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ORIGINAL

The Immediate Effects of External Kinesio-tape Wrapping for Inner Arch Support on the Lower Leg EMG for Gait in Stiletto Heels

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Purpose: The purpose of this study was to analyze the effects of using external kinesio-tape wrapping for inner arch support on the lower extremity EMG for gait in stiletto heels.

Methods: Subjects for this study were two female college students who had been wearing stiletto heels almost every day of the week for more than three years. The independent variable was the presence or absence of kinesio-tape wrap for inner arch support. Dependent variables were EMG readings for the four muscle groups: the medial and lateral gastrocnemius, the tibialis anterior, and the peroneus longus. EMG readings were taken using the NORAXON (USA). The Paired t-test within the subject repeated measure design for the presence and absence of inner arch support ($p<0.05$) was used via SPSS 18.0.

Results: With kinesio-tape wrap for inner arch support, there was a statistically significant decrease in the muscle force mean values for the peroneus longus and the medial and lateral gastrocnemius, in the maximum muscle forces of the peroneus longus and the lateral gastrocnemius.

Conclusion: External kinesio-tape wrapping for inner arch support in stiletto heels could have an effect to reduce peroneus longus, and medial/lateral gastrocnemius activities that could result in decreased fatigue and discomfort.

Keywords: Stiletto heel, Kinesio-tape wrapping, Inner arch support, EMG

I. INTRODUCTION

For humans, shoes have been an important and necessary item for almost as long as we have existed. There has been long standing evidence that humans have tried to provide some forms of protection for their feet. Throughout history, we can see that the shoe has developed beyond basic protection against the elements into a full-fledged fashion item and symbol of success (Kunzie, 2013; Wade, 2013).

With the evolution of the shoe as a form of fashion, creating more restrictions to natural movement, people have started to suffer consequences with pain (Dufour et al., 2009) and discomfort (Au & Goonetilleke, 2007) that can lead to misalignment, degeneration, osteoarthritis (Riskowski, Dufour, & Hannan, 2011) of the foot or toes (Stomp, Krabben, van der Helm-van, Mil, & Reijnierse, 2014; Daniel et al., 2014). High heels are the number one cause of shoe-related foot pain, and 71% of heel-wearers said their feet hurt when they wear them, according to a 2014 American Podiatric Medical Association survey of 1000 US adults (Edge Research, 2013).

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This has raised concerns related to creating and designing shoes that can lessen the pain and discomfort suffered by the wearer. Podiatric medicine and the shoe industry have been working to mediate this problem. Many studies have been conducted on the relationship between the shoe and the foot (Stomp, Krabben, van der Helm-van, Mil, & Reijnierse, 2014; Cronin, 2014; Miller, Whitcome, Lieberman, Norton, & Dyer, 2014) and the effects that certain shoe forms can have to the overall development of the foot.

Shoes classified as high heels are one of the most restrictive and damaging shoes that are designed for common use, which specifically targets the female population. Extensive wear of high heeled shoes has been linked to serious conditions relating to knee, ankle, metatarsal, phalanges pain or misalignment. Other related symptoms can be present in the lower back, hip joints, etc. With prolonged wear, permanent changes in posture (Silva, Siqueira, & Silva, 2013) and walking patterns can occur (Blanchette, Brault, & Powers, 2011; Simonsen et al., 2012; Chien, Lu, & Liu, 2013; Cronin, 2014). Frequent wears can experience a permanent shortening or decreased function of the Achilles tendon and gastrocnemius muscles (Csapo, Maganaris, Seynnes, & Narici, 2010). The contraction of these muscles can make it difficult for women to return to wearing flat shoes and performing basic motions such as squatting. Failure to be able to move into a squatting position can lead to degeneration of their hip joints, which can cause serious issues later in life. In addition, high heel related problems such as ingrown toe-nails, bunions, severe pronation, hallux valgus, pain in the third and fourth metatarsals, and cuboid syndrome (Cronin, 2014).

Excessive use of high heels can also directly influence the underlying muscle structure of the foot and calf (Simonsen et al., 2012), as well as venous function (Tedeschi, Dezzotti, Joviliano, Moriya, & Piccinato, 2012).

