques could lead to decreased calcaneus frontal motion immediately after application, but this effect disappeared after 20 minutes of walking. This study provides a theoretical basis for clinical practitioner to choose appropriate calcaneus correction treatments for FFT in both static stance position and during walking, potentially reducing the risk of potential PFPS in young female adults with FFT [31].

Methods

Participants

Using G-power 3.1.9.6, a sample size estimation for repeated measure ANOVA with an effect size of 0.3 in Navicular Drop Distance (NDD), α of 0.05, power of 0.9, a dropout rate of 15% indicated a minimum of 40 participants 29. As this research studied bilateral lower limbs, 20 college female students (age: 23.6 ± 3.0 years; height: 160.2 ± 4.8 cm; weight: 54.9 ± 7.2 kg; BMI: 21.3 ± 2.4 kg/m^2) with FFT were recruited, and data from both feet were collected. The inclusion criteria were young female adults aged 18–28 years with a NDD value ≥ 8 mm when transitioning from the sitting position with 90 degrees hip and knee flexion to bipedal support position [32,33] as NDD is considered a composite and reliable measure for FFT [34]. Participants with a history of lower extremity musculoskeletal issues, operations, nervous system disorders, metabolic diseases or AT materials allergies were excluded. All participants signed informed consent forms. This study was approved by the Ethics Committee of Shanghai University of Sport (No.102772021RT026).

Taping Procedure

The taping area received an additional skin membrane to prevent allergies and alleviate the discomfort of restraint caused by AT during walking. Participants randomly received either ALD or MLD treatments using 38 mm wide rigid AT (Kindmax, Leuko sport. BDF) (Figures 1 & 2). The taping techniques' order was counterbalanced to mitigate treatment order effects on results 46. Participants were separated into two groups via a coin toss, with group 1 receiving ALD taping first and group 2 receiving MLD taping first 29. A 10-day washout period was implemented to alleviate any learning effects.

 DOI: 10.26717/BJSTR.2023.54.008504

Note:
1. Anchor stirp: extending from the first metatarsophalangeal joint to the heel, ending at the fifth metatarsophalangeal joint.
2. Applying a strip from the outer edge of the foot to the inside, passing through the sole and ending at the medial dorsal foot.
3. Arch construction strip: applying an inverted figure-8 strip above the external malleolus, passing through the bottom of the midfoot to the inside.
4. Calcaneal lift belt: extending from above the external malleolus through the heel plantar surface,

Figure 1: Augmented low dye taping technique.

Note: 1. Anchor stirp: extending from the first metatarsophalangeal joint to the heel, ending at the fifth metatarsophalangeal joint; 2,3,4 Applying three parallel tapes from the foot dorsum downward across the transverse arch, ending at the starting anchor point; 5. the plantar view; 6. the dorsal view.

Figure 2: Modified low dye taping technique.

Outcome Measures

Calcaneus frontal motion data were collected from both feet. The RCSP was measured in a static stance position. The calcaneus frontal motion was measured at baseline, after applying ALD and MLD taping techniques, and after 20 minutes of walking in uniform shoes (Fei Yue, FXY-071HQ-1, China).

Resting Calcaneus Stance Position

RCSP, a common measurement for assessing foot posture, served as a reliable indicator of foot arch deformity. The theoretical normal value for RCSP ranged from -2 to 2 degrees [35]. This test involves measuring the angle between the bisector of the calcaneal and the vertical line of the ground in upright position [1,35]. A negative angle, indicating a medially sloping calcaneal bisector, suggests pes cavus, while a lateral slope indicates FFT [1,35].

Calcaneus Frontal Motion

To compare changes in calcaneus frontal motion before and after applying AT techniques during walking, the STT-IWS 3D IMU system (STT system, Basque Country, Spain) was used. The IMU sensors were placed upward and backward in accordance with the X-axis, utilized the 'Lower Train' model to record angle data 31. Seven sensors were strategically positioned on the spinous process of the fourth lumbar vertebra, front thighs, front tibia of both calves and both feet, ensuring precise measurement. Participants adopted a standard position with feet shoulder-width apart and arms extended in a 'T' shape. Baseline data were recorded after 1 minute of walking before taping. Subsequently, participants walked continuously for 20 minutes and divided into ten 2-minute stages. The angle data were recorded during the 1st and 10th stages, maintaining a controlled walking speed of 3.9–5.8 km/h [36,37]. To minimize measurement errors related to walking displacement, IMU sensors were placed based on the positions of lower limb bones rather than muscle surfaces. Marked points were initially positioned on the lower limbs, facilitating consistent sensor replacement in their original positions during walking.

