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Effect of dynamic taping on pelvic movements in individuals with asymptomatic flexible flat-foot

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Abstract

Introduction. **The mechanical efficiency of one structure may be affected by the alignment of another segment. Inaccurate signals transmitted from distal to proximal segments result in altered biomechanics of the upper segments.** Aim of Study. **This study aimed to investigate the effect of dynamic taping on pelvic mobility in individuals with flat-foot.** Material and Methods. **Forty-two volunteers aged 20-32 years were recruited to this study. Participants were documented as normal-arched (n = 21) or flat-arched (n = 21). Participants' pelvic symmetry index was assessed using a G-Walk tri-axial accelerometer. Individuals with a flat-arched foot were taped with dynamic tape and the pelvic assessment process was repeated.** Results. **Pre-taping results showed that pelvic anterior-posterior (p = 0.029) and pelvic oblique symmetry indexes (p = 0.020) of the normal-arched group were significantly higher compared to the flat-foot participants. Application of dynamic tape increased symmetry indexes of the pelvis and navicular height with flat-arched foot. After taping, independent sample t-test showed no significant difference in symmetry indexes in the comparison of the control group and flat foot group in frontal (p = 0.734), sagittal (p = 0.120) and transverse (p = 0.127) planes.** Conclusions. **Dynamic taping can support the arch. In individuals with low arches, ensuring proper foot alignment after taping increases the biomechanical efficiency of the pelvis.**

KEYWORDS: gait analysis, foot, taping, arch.

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Introduction

The medial longitudinal arch (MLA) is the inner arch of the foot. The arch is supported by the plantar fascia, plantar ligaments and muscles, especially tibialis posterior, which is the most important muscle in the maintenance of the arch and controlling the pronation movement [6].

Flat-foot is defined by the loss of the MLA of the foot. A decrease in medial arch height causes anatomic and biomechanic changes in foot structure [15]. Foot arch height alterations may lead to changes in load distribution. Foot arch structure is a recommended intrinsic risk factor for lower extremity injury [2].

Many compensations in lower extremity alignments, including excessive subtalar pronation, are associated with lower MLA [15]. Subtalar pronation is a normal biomechanical action occuring during the stance phase of the gait cycle. During the gait cycle the subtalar joint pronates to absorb the shock of heel strike. In the presence of low MLA height, subtalar pronation becomes excessive and overuse injuries such as sacroiliac pain, low back pain, and patellofemoral pain can occur [10, 11]. During pronation, the tibia internally rotates and the rotation of the tibia is accompanied by the rotation of the femur in the same direction, but of lesser amplitude. It has been showed that internal rotation at the femur causes the femoral head to put pressure on the posterior area of the acetabulum. This pressure on the posterior part of the pelvis would cause the pelvis to tilt anteriorly. Based on this interaction of the mechanical chain, excessive subtalar pronation has been shown to have an effect on the pelvis [5].

The foot is a component of the biokinetic chain that connects the lower extremity to the spine via the pelvis [5, 28]. Inappropriate biomechanics in the distal parts of the body may influence its proximal segments, mechanical efficiency of muscles and proprioceptive orientation [28]. Flat-foot causes inadequate gait due to decreased impact absorption of the foot. Patients with a low arch may develop lower extremity pain, abnormal gait pattern and difficulty walking.

Although flat-foot is a very common foot deformity, there is no consensus on its treatment. Patients with flat-foot commonly used foot arch supports such as taping and orthosis. Authors and clinicians have suggested that arch tapings are a common intervention strategy for patients with pain or injury due to overpronation [26]. Recent studies have shown that the use of the dynamic taping technique is increasing. Although the principles of use for dynamic tape and kinesio tape seem similar, their material and mechanical properties are different [22]. The viscoelastic structure of the tape provides 200% stretching. Thanks to its strong recoil and elastic resistance, dynamic tape helps joint movement by reducing the load on the tissue, thus enhancing movement patterns [16].

Aim of Study

While there are many different types of interventions for MLA, there are limited studies examining the biomechanical effectiveness of these interventions on the upper segments. The purpose of this study was to determine the effect of dynamic taping on pelvic mobility in flat-foot individuals during walking.

