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Original Article

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Ankle Sprain Affects Lower Leg Muscle Activation on Vertical Landing, Half Point, and Gait in Female Ballet Students

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Purpose: This study aimed to investigate effect of ankle instability on peripheral muscle activation among female ballet dancers to provide information on the development of prevention programs for ankle injury rehabilitation.

Methods: 32 female ballet dancers were randomly divided into two groups: experience ankle sprain group (n = 16, age, 20.7 ± 0.8years, BMI 18.6 ± 1.2kg/m2) and non-experience ankle sprain group (n = 16, age = 21.0 ± 0.8 years, BMI 19.6 ± 2.0kg/m2). Activation of the peroneus longus, tibialis anterior muscle, and gastrocnemius during vertical landing, half pointe, and gait between the two groups were measured. Body composition analyzer was used to examine skeletal muscle mass and body fat mass.

Results: A total of 32 patients were included. In the experience ankle sprain group (n = 16: left sprain 14, right sprain 2), average ankle sprain injury occurred 7.5 months before the study. The average age of the dancers in the experience ankle sprain group and non-experience ankle sprain group was 20.7 ± 0.8 and 21.0 ± 0.8years, major period was 64.5 ± 23.8 and 71.6 ± 25.8months, BMI was 18.6 ± 1.2 and 19.5 ± 2.0kg/m2, respectively. No significant differences were found on body composition between the two groups ($p > 0.05$). The experience ankle sprain group showed significantly lower tibialis anterior and peroneus longus muscle activation ($p < 0.5$), while gastrocnemius muscle activation appeared to be significantly higher ($p < 0.05$) during landing, half pointe, and normal gait.

Conclusion: Ankle sprain can cause a decline in peripheral muscle activation and coordination, which increased the risk for repetitive ankle sprain in the future. Moreover, ankle peripheral muscle selective strength training, coordination program development, and application need to be considered to prevent ankle sprain.

Keywords: Ballet, Ankle Injuries, Muscles

INTRODUCTION

Ballet requires harmony in movement and rhythm. It has known positive effects on physical function, muscle strength, and fitness. However, to perform a graceful and high-quality dance, dancers often challenge their limit and go beyond their capability, which lead to a higher risk of injury.[1] Specifically, the ankle, foot, and knee are the most common sites of injuries.[2] Ballet shows the highest injury rates in the same area during ballet performance and practice.[1]

Particularly, jump and landing movement cause the most injuries in ballet dancers.[3] Due to gravitational acceleration on body weight, landing movement may deliver 10 times greater pressure on lower extremities depending on the weight and cause of overloading.[4] To compensate this, lower extremity muscles use eccentric contraction to adjust joint movement.[5] Moreover, ground reaction force in female dancers was found to be higher than that of male dancers, and it increases the degree of knee joint flexion.[6] To prevent foot and ankle injury, balance movement at the lower extremity joint is necessary.[7] However, ballet requires both artistry and physical mobility; thus, it is not easy to perform ballet in the normal range of physical mechanism.[8]

Pointe is the most basic and frequently performed movement in ballet. In pointe, because the tips of the toes are used to support the body, instantaneous power is required to raise the heel and hyper-plantar flexion the ankle to maintain the stability. The half-pointe movement bears the basic pointe-movement which poses as the

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same ankle movement as the one of half-pointe movement.[9] Generally, ankle joint injury occurs due to hyper internal rotation and inversion with plantar flexion of the ankle. This often causes damage to the lateral ligament and anterior talofibular ligament and leads to chronic ankle instability.[10] Ankle instability is one of the factors that inhibit ankle peripheral muscle activity and movement harmony. Moreover, ankle injury rehabilitation requires time and disrupts ballet practice and performance.[7] In addition, ankle injury patients mostly have a high risk of ankle injury recurrence, which leads to chronic ankle instability.[11]

Ankle injury mostly occurs because of excessive load or weak muscles do not contract spontaneously. Especially, contraction of the peroneus longus maintains eversion of an inverted ankle, and the tibialis anterior muscle maintains dorsiflexion and avoids hyper plantar flexion to prevent ankle sprain.[12-14] In other words, delayed activation of peripheral muscles and low muscle contraction are the main causes of ankle injury. Moreover, the main action of the gastrocnemius muscle is to lift the heel, however, when peripheral muscle movements are not balanced, unstable ankle movement will ensue. Despite the numerous investigations focusing on ballet dancers, studies of ankle injury frequency and risk are limited. Under-investigation of ankle injury and muscle activation function leads to little known information regarding prevention of ankle injury recurrence.