Women are aware of a lot of these conditions; however, their immediate desire to wear heels outweighs their concern for what can happen in the long run. There is an increasing demand to create a high heeled shoe that eliminates most, if not all of these problems.

People usually thought that the important characteristics of comfortable shoes appear to be good fit, suitable heel height, no localized pressure under the ball of the foot, and attractive appearance. Meanwhile, shoes with poor fit in the forefoot region tend to be perceived as uncomfortable (Au & Goonetilleke, 2007).

When looking for shoes, it is recommended that you look for shoes that provide inner arch support and keep toes from crowding and bending (Miller, Whitcome, Lieberman, Norton, & Dyer, 2014).

The purpose of this study was to analyze the effects of inner arch support with external kinesio-tape wrapping on the lower extremity EMG for gait in stiletto heels.

II. METHODS

1. Subjects

Subjects for this study were two female college students who had been wearing stiletto heels almost every day of the week for more than three years. They had severe pes planus with a mean of -5 degrees according to RCSP (resting calcaneus standing position).

2. Variables

The independent variable for this study was the presence or absence of kinesio-tape wrap for inner arch support. The dependent variables were EMG of the peroneus longus, the tibialis anterior, and the medial and lateral gastrocnemius muscles (Figure 2).

3. Equipment

A force platform (9281B, Kistler) was used to analyze the effects of external kinesio-tape (Dowha Kinesiotape, Korea) wrapping for inner arch support on the lower extremity EMG (NORAXON, USA) during gait in stiletto heels. EMG values were recorded as subjects performed ten trial walks with and without kinesio-tape wrap for inner arch support at their natural pace on a 10 meter concrete laboratory walkway. Inner arch support was provided using kinesio-tape externally on the shoes. The kinesio-tape wrapped under the arches, around the top of the foot, provided arch support. Subjects used their own stiletto heels for this study. Heels were exactly 12 cm from the ground with a 9 cm drop from the heel to the forefoot (Figure 1).

Figure 1. Subject walking without and with kinesio-tape wrap for inner arch support in stiletto heels

4. Data analysis

Statistical analysis was performed via SPSS 18.0 and included the independent *t*-test within the subject repeated measure design to reduce inconsistencies between subjects and shoes for the presence and absence of inner arch support ($p<0.05$).

III. RESULTS

With inner arch support, there was a statistically significant decrease in muscle force mean value for three muscles (the peroneus longus and the medial/lateral gastrocnemius). As well, there was significant decrease for maximum muscle force in two muscles (the peroneus longus and the lateral gastrocnemius).

1. The mean value of the EMG according to the band usage

The mean value of the EMG significantly decreased in the peroneus longus and the medial/lateral gastrocnemius muscles when wrapped, compared to unwrapped, while walking. Meanwhile, the tibialis anterior muscle decreased when wrapped, but not significantly (Table 1, Figure 3).

2. The mean of the maximum value of the EMG according to the band usage

The maximum value of the EMG significantly decreased in the peroneus longus and the lateral gastrocnemius muscles; there were also decreases with the medial gastrocnemius muscle and anterior tibialis muscle when wrapped, rather than unwrapped, while walking (Table 2, Figure 4), but they were not significant.

IV. DISCUSSION

Most women enjoy wearing high heels, usually for fashion; they feel it is an essential part of any feminine

Figure 2. Selected Muscles and EMG Equipment

Table 1. The mean value of the EMG according to the band usage (μV)

	Group	N	Mean (SD)	t
Tibialis Anterior	Without Band	10	16.71 (1.91)	.93
	Band	10	15.80 (2.41)	
Peroneus longus	Without Band	10	36.97 (6.03)	3.25**
	Band	10	29.60 (3.88)	
Medial gastrocnemius	Without Band	10	10.08 (2.69)	2.67*
	Band	10	6.74 (2.90)	
Lateral gastrocnemius	Without Band	10	13.55 (2.77)	3.30**
	Band	10	9.96 (2.05)	

*$p<.05$, **$p<.001$

Table 2. The mean of the maximum value of the EMG according to the band usage (μV)