Material and Methods

Participants

This prospective, cross-sectional study received approval from the ethical committee of the university (Research code: 2017-405/19.08.2022) and followed the guidelines of the Declaration of Helsinki. In this study, 21 flat-footed individuals and 21 participants who had normal MLA height were selected. The age of participants ranged from 20 to 32 (mean 22.42 ± 1.82 years) years of age. Participants were excluded from the study if they had a history of a lower extremity injury or surgery in the previous 3 months, were unable to walk pain-free and suffered from known allergy to sports tape. Flat-footed participants met the inclusion criteria of having a navicular drop of more than 8 mm and all subjects were screened by one investigator [17]. The dominant extremity was taken into account in the evaluation for flat-foot. All participants provided written informed consent. The sample size was calculated based on the study of Wang et al. [27], who searched the effects of taping on the lower extremity in flat-footed individuals. The minimal number of participants required to attain a power of 0.8 and a bilateral α level of 0.05 was calculated to be 21 per group.

Procedures

The measurements were conducted by two clinicians. The navicular drop test and dynamic taping were conducted by one investigator and pelvic analysis by the other. Pelvic analyses were made by a blinded researcher. Each participant completed a self-report questionnaire on his/her demographic information. Each participant's measurements were performed during one visit at the laboratory.

Participants with a navicular drop of less than 8 mm were referred to as the control group. This group performed only pelvic analysis without taping during walking. Individuals with a navicular drop greater than 8 mm were initially subjected to gait analysis without tape. After a 15-minute break, the participants in the taping group were taped and the gait analysis was repeated.

Navicular-drop measurement

The subject was seated on an adjustable height chair with hips and knees at 90° and the foot resting on the floor with the ankle joint in a subtalar neutral position. The navicular tuberosity was palpated and marked with a marker. The distance from the floor to the navicular tuberosity was measured and recorded using height calipers. The subjects then stood in a natural stance on a flat surface, feet shoulder-width apart. The distance between the ground and the navicular protrusion was measured again. Navicular fall height was calculated by subtracting the standing and sitting measurements [1]. Navicular fall height was measured by the same investigator in all cases. The intra-rater reliability of the navicular drop test assessed using the intra-class correlation coefficient (ICC) is reportedly 0.73-0.96 [20]. The reliability and validity of the navicular drop test have been reported previously [1]. The navicular height was calculated by measuring the distance between the ground and the navicular tubercle while the patient was in the standing upright position [17].

Dynamic Tape® taping technique

In this study, the arch support technique was used with 5 cm × 5 m of Dynamic Tape®. The individuals were placed in the supine position. Forefoot adduction, calcaneal varus, and the big toe were placed in a flexion position. The taping was started from the proximal thumb, following the medial plantar surface of the foot, the tape was looped around the calcaneus, passed through the sole of the foot, pulled upwards to the navicular, and the navicular was raised. The dynamic taping technique is shown in Figure 1. After taping, the 1st MTP joint should be in flexion, the calcaneum inverted, and the metatarsals should be convex on the dorsum of the foot. If these changes are not present in non-weight bearing, the technique is unlikely to apply a genuine force into the system so it cannot affect foot biomechanics [16].

Figure 1. Dynamic tape arch support technique

Pelvic assessment

Pelvic mobility was evaluated while individuals walked freely wearing casual shoes along a 10-m walkway using a wireless tri-axial accelerometer. The analysis system was based on the center of mass using a wireless tri-axial accelerometer (G-Walk, BTS Bioengineering S.p.A., Italy) that was attached to the 5th lumbar vertebra and tightened with Velcro™. The accelerometer data were wirelessly transferred by a Bluetooth system and analyzed with the BTS G-Studio software (BTS Bioengineering S.p.A., Italy) of a computer [4]. The weight of the accelerometer was 37 g, with dimensions of 70 × 40 × 18 mm. The frequency of the accelerometer was from 4 to 1000 Hz, and sensor fusion was 200 Hz. The spatiotemporal parameters and pelvic oscillation including all the three planes were analyzed using a software program. The parameters evaluated using the G-Walk were the anterior-posterior tilt symmetry index of the pelvis, the oblique symmetry index of the pelvis, and the rotational symmetry index of the pelvis. The symmetry index is a ratio of mobility between the right and left pelvic structure during walking. The index ratio being close to 100% indicates that the right and left parts of the pelvis have equal mobility in the specified plane. Also, the index ratio being close to 100% is one of the indicators of the appropriate gait pattern [12]. An example of pelvic reporting is shown in Figure 2.