Therefore, this study aimed to investigate the effect of ankle instability on peripheral muscle activation among female ballet dancers to provide information on the development of prevention programs for ankle injury rehabilitation.

METHODS

1. Subjects

In this study, female ballet dancers with 3 or more years of experience who have no ankle or muscle disorder and pain were recruited. Recruited dancers were divided into two groups: 16 female dancer with ankle sprain within a year (experience ankle sprain group) and 16 female dancers without ankle sprain experience (non-experience ankle sprain group). All participants fully understand the study protocol, and voluntary joined the study.

A total of 32 patients were included. In the experience ankle sprain group (n = 16: left sprain 14, right sprain 2), average ankle sprain injury occurred 7.5 months before the study, and average rehabilitation period was 3.3 weeks. The average age of the dancers in the experience ankle sprain group and non-experience ankle sprain group was 20.7 ± 0.8 and 21.0 ± 0.8 years, major period was 64.5 ± 23.8 and 71.6 ± 25.8 months, and BMI was 18.6 ± 1.2 and 19.5 ± 2.0 kg/m^2, respectively. No significant difference was found in physical characteristics between the two groups.

2. Experimental methods

1) Measurement procedures

In this study, activities of the lower muscles, namely, tibialis anterior, peroneus longus, and gastrocnemius, during landing after a vertical jump, gait on half pointe; and normal gait were measured. To regulate the jump height, a stick was placed horizontally at a 20 cm height from the base, and participants were instructed to jump and touch the bar. For the measurement of the jump height, each participant was given two chance practices before the test. Each participant did a total of three jumps, and the mean jump height was used in the analysis. Landing was counted from when the toe touched the ground until the entire sole touched the ground. In normal gait and half pointe gait, from a total of five gait cycles, only three cycles were analyzed, and the average muscle activation was measured. In both half pointe and normal gait, electromyography (EMG) was used to measure from the stance phase.

2) Measurement tools

All participants' physical characteristics were analyzed with body composition analyzer (Inbody 720, Biospace, Korea).

A wireless foot switch (DTS FootSwitch, Noraxon Inc., USA) was used to measure muscle activation in a specific section on the gait cycle. All participants performed all motions bare foot. All motion activities of the peroneus longus, tibialis anterior muscle, and gastrocnemius were measured. In this study, only the medial part of the gastrocnemius was measured. Movements were performed randomly, and to minimize muscle fatigue, a 2 min rest was given between each movement. Muscle activation was measured using the surface EMG system (Myosystem TM DTS, Noraxon Inc., USA), and the results were analyzed using an EMG analyzer program (MyoResearch XP Master Edition 1.06, Noraxon Inc., Scottsdale, AZ, USA). Ag/AgCl surface electrodes (IWC-DTS, 9113A-DTS, Noraxon Inc., USA) were placed with intervals of 1, 2 cm. Before

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placement of the surface electrodes, to decrease skin resistance and to fix the electrodes on the skin, skin hair was shaved and cleansed with alcohol.[15] The EMG sampling ratio was set at 1,024 Hz, band-pass filter at 20-500 Hz, and notch filter at 60 Hz. All collected data were quantified by root mean square. For data analysis, muscle activities of the peroneus longus, tibialis anterior muscle, and gastrocnemius were measured in anatomic position for 5s. All mean data collected from landing, half pointe, and normal gait were converted into %RVC for analysis.

3. Data analysis

The statistical processing and analysis used ISM SPSS Statistics Ver. 25.0 (IBM Co., Armonk, USA). Comparison between experience ankle sprain group and non-experience ankle sprain group was performed using independent t-test. p value of <0.05 was considered significant.

RESULTS

No significant differences were found on fat mass and skeletal muscle mass between the groups ($p>0.05$)(Table1). The tibialis anterior and peroneus longus showed significantly lower muscle activities in the experience ankle sprain group than in the non-experience ankle sprain group during landing, half pointe, and normal gait ($p<0.05$) (Table2). On the contrary, the gastrocnemius showed significantly higher muscle activation in the experience ankle sprain group than in the non-experience ankle sprain group ($p<0.05$)(Table 2).

DISCUSSION

In this study, we investigated the effect of ankle sprain on muscle activations among female ballet students during landing, gait, and half pointe. This study showed low activation of the tibialis anterior and peroneus longus muscle in the experience ankle sprain group while performing the three movements, on the contrary, the activation of the medial gastrocnemius muscle while landing and half pointe was greater in the experience ankle sprain group but was lower during normal gait.