	Group	n	Mean (SD)	T
Tibialis anterior	Without Band	10	29.65 (2.98)	1.68
	Band	10	26.97 (4.08)	
Peroneus longus	Without Band	10	61.03 (10.97)	3.30**
	Band	10	44.92 (10.87)	
Medial gastrocnemius	Without Band	10	19.06 (12.07)	2.05
	Band	10	10.66 (4.64)	
Lateral gastrocnemius	Without Band	10	18.60 (5.76)	2.39*
	Band	10	13.58 (3.27)	

*$p<.05$, **$p<.001$

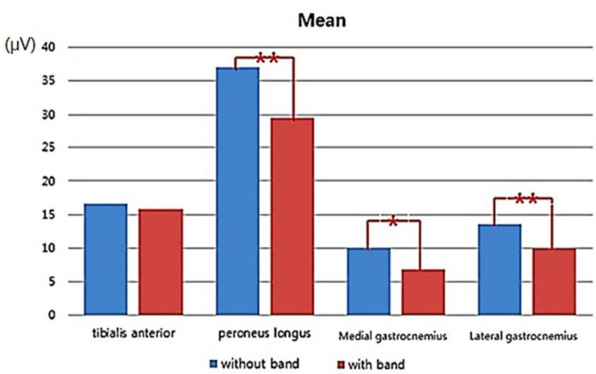

Figure 3. Differences in mean values according to band usage

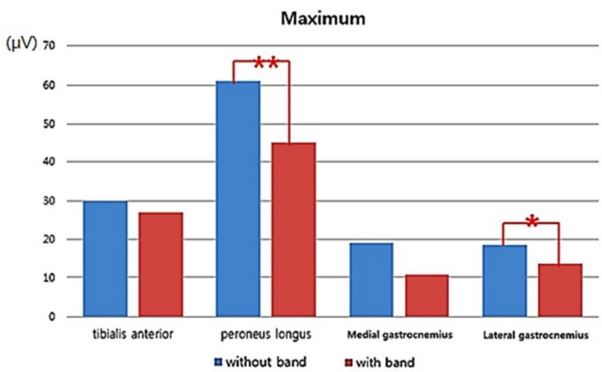

Figure 4. Differences in maximum values according to band usage

wardrobe. However, there can be a lot of serious health problems (Greenberg & Davis, 1993) when these types of shoes are worn consistently over a long-term period. There are various side effects of wearing these shoes from less severe conditions such as ingrown toenails (Stomp, Krabben, van der Helm-van, Mil, & Reijnierse, 2014), bunions to more severe conditions such as hallux valgus, over pronation (Miller, Whitcome, Lieberman, Norton, & Dyer, 2014), cuboid syndrome, Haglund's deformity, etc.

The center of those problems connected with high heels is peroneus longus. In this study, for the mean value, the peroneus longus, medial gastrocnemius, and lateral gastrocnemius all decreased. But, for the maximum value, only the peroneus longus and the medial gastrocnemius decreased significantly.

Among these muscles, the result shows that the peroneus longus experienced the largest difference in the mean value and maximum value. Furthermore, the maximum value has more significance than the mean value to indicate pain and discomfort. As a result, the peroneus longus had an important role in reducing muscle activity through inner arch support with an elastic band. Based

on this result, women can reduce problems connected with peroneus longus by wearing inner arch support with an elastic band.

Meanwhile, the tibialis anterior did not change significantly because it was used during dorsiflexion. Also, high heel walking led to frequent use of the plantar flexion. Regarding the tibialis anterior, inner arch support did not effect this muscle's activation.

The origin of the peroneus longus is at the head of the fibula, and inserts through the plantar surface of the cuboid, is attached to the medial cuneiform and is linked to the underside of the 1st and 2nd metatarsals. It controls the ability to walk and jump as well as knee stability.