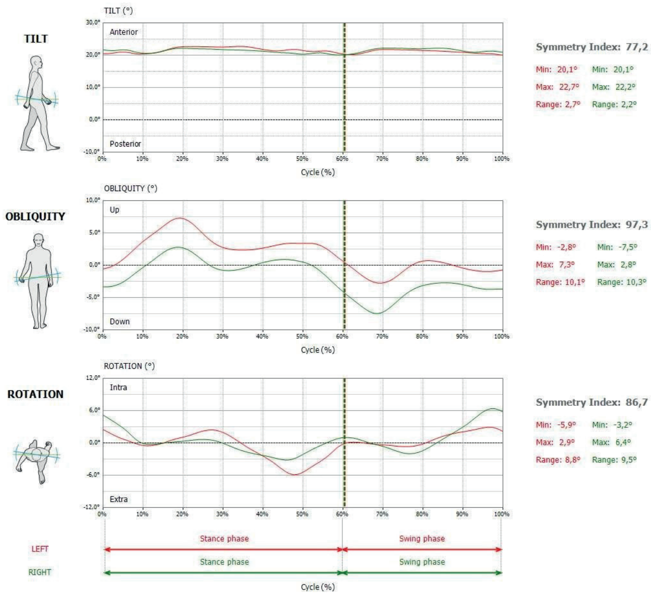


Figure 2. Pelvic report

Statistical analysis

The Statistical Package for Social Sciences (S.P.S.S.) Version 29.0 statistical software package was used in data analysis. Visual (histogram, probability graphs) and analytical methods (Kolomogrov–Smirnov/Shapiro–Wilk's test) were used to examine whether the variables showed normal distribution [7]. Independent groups t-test was used for the variables showing normal distribution in the comparison of the measurement results for flat-foot individuals and the control group. The effect size for independent sample t-tests were calculated using Cohen's d standards. Cohen's d results were interpreted using thresholds of 0.2, 0.5, and 0.8 for small, medium, and large effects, respectively. Repeated-Measure Analysis of Variance (ANOVA) was used to compare the effect of dynamic taping on the pelvic symmetry index at different time points. The effect size for Repeated-Measure ANOVA was computed according to partial eta-squared (η_p^2) standards.

Results

A total of 42 subjects, 16 male and 26 female, met the inclusion criteria and no difference was found between the age, body weight, height and body mass indexes (BMI) of the individuals with flat-foot and controls included in the study ($p > 0.05$). A statistically significant difference was observed between the two groups in navicular height ($p < 0.05$). Descriptive data of the individuals are summarized in Table 1.

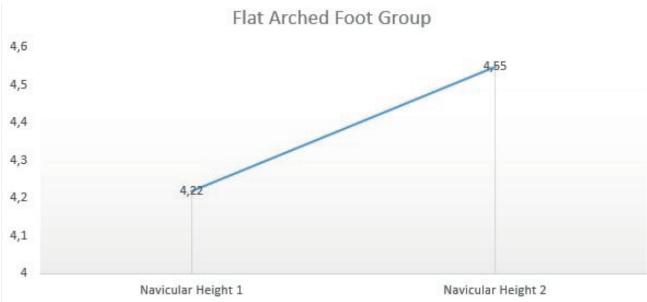
The pre-taping data set revealed that the pelvic anterior-posterior and pelvic oblique symmetry indexes of the control group were statistically significantly higher compared to the flat-foot participants ($p < 0.05$). The difference between the groups had a large effect size according to Cohen's d standards (0.699 and 0.750 for the pelvic anterior-posterior and pelvic oblique symmetry index, respectively). However, there was no statistically significant difference in the pelvic rotational symmetry index between the two groups ($p > 0.05$, Table 2). A more appropriate gait pattern was observed in the control group.

Figure 3 shows the change in mean navicular height after taping in individuals with flat arched foot and Table 3 indicates marked changes in the symmetry index of pelvis before and after taping for the flat-foot group.

