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Original Article

Gastrocnemius Kinesio Taping: A Strategy to Preserve Lower Limb Damping during Fatigue and Its Implications for Injury Prevention

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ABSTRACT

Background: This study aimed to investigate the impact of Kinesio tape (KT) on the viscoelastic properties of the lower limb, specifically stiffness and damping, before and after a fatigue protocol. KT is a commonly used therapeutic intervention believed to prevent injury, yet the available evidence on its effectiveness remains limited.
Methods: In this pre-post study, fifty healthy participants underwent countermovement jumps before and after a fatigue protocol. The study assessed the body's viscoelastic behavior under two conditions: with and without Kinesio tape (KT) applied to the gastrocnemius muscle, in both fatiguing conditions.
Results: The findings revealed a notable reduction in lower limb damping among male participants after fatigue in the condition without tape. Conversely, in the condition with tape, there was no significant change in damping, indicating that KT may prevent the significant decrease in lower limb damping induced by fatigue.
Conclusion: The study offers evidence supporting the beneficial effects of KT in maintaining shock absorption capacity post-fatigue. These benefits may stem from KT's potential to enhance muscular activity and contraction force. Given that muscles act as primary shock absorbers, KT application could bolster their ability to dampen sudden impact forces post-exhaustion, potentially lowering the risk of impact-related injuries. These findings advocate for the use of KT as a preventive measure.

Introduction

Kinesio Tape (KT) is a commonly used therapeutic modality in physiotherapy and sports physiotherapy, renowned for its purported advantages in pain reduction, enhancing activity levels, and injury prevention [1]. Past studies have shown favorable outcomes associated with KT, such as increased range of motion, muscle activation, strength, power, and pain alleviation. Moreover, there is a suggestion that KT's benefits are particularly evident during challenging activities like multi-joint tasks or in situations of fatigue [2-9].

Fatigue is a physiological condition commonly encountered during both everyday activities and sports engagements, and it can have detrimental effects on biomechanical parameters, elevating the risk of injuries [10]. In our prior research, employing a mass-spring-damper modeling approach, we determined that fatigue can lead to heightened stiffness in both males and females, along with a reduction in the shock absorption capacity

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of the lower limb, particularly notable in males [11]. Stiffness denotes resistance to deformation, while shock absorption capacity reflects the damping properties of the body. These parameters characterize the viscoelastic response of the body to external forces [12, 13].

Applied forces represent one of the primary causes of injuries in sports activities. Activities such as running and jumping, which are prevalent in various sports, subject the body to substantial ground impact forces [14-16]. Extensive research has delved into the alterations in viscoelastic behavior during jumping and running [13, 17, 18]. The viscoelastic response of the human body during functional and multi-joint tasks is influenced by the overall stiffness and damping properties of tendons, ligaments, muscles, and bones across the entire body or within specific segments (e.g., the leg). Biomechanical models are employed to quantify these properties [12, 13]. Previous studies have indicated that diverse factors, including exercises, variations in functional parameters, and fatigue, can impact the global viscoelastic behavior. Moreover, these alterations can affect performance and the likelihood of injury [13, 17, 18]. As noted earlier, we observed an elevation in stiffness in both genders and a reduction in damping of the lower limb, specifically in men [11]. Therefore, considering that changes in viscoelastic behavior can influence injury risk, identifying methods to mitigate these changes in the human body following fatigue could be advantageous.

Therefore, this study aimed to investigate the potential influence of KT on the viscoelastic alterations occurring in the lower limb as a result of fatigue. Based on the hypothesis that KT, as an elastic element, could interact with the body and modulate its viscoelastic behavior, we aimed to examine its effects on stiffness and damping. While some studies have explored the impact of KT on ankle and center of mass stiffness [19, 20], none have specifically addressed its effects on segmental stiffness or damping behavior. Thus, our study aimed to fill this gap by examining the effects of KT on lower limb stiffness and damping during a fatigue-inducing landing task using force data and a mass-spring-damper model. By investigating the potential preventive effects of KT on lower limb injuries, our study contributes to understanding how KT may mitigate viscoelastic changes induced by fatigue.