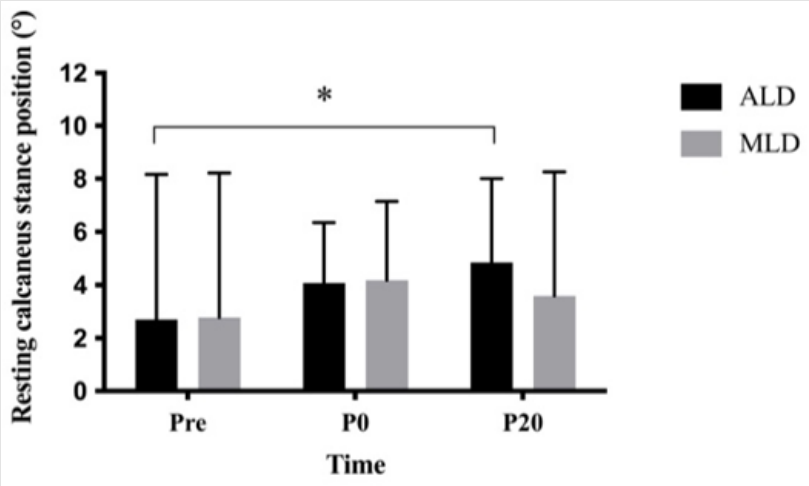
Statistical Analysis

IBM SPSS (Version 20.0, Chicago, IL, United States) was performed for statistical analysis. Data were presented as mean ± standard deviation $\left(\bar{X} \pm SD\right)$. Two-factor repeated-measure ANOVA was employed to assess differences between ALD and MLD taping techniques at baseline, post-taping and after 20 minutes of walking. The effect size, indicated by partial Eta square (ηp^2), was categorized as small ($0.01 \leq \eta p^2 < 0.06$), medium ($0.06 \leq \eta p^2 < 0.14$) or large ($\eta p^2 \geq 0.14$) 9. The significance level was set at $p < 0.05$.

Results

Resting Calcaneus Stance Position

There was no significant interaction between time points and the two AT techniques in RCSP [$F(2, 156) = 1.09$, $p = 0.339$, $\eta p^2 = 0.014$]. The main effect of RCSP was observed at three time points, and walking time had a significant effect on RCSP [$F(2, 156) = 4.882$, $p = 0.009$, $\eta p^2 = 0.059$]. The RCSP value significantly increased after 20 minutes of walking with ALD taping compared to baseline ($p = 0.004$, 95% Confidence interval (CI) = 0.699–3.579) (Figure 3).

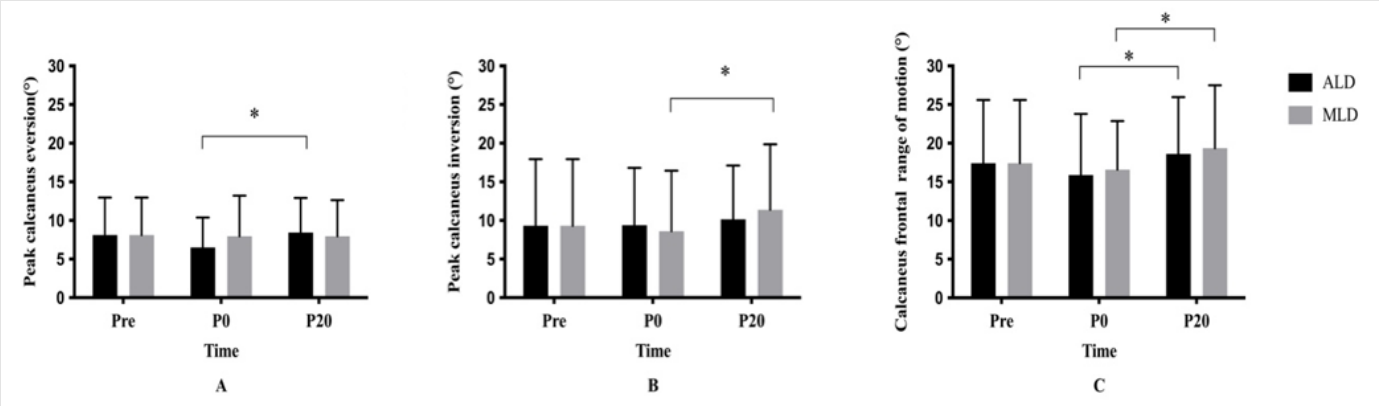


Note: Pre represents baseline, P0 represents post-taping, and P20 represents after 20 minutes of walking. * Indicates statistical significance ($p < 0.05$).