Table 1. The characteristics of the subjects

	Flat-foot group (n = 21)	Control group (n = 21)	p significant (2-tailed)
	Mean ± Standard deviation	Mean ± Standard deviation	
Age (year)	22.57 ± 2.34	22.29 ± 1.31	0.628
Height (cm)	170.62 ± 7.56	167.48 ± 8.00	0.198
Body weight (kg)	62.24 ± 9.21	61.14 ± 11.80	0.739
BMI (kg/cm^2)	21.28 ± 1.83	21.71 ± 3.32	0.602
Navicular height (cm)	4.22 ± 0.32	4.53 ± 0.35	*0.041

* $p < 0.05$



Note: Navicular Height 1 – pre-taping height, Navicular Height 2 – post-taping height

Figure 3. The change in mean navicular height after taping in individuals with flat arched foot

Table 2. Pre-taping, a comparison of pelvic symmetry index variables between groups

	Flat-foot group (n = 21)	Control group (n = 21)	Effect size Cohen's d	p significant (2-tailed)
	Mean ± Standard deviation	Mean ± Standard deviation		
Anterior–posterior tilt symmetry index (%)	71.30 ± 14.61	80.29 ± 10.83	–0.699	***0.029**
Oblique symmetry index (%)	96.94 ± 2.74	98.46 ± 0.79	–0.750	***0.020**
Rotational symmetry index (%)	97.87 ± 2.39	97.71 ± 1.48	–0.084	0.788

* $p < 0.05$

Table 3. Effect of dynamic taping on pelvic symmetry index

	Before taping (n = 21)	After taping (n = 21)	Repeated measure ANOVA		
	Mean ± Standard deviation	Mean ± Standard deviation	F	p	η_p^2
Anterior-posterior tilt symmetry index (%)	71.30 ± 14.61	81.70 ± 15.42	18.577	***0.001**	0.482
Oblique symmetry index (%)	96.94 ± 2.74	97.46 ± 2.76	6.543	***0.019**	0.247
Rotational symmetry index (%)	97.87 ± 2.39	98.35 ± 1.19	1.683	0.209	0.078

* $p < 0.05$

Table 4. Post-taping, comparison of pelvic symmetry index variables between groups

	Flat-foot group (n = 21)	Control group (n = 21)	Effect size Cohen's d	p significant (2-tailed)
	Mean ± Standard deviation	Mean ± Standard deviation		
Anterior-posterior tilt symmetry index (%)	81.70 ± 15.42	80.29 ± 10.83	0.106	0.734
Oblique symmetry index (%)	97.46 ± 2.76	98.46 ± 0.79	–0.490	0.120
Rotational symmetry index (%)	98.35 ± 1.19	97.71 ± 1.48	–0.136	0.127

The paired t-test revealed that values of the anterior-posterior tilt symmetry index and the oblique symmetry index increased significantly after dynamic taping compared with their values before taping ($p < 0.05$). However, the rotational symmetry index increased slightly, although there was no significant difference compared with the baseline ($p > 0.05$).

The independent sample t-test showed no significant difference in symmetry indexes in the comparison of the control group and the flat-foot group after taping ($p > 0.05$, Table 4).

Discussion

This is the first study to examine the effects of Dynamic Tape® on the pelvis in participants with asymptomatic flexible flat-foot. We found significiant differences in the pelvic symmetry index between the control group and the flat-foot group. In the first measurements, the pelvic symmetry index was higher in the control group. However, the symmetry indices of the flat-foot group increased after dynamic taping and then no index difference was observed between the two groups.

Previous studies showed that low arched feet affect lower extremity biomechanical alignment. Individuals with low arched feet have been suggested to be at a greater risk of lower extremity injury [2]. Different attempts have been made towards MLA in order to eliminate these negative effects caused by the low arched feet. Twomey and McIntosh aimed to investigate the effects of low arched feet on lower limb gait kinematics in children. Results of their study showed that the low arched group was more externally hip rotated by 6-7° throughout the stance phase and the pelvis of participants in the low arched group was more internally rotated (1-2°) in the transverse plane [24]. As the low arched foot makes initial contact with the ground, the hip is forced into a more external position and this may also lead to a compensatory internal rotation of the pelvis. Also, changes in load distribution due to the loss of a natural foot arch may affect myofascial structures. Thus, the increased tension in the surrounding soft tissues will spread to the upper segments of the body. Incorrect tension in the long term may cause permanent biomechanical changes in the lower extremity. We also observed changes in pelvic mobility of flat-foot individuals in this study. There was asymmetrical pelvis mobility especially in the sagittal (anterior-posterior pelvic tilt) and frontal planes (oblique pelvic tilt). This is due to the compensatory mechanisms reaching from the foot to the pelvis as a result of a unilateral flat arched foot.