Materials and Methods

Design

This study employed a pre- and post-design to examine the effects of KT under two conditions: before and after inducing fatigue. The participants were divided into male and female groups, with each group subjected to two fatigue-inducing scenarios. In each fatigue condition, KT was either applied or not applied to the gastrocnemius muscle. The independent variables of the study included the fatigue condition (pre- and post-fatigue), KT application (with and without KT), and gender (male and female). The dependent variables assessed were stiffness and shock absorption capacity, determined through the analysis of force data.

Participants

The experimental data were sourced from a previous study [19]. A total of 50 healthy non-athlete individuals participated, comprising 26 females (mean age 28.15±3.67 years, mean body mass 56.74±6.73 kg, mean height 1.62±0.04 m) and 24 males (mean age 26.62±4.45 years, mean body mass 75.16±12.78 kg, mean height 1.80±0.07 m). Sample size determination was performed using G*power version 3.1.9.2 (α=0.05, β=0.2) [21]. Participants had no history of orthopedic, neurological, or rheumatologic conditions and had not undergone surgeries on the lower extremity or lumbar vertebral area. All participants were physically active, engaging in physical activity at least twice a week. Before participation, all participants provided informed consent. This study was registered with the Ethics Committee of the Iran University of Medical Sciences with the registration number IR.IUMS.REC.1394.9211342213 and the Iranian Registry of Clinical Trials under the code IRCT2016091928310N3.

Test Procedure

The participants underwent a single leg countermovement jump both before and after a fatigue protocol targeting the plantar flexor muscles. The fatigue protocol involved performing five sets of heel raises at the pace of a metronome set to 40 beeps per minute [22]. Each participant continued with each set until they were unable to maintain the metronome pace for five consecutive clicks or were unable to continue the task. The pre-fatigue condition was always conducted before the post-fatigue condition. Before and after the fatigue protocol, participants randomly executed countermovement jumps under two conditions: one with KT applied to the gastrocnemius muscle and the other without. Each condition was separated by a rest period of 20-30 minutes. A standard 2-inch Y-shaped KT (K-Active classic Tape, 5 m/2.5 cm, Nitto Denko, Japan) was applied to the stretched gastrocnemius muscle. To facilitate muscle activity, a skilled physiotherapist applied the KT with approximately 35% tension, extending from the muscle’s origin to its insertion (Figure 1). The tape’s length was customized for each participant, considering the individual length of their gastrocnemius

Figure 1: Kinesio taping was applied over the gastrocnemius muscle.

muscle before the tape's application, ensuring that the tape maintained approximately 35% tension, considered optimal for enhancing muscle function. Two KT anchors were released from tension [1].

The plantar flexor muscles were chosen to be fatigued and taped due to their crucial role in jumping and damping the impact forces that occur during landing [23, 24]. Additionally, taping of these muscles is commonly performed in sports activities.

Data Collection and Processing

We collected force data using a piezoelectric force plate (Kistler type 9260AA, Kistler Instrument Corporation, Winterthur, Switzerland) at a sampling frequency of 1000 Hz. Subsequently, the data underwent filtration using a second-order zero-lag Butterworth filter with a cut-off frequency of 40 Hz. Employing a mass-spring-damper model and the force data, we calculated the stiffness and damping of the lower limb under conditions both before and after inducing fatigue, with and without the utilization of KT. The model formula and calculation process have been previously described [11].

In summary, we employed a mass-spring-damper model with two degrees of freedom [13] to evaluate the stiffness and damping characteristics of the lower limb. This model allows us to quantitatively assess the viscoelastic properties of the lower limb by considering the collective contributions of ligaments, tendons, fascia, muscles, and bones [12, 13]. The model consisted of two masses representing the body, along with two springs for elastic characteristics and two dampers for the viscosity behavior of the body. The method used to determine the masses allowed us to assess the viscoelastic behavior across the entire body, encompassing both one lower limb and other anatomical regions [11, 25].