Figure 3: RCSP changes with ALD and MLD taping techniques.

Calcaneus Frontal Motion

The main effect difference was observed across different time points, with walking time significantly affecting calcaneus frontal range of motion (ROM) [F (2, 148) = 5.63, p = 0.004, ηp^2 = 0.071] (Figure 4). Paired T-test results for calcaneus frontal ROM at three time points showed that ALD performed higher peak calcaneus eversion (p = 0.02, 95% CI = 0.318–3.542) and frontal ROM value after 20 minutes of walking than post-taping (p = 0.003, 95% CI = 0.974–4.47). The peak calcaneus inversion value with MLD significantly increased after 20 minutes of walking compared with that post-taping (p = 0.001, 95% CI = 1.255–4.301), and the frontal ROM increased significantly after walking for 20 min compared with that post-taping (p = 0.002, 95% CI = 1.032–4.528).



Note: (A) Peak calcaneus eversion; (B) Peak calcaneus inversion; (C) Calcaneus frontal range of motion; ALD-augmented low Dye; MLD-modified low Dye; Pre-baseline; Pre represents baseline, P0 represents post-taping, and P20 represents after 20 minutes of walking. * Indicates statistical significance ($p < 0.05$).

Figure 4: Calcaneus frontal motion with ALD and MLD taping techniques at baseline, post-taping and after 20 minutes of walking.

Discussion

This study aimed to compare the changes in calcaneus frontal motion after two AT techniques in young female adults with FFT during a 20-minute walking session. An unexpected finding was that ALD resulted in higher RCSP after 20 minutes of walking than baseline. Additionally, the peak calcaneus eversion and frontal ROM values significantly increased with ALD after 20-minute walking. Similarly, MLD taping led to significant increases in peak calcaneus eversion and frontal ROM after 20-minute walking compared to post-taping. This suggests that the degree of calcaneus frontal motion of participants in this study was not so severe to interfere and did not show a significant immediate change, and the acute effects after walking reflected the natural changes. Furthermore, the limiting effect of ALD and MLD on FFT is focused on midfoot deformity, while little improvement was found in hindfoot motion. These findings caution against the routine use of AT in clinical practice for intervening in calcaneus frontal motion in young female adults with FFT.

Effects of AT on RCSP

No clear acute calcaneus correction function was investigated for either taping technique. Surprisingly, RCSP significantly increased in FFT with ALD after 20-minute walking, indicating higher RCSP with ALD after walking than MLD. These results suggest that neither taping technique may be effective for calcaneus frontal motion correction. The findings differ from Harradine and Whitaker' study, where RCSP significantly decreased after applying AT in patients with FFT, but the restriction effect disappeared after 30-minute walking [22,23]. The discrepancy may be attributed to the smaller baseline value of calcaneal eversion in this study compared to previous studies [22,23]. This implies that AT might have a more immediate effect in FFT with a large baseline value of RCSP, but the correction to midline position was not significant. Consequently, when addressing midfoot issues, clinicians should consider the influence of hindfoot deformity severity in the prescription for FFT.

Effects of AT on Calcaneus Frontal Motion

In this study, no significant differences were found in peak calcaneus eversion, peak inversion, and frontal ROM in FFT after a 20-minute walk with two taping techniques compared to baseline values. However, after 20-minute walking with ALD, there was a significant increase in peak eversion and frontal ROM compared to post-taping. Similarly, after 20-minute walking with MLD, peak calcaneus inversion and frontal ROM were higher than post-taping. This study indicated that both taping techniques had no acute significant effects on calcaneus frontal motion immediately, and natural changes of calcaneus frontal motion were observed after 20 minutes of walking. Clinical practitioners seeking an immediate and convenient method to control abnormal calcaneus eversion over an exercise session in

FFT should consider alternative taping techniques or temporary foot orthoses, as orthoses have been shown to more effectively alter the timing of hindfoot frontal motion [38]. Mechanically, the increased stiffness and superior load-deformation properties of orthoses may outweigh those imposed by the application of AT. However, this doesn't imply that ALD should not be used in conditions such as lower extremity pain and injury [19], as there may be other unexplored beneficial mechanisms to foot function. Bishop, et al. [38] used a three-dimensional motion capture system to measure the peak calcaneus eversion in FFT during walking, finding no significant difference in calcaneus frontal ROM with low dye taping. Limited studies have explored the acute effects of AT on calcaneus frontal motion in FFT, prompting an analysis of studies involving healthy participants. This study was consistent with the results of O'Sullivan, et al. [25], showing no significant change in the mean calcaneus position with low Dye in healthy feet. Similarly, Harradine, et al. [22] studied seven patients with foot disease and found no significant difference in calcaneus frontal motion after taping compared to baseline.