As reported, 85% of ankle injuries transpire during inversion and internal rotation in plantar flexion, causing damage at the lateral organ.[16] Among ankle injury patients, 33% have chronic ankle sprain.[17] Especially, in ballet dancers, ankles are frequently used to perform movements and to support body weight. Without proper treatment and maintenance, peripheral ligaments and muscles continuously weaken, leading to chronic sprain due to muscle overuse and fatigue.[15] Particularly, in ankle injury, the peroneus longus muscle, which is easily damaged, maintains ankle eversion and the tibialis anterior muscle maintains dorsiflexion, which become antagonists

Table 1. The comparison of fat mass and skeletal muscle mass in each group

	Experience ankle sprain group	Non-experience ankle sprain group	t	p
Fat mass (%)	13.34±2.21	12.92±2.65	0.5	0.10
Skeletal muscle mass (%)	19.82±2.03	19.31±1.52	0.7	0.09

Mean±SD , *p<0.05.

Table 2. The comparison of muscle activities in each group

unit: %RVC

Motion	Muscle	Experience ankle sprain group	Non-experience ankle sprain group	t	p
Landing	TA	4395.42±1500.31	8318.91±3293.83	-4.33	0.00*
	PL	562.64±244.65	2427.93±860.35	-8.34	0.00*
	Gas	4797.61±2439.73	1321.34±918.43	5.33	0.00*
Half pointe	TA	1069.81±568.04	1805.75±541.14	-3.75	0.00*
	PL	737.63±417.69	2938.21±1007.83	-8.06	0.00*
	Gas	12186.41±7461.65	3858.41±2539.54	4.22	0.00*
Gait	TA	1682.63±817.01	3151.32±1237.04	-3.96	0.00*
	PL	313.42±194.48	1419.78±1046.07	-4.15	0.00*
	Gas	2401.90±2210.31	865.92±439.83	2.72	0.00*

Mean±SD, *p<0.05, TA: tibialis anterior muscle, PL: peloneus longus muscle, Gas: gastocnemius medial.

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to sprain direction. Peroneus longus and tibialis anterior muscle of the ankle sprain experienced were inhibited not only lower intensity gait, but also high intensity landing from a jump. Participants with ankle injury exerts a low load on the injured ankle; in daily life, such as during gait, which needs repetitive movement, the low activation of the peroneus longus muscle and tibialis anterior muscle places a high risk of ankle injury not only during ballet performance or practice but also in daily living.

Those who have experienced ankle sprain usually put less pressure on their ankles which results in less activation of those affected muscles including peroneus longus and tibialis anterior muscle. As a result, they become prone to be further ankle sprain when performing ballet and doing regular excise as well. Moreover, landing and half pointe, which are the most commonly performed movements in ballet performance and practice, are risk factors of repetitive ankle injury. These results are consistent with those in existing research that weakened and delay contraction of the peroneus longus muscle and tibialis anterior muscle lead to a loss in ankle muscle coordination.[18-20] Alternating activation of the tibialis anterior muscle and medial gastrocnemius play a direct role in maintain anteroposterior balance.[21] Ankle sprain causes changes in somatic sense and posture.[22]

Furthermore, skeletal muscle injury causes scar tissues that interrupt force delivery.[23] Injury decreases proprioceptive sense and leads to error in sensory input, causing impaired muscle contraction and force delivery.[24] However, further research on skeletal muscle injury will support the results of this study. Moreover, no difference in skeletal muscle mass was found between both groups, which suggests no difference in skeletal muscle but ankle injury experience.

From this study results, gastrocnemius muscle activation is higher in the experience ankle sprain group than in the non-experience ankle sprain group, which was due to ankle sprain experience, less use of the tibialis anterior muscle, and changes in somatic sensory effects during gastrocnemius activation. Moreover, to complement the weakened muscle during ankle dorsiflexion and eversion, the gastrocnemius become overactive to reduce load and speed toward the ankle in every movement. This means that ankle sprain directly affects the activation and coordination of non-injured peripheral muscles. Such decrease in peripheral ankle muscle activation and coordination indicates a high risk for repetitive ankle sprain. Furthermore, to prevent ankle sprain, ankle peripheral muscle selective strength training and coordination program development and application need to be considered.

This study had some limitations. This study was measured only muscle activities. In future studies, as ankles affect physical balance, not only activation of ankle peripheral muscle but also all body muscles affecting balance needs to be studied further. In addition, whether ankle injury causes peripheral muscle fatigue not only during physical activity but also at rest might be investigated in the future. And It is considered necessary to study about muscle activities, fatigue and muscle firing time according to detail the frequency and severity of ankle sprains in future studies.

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