Statistical Analysis

The study examined the stiffness and damping characteristics during the landing phase of the countermovement jump, both before and after the fatigue protocol, under two conditions: with and without KT. Due to the non-normal distributions of all variables as determined by the Shapiro-Wilk test and their persistence even after log-transformation, non-parametric statistical tests were employed. The Wilcoxon signed-rank and Mann-Whitney U tests were conducted using the statistical software SPSS version 17 (SPSS Inc, Chicago, IL, USA) to analyze all relevant conditions involving fatigue and KT. An effect size of 0.1 was considered small, 0.3 medium, and 0.5 large [26]. P values less than 0.05 were considered statistically significant.

Results

Table 1 presents descriptive statistics for stiffness and damping, including median values and interquartile ranges.

Following analysis with the Wilcoxon signed-rank test, a notable reduction in lower limb damping was observed in men after fatigue in the without-tape condition (P=0.026, effect size=0.32) [11]. Conversely, in the with-tape condition, there was no significant change in lower limb damping (P=0.317), suggesting that KT application effectively mitigated the significant decrease in lower limb damping associated with fatigue. Table 2 provides detailed outcomes of the Wilcoxon signed-rank test.

Moreover, to bolster the statistical analysis, Mann-Whitney U tests were conducted to compare the various conditions between the two groups. The outcomes of these tests unveiled non-significant differences (P>0.05), suggesting that the observed effects were primarily associated with fatigue-induced alterations in lower limb damping and the protective influence of KT in men rather than disparities between the groups.

Discussion

In this study, our main objective was to examine how KT influences the global viscoelastic behavior by assessing changes in fatigue-induced stiffness and damping. In our previous research, we noted an increase in lower limb stiffness due to fatigue in both genders, with only men displaying a decrease in lower limb damping [11]. Here, we specifically delved into analyzing the

Table 1: Median (interquartile ranges) of the lower limb damping and stiffness in the before-and-after fatigue protocol for the conditions with and without Kinesio Tape (Kinesio Tape (KT) and No Kinesio Tape (NK), respectively)

Parameters	Group	Before Fatigue		After Fatigue	
		NK[a]	KT	NK[a]	KT
Damping ($kN.s.m^{-1}$)	Men	0.85 (0.35)	0.82 (0.47)	0.30 (0.60)	0.57 (0.69)
	Women	0.70 (0.34)	0.77 (0.29)	0.56 (0.70)	0.70 (0.68)
Stiffness ($kN.m^{-1}$)	Men	15.59 (81.79)	14.95 (64.08)	133.91 (177.66)	138.98 (168.66)
	Women	14.51 (27.33)	13.86 (12.82)	110.37 (137.58)	109.14 (153.09)

[a]These results have been reported previously [11].

Table 2: P-value (effect size) of Wilcoxon signed-rank test results in various fatiguing and taping situations

Parameters	Group	Before Fatigue-With and without tape	After Fatigue-With and without tape	Without tape-Before and After fatigue	With tape-Before and After fatigue
Damping ($kN.s.m^{-1}$)	Men	0.39 (0.12)	0.20 (0.18)	0.02* (0.32)	0.31 (0.14)
	Women	0.12 (0.21)	0.48 (0.09)	0.36 (0.12)	0.39 (0.11)
Stiffness ($kN.m^{-1}$)	Men	0.88 (0.02)	0.93 (0.01)	0.001* (0.48)	0.001* (0.47)
	Women	0.92 (0.01)	0.97 (<0.01)	0.001* (0.47)	0.001* (0.48)

*Statistically significant. [a]These results have been reported previously [11].

effect of KT on viscoelastic parameters under pre- and post-fatigue conditions. Given our earlier finding that fatigue significantly diminishes lower limb damping in the without-KT condition, the absence of a difference between pre-and post-fatigue situations with KT suggests that KT effectively mitigates the decline in lower limb damping associated with fatigue.