There are numerous studies aimed at re-raising low MLA [14, 25]. Ankle and foot taping is a common clinical intervention used to treat and prevent foot arch disorders [23]. Many different taping techniques have been introduced in the literature to limit excessive foot pronation. Low dye and reverse-6 methods are the most popular anti-pronation taping techniques [3]. Franettovich et al. announced that combining the low dye and reverse-6 taping methods resulted in a greater change of the MLA height and this taping technique was referred to as the "augmented low-dye." Their study showed that individuals with at least 10 mm of navicular drop had an average of 9.4 mm in the height of the arch after "augmented low-dye" taping [8]. In another study investigating the effectiveness of augmented low-dye taping and ankle brace in individuals with low arches, muscular activations were compared. In that study it was shown that the taping method only in the tibialis posterior muscle had a 15% decrease in the peak EMG value compared to bracing [9]. Franettovich et al. suggested that the taping technique used in this study could be useful in managing overuse and dysfunction of tibialis posterior, by reducing their level of activation during walking. Reducing the extra load on the tibialis posterior muscle will support the arch of the foot. In the systematic review compiled by Radford et al. researches showed that the low dye technique increased the arch height by an average of 5.9 mm [19]. The current study showed that the navicular height of individuals with flat-foot increased by 3.3 mm as a result of dynamic taping. The increase in foot arch height seen in the present study is smaller than in most previously published literature when using other taping techniques. The main factor that will cause this result may be connected with the use of elastic tape in this study instead of the rigid tape used in other studies. However, except for the current study none of those researches investigated the effect of increased arch height on pelvis biomechanics.

Abnormal biomechanical alignment originating from the distal parts may influence joint loads, mechanical efficiency of muscles, and the proprioceptive process [21]. Inaccurate signals transmitted from distal to proximal segments result in an altered neuromuscular function and control of the upper segments. The position of one segment may be affected by alignment deviations of an adjacent segment or result from compensatory changes toward a more efficient dynamic function. Misalignment can be seen in structural or functional characteristics [18]. Since individuals are structurally different, the positioning of adjacent segments in response to a particular alignment difference will also be unique to that individual.

Nguyen et al. examined relationships among lower extremity alignment characteristics. One of the subjects investigated in the Nguyen multi-factor analysis study is the relationship between the ankle joint and the knee joint. Their findigs showed that participants with a greater genu recurvatum also had an increased navicular drop [18]. Magnetic resonance imaging studies have shown that genu recurvatum is accompanied by a rotation of the tibiofemoral joint [13]. Genu recurvatum results in a medial rotation of the femur relative to the tibia and a medially rotated posture around the knee joint may increase medial rotational stress at the ankle, resulting in greater pronation and navicular drop. Also, their study showed that the position of the segments relative to each other changes with a kinetic interaction. Participants who had greater pelvic angles also had greater internal rotation at the hip. An increased hip internal rotation may also lead to compensatory external rotation of the tibia on the femur. It has been suggested that this compensatory mechanism, which starts from the pelvis and progresses to the tibia, would result in an increase in the quadriceps angle, and an excessive quadriceps angle increases the risk of lower extremity injury [18]. However, further studies are needed to confirm whether the mechanisms of action are from the proximal to distal plane or vice versa.

One of the strengths of the current study is connected with the fact that the effects of foot and ankle tape intervention on the pelvis have not been investigated before. Another strength is that the effectiveness of dynamic tape is evaluated with a 3D accelerometer, which provides the opportunity to analyze it in all 3 planes of the pelvis. The use of objective evaluation tools will increase the level of evidence of the research. One of the limitations of this study was that only immediate effects of the tape were evaluated and it is not known how long these effects would last after taping. The second potential limitation of this study was related to the collection and analysis of kinematic variables rather than kinetic data. Examination of muscular strength and muscular activation could also contribute to the interpretation of kinematic changes. In addition, the absence of a sham group in this research is another limitation of our study. This may limit the explanation of the actual effects of taping.

Conclusions

The results of the current study revealed that the application of dynamic tape can reinforce the medial longitudinal arch. The use of dynamic tape increased the height of the navicula and preserved the natural curve. After dynamic taping in individuals with low arched feet a more symmetrical movement of the pelvis is found during walking. The dynamic taping method improves the function of the upper segments by providing correct alignment at the foot.

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Conflict of Interest

The authors have no conflicts of interest to report.

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