In addition, a systematic review indicated that low dye taping could not induce acute changes in peak calcaneus version and calcaneus frontal ROM during gait [39]. These studies confirmed that AT has no acute effect on calcaneus frontal motion, whether walking with healthy feet or in FFT. However, Keenan, et al. [30] reported inconsistent results using a two-dimensional Mac-reflex system (Qualisys AB, Gothenburg) to measure changes in calcaneus frontal motion during gait in healthy feet. The results showed that both low dye and high dye taping significantly reduced calcaneus peak eversion, while high dye significantly increased peak calcaneus inversion and decreased frontal ROM [30]. Subsequently, a motion analysis system was applied to measure calcaneus frontal motion changes during gait in FFT, and a significant decrease was found in calcaneus inversion and eversion [25]. Similarly, in another study conducted by Bishop, et al. [38], the peak calcaneus eversion was increased significantly with MLD in FFT. These studies showed that peak calcaneus eversion was changed with AT during gait in FFT. The participants characteristics with RCSP baseline value varied may account for the discrepancies, and no significant difference was observed in calcaneus frontal motion post-taping with lower RCSP baseline values than previous studies. However, calcaneus eversion with low dye taping in healthy feet changed significantly. Previous studies demonstrated increased eversion in FFT compared to neutral feet 39, with baseline calcaneus eversion values in FFT during walking surpassing those in normal populations. However, ALD and MLD, passing through the midfoot, did not limit calcaneus frontal motion during post-taping walking. Neither ALD nor MLD performed acute effects on calcaneus frontal motion in FFT during walking. The variations in direction and magnitude of calcaneus frontal motion during gait suggest the influence of individual differences in factors regulating foot complex biomechanical performance. This includes activation patterns of the medial and lateral gastrocnemius and the adaptability of joint morphology between tarsal bones and surrounding soft tissues [36,40]. In this study, after 20 minutes of walking with ALD in FFT, the peak eversion increased, aligning with the calcaneus frontal ROM. The peak calcaneus inversion and frontal ROM increased with MLD after 20 minutes of walking, and no significant difference was observed compared to baseline. The reasons for this discrepancy could be the pull force of ALD on calcaneus was perpendicular, while strain of MLD on calcaneus frontal provides a counterforce to keep it in a relative inversion position after a 20-minute walking session. This finding resonated with Moss et al.'s findings during running [41]. Similarly, Harradine, et al. [22] used a high-speed camera and found no significant change in the pronation angle during gait with high dye taping after 30 minutes of walking, which is consistent with the peak pronation velocity. Subsequent studies on calcaneus frontal motion also confirmed that AT lost some of its restrictive properties after 30 minutes of moderate-to-heavy intensity exercise [42].

Limitations

Two AT techniques were employed to evaluate the changes in RCSP and calcaneus frontal motion in female FFT at baseline, post-taping, and after 20 minutes of walking. However, this study has certain limitations. Firstly, the high-speed camera system was not used to track calcaneus frontal motion during walking, and the IMU sensors were less reliable than the high-speed camera system in the ankle frontal plane [43,44]. Secondly, the study only included female participants, imitating generalizability to males. In addition, the analysis primarily focuses on the acute effects of AT during gait, leaving the impact of AT on long-term, high-intensity exercise for future exploration [45,46].

Conclusion

This study indicated that acute effects of AT on calcaneus frontal motion were limited in young female adults with FFT. ALD taping exhibited higher RCSP on walking time compared to MLD taping. Therefore, caution should be taken when using AT to address calcaneus frontal motion in young female adults with FFT in clinical practice. Furthermore, when addressing midfoot issues, clinicians should consider the influence of hindfoot deformity severity in the prescription for FFT.

Acknowledgements

Not applicable.

Funding

No sources of funding were used to assist in the preparation of this article.

Availability of Data and Materials

All data generated or analyzed from experiments are included in this published article and its supplementary information files.

Declarations

Ethics approval and consent to participate.

Not applicable.

Consent for publication

Not applicable.

Competing Interests

All authors declare that they have no competing interests.

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ISSN: 2574-1241

DOI: 10.26717/BJSTR.2023.54.008504

Lin Wang. Biomed J Sci & Tech Res