A significant finding from this study was the ability of KT to preserve lower limb damping. Given that impact loads are a major contributor to sports-related injuries [14, 16, 24], the decrease in damping observed in men after fatigue [11] could potentially increase their susceptibility to impact-related injuries. However, applying KT to the gastrocnemius muscle effectively counteracted the decline in damping post-fatigue. This preventive effect could be linked to increased blood flow or enhanced muscle activation induced by KT.

Our fatigue protocol specifically targeted the plantar flexor muscles, with KT applied to the gastrocnemius. We hypothesize that KT's potential to increase blood flow [1, 27] facilitated the clearance of accumulated lactic acid in the fatigued muscles. Additionally, KT may have facilitated muscle activity and contraction force, countering the impact of fatigue on muscle activation [2-4, 6-9]. Considering muscles' critical role as primary shock absorbers [28, 29], KT likely preserves muscular function in effectively dampening impact forces post-fatigue, thereby reducing the risk of impact-related injuries. This preventive effect of KT on fatigue aligns with previous literature where it prevented reductions in power, work, and moments following fatigue [7-9].

Our results indicated that KT did not influence the stiffness of the lower limb, consistent with previous findings showing no impact of KT on local ankle joint stiffness or center of mass stiffness [19, 20]. This suggests that KT may not alter stiffness. However, it's essential to consider that KT was applied over a single muscle or body segment in these studies. Applying KT to multiple muscle groups might yield different results. Additionally, this study only examined the acute effects of KT, and further research is needed to explore its long-term effects, as its elastic effects may diminish after a few days.

One of the key strengths of this study is the utilization of a two degree-of-freedom mass-spring-damper model within the fields of physiotherapy and sports. Previous studies in rehabilitation and sports have typically used simpler one-degree-of-freedom models with only two elements (mass and spring), limiting their ability to assess global stiffness related to the center of mass [17, 18]. In contrast, our study employed a more intricate model with three elements (mass, spring, and damper), allowing for a comprehensive investigation of viscoelastic behavior during functional and multi-joint activities. Despite the complexity of the calculations involved, these multi-degree-of-freedom models provide researchers with a more detailed understanding of viscoelastic behavior [12, 13].

To our knowledge, only one prior study has previously employed a mass-spring-damper model to examine viscoelastic behavior during landing in athletes after ACL reconstruction [30]. As for KT, which is widely used in physiotherapy and sports, previous studies have primarily focused on investigating its impact on stiffness, with one study examining local stiffness at the ankle level and another examining global stiffness related to the center of mass, using a simple mass-spring model that solely considers elastic behavior [19, 20]. In contrast, our study employed a model with more degrees of freedom, allowing us to examine the behavior of the lower limb comprehensively. This approach provided more detailed insights compared to solely assessing the behavior of the center of mass in a one-degree-of-freedom model. Moreover, by incorporating the damper element, we were able to explore the influence of KT on both stiffness and damping behavior. The utilization of this more intricate model facilitated our understanding of the shock absorption effect of KT, which holds significant implications for injury prevention.

Conclusion

In summary, this study demonstrates the beneficial effect of KT in preserving shock-absorption capacity and restoring damping behavior, indicating its potential as an effective preventive intervention. The findings suggest that KT can effectively dampen applied impacts and contribute to injury prevention. This damping effect of KT may be attributed to its interaction with the musculoskeletal system, including increased blood flow, enhanced muscular activity, and altered kinematics. These results have important implications for sports physiotherapists and sports medicine physicians, highlighting the potential of KT as a valuable tool in promoting musculoskeletal health and reducing the risk of impact-related injuries.

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Conflict of Interest: None declared.

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