The main role of the peroneus longus is to evert and abduct the foot. Because of that, a repetitively contracting peroneus longus muscle will cause excessive eversion and abduction of the foot. In addition, if the peroneus longus repetitively contracts, plantar flexion (Johanson, Allen, Matsumoto, Ueda, & Kevin, 2010) at the transverse tarsal joint of the foot will get weak (Foster, Blanchette, Chou, & Powers, 2012). Furthermore, an over active peroneus longus muscle can lead to bunions (Blanchette, Brault, & Powers, 2011). Tight fitting shoes can cause a painful bony growth on the joint of the medial side of the big toe, which forces the big toe to angle in toward the other toes. The next stage of the progression of foot bone misalignment is hallux valgus (McBride et al., 1991). The following stage is pes planus (Nigg, 2001). Pes planus is the misalignment of the ankle bone. When the peroneus longus is constricted for a long period of time, it can lead to cuboid syndrome, too. Cuboid syndrome may develop due to excessive traction on the cuboid. This may occur in association with peroneus longus tendinopathy. Cuboid syndrome may also develop following a sprained ankle whereby the foot (Kogler, Veer, Verhulst, Solomonidis, & Paul, 2001; Ko, Hsiao, Kang, Wang, Shau, & Wang, 2009) and ankle are turned inward excessively (inversion) (Chien, Lu, & Liu, 2013), thereby causing damage to the connective tissue holding the cuboid bone in position. People who develop this condition have excessively pronated feet (Nyska, McCabe, Linge, & Klenerman, 1996) although the condition may also be seen in those with lateral ankle instability (Hong, Lee, Lin, Tang, & Chen, 2013). Cuboid syndrome refers to the dislocation or subluxation of the cuboid bone.

Another side effect is excessive eversion and abduction of the foot that can increase angular momentum of the 3rd and 4th metatarsals (Stomp, Krabben, van der Helm-van, & Reijnierse, 2014). It can create a thickening of tissue around the nerve (Cronin, Barrett, & Carty, 2012; Melvin, 2014) between the 3rd and 4th metatarsals and toes, which can lead to terrible pain and numbness around the 3rd and 4th metatarsal. This is Morton's neuroma.

When the peroneus longus contracts repetitively, the medial gastrocnemius is more active. Meanwhile, the lateral gastrocnemius is hardly used, relatively. That led to muscle imbalance (Järvinen, Kannus, Maffulli, & Khan, 2005). That is why people who wear high heels usually have bow-shaped legs. Additionally, calf muscles adjust to the angle of the high heels and then contract, so the gastrocnemius and Achilles tendon may shorten and tighten (Csapo, Maganaris, Seynnes, & Narici, 2010). As a result, they can not do a deep squat nor use a squatting toilet comfortably or at all. In this study, high heels wrapped in kinesio-tape to support the inner arch could reduce lateral and medial gastrocnemius activities, but imbalanced lateral and medial gastrocnemius could not be solved due to heel height and narrow toes of the high heels.

A possible outcome of this situation is Haglund's deformity, also known as posterior Achilles tendon bursitis (Kolodziej, Glisson, & Nunley, 1999). This deformity causes inflammation of the bursa that lies between the Achilles tendon and the skin of the heel (Stephens, 1994). Commonly known as heel bump, this form of bursitis usually develops when a bony projection develops on the back of the inner posterior heel bone.

To summarize the results, the peroneus longus plays an important role to prevent pain, discomfort, and abnormal alignment of shoe related high heel problems, such as bunions, halux valgus, pes planus, cuboid syndrome, calf muscle shortening, and Haglund's deformity.

V. CONCLUSION

Elastic band wrappings can support the inner arch, which results in a reduction of muscle activity, especially in the peroneus longus and medial and lateral gastrocnemius muscles for the people who had pes planus. Reduced muscle activity can lead to a reduction in pain and dis-

comfort, which can prevent injury or deformities from developing or worsening in the future.

Two subjects were used for this study, which provided some limitations; a larger subject group would yield more data for future research.

Study of the level of elasticity and the type of band will be performed in the future. In addition, further research should be conducted to determine the correlation between the type of band and level of elasticity among the different foot types. Furthermore, future studies will also investigate whether or not this inner arch support improves balance and increases stability while walking. Regardless of the mechanism behind these revealing results, future studies need to develop and design wrap-around inner arch supports as a way to ameliorate the pain and discomfort associated with high heeled shoes.

Exercise programs could be developed to help alleviate the pain associated with wearing stiletto heels.

In the interest of fashion, women do not prefer shoes that have built-in inner arch support wrappings or alterations. They tend to choose uncomfortable shoes and deal with the effects. If a woman is more concerned with her overall foot health it would be beneficial for her to wear heels with a band for inner arch support.

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