THE EFFECTS OF COMPRESSION TIGHTS ON DYNAMIC KNEE MOTION DURING A DROP VERTICAL JUMP IN FEMALE COLLEGE ATHLETES

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The purpose of this study is to evaluate the ability of compression tights to influence knee motion during a drop vertical jump (DVJ) in healthy college-aged female athletes. 23 athletes participating in jumping sports (volleyball, basketball, and soccer) were tested. A standard Helen-Hayes 29-marker set was applied to the subjects and recorded using 8 visible-red cameras and 2 force plates. Average hip internal rotation was reduced by 1.9° (p= 0.005), hip abduction range of motion was 2.4° less (p= 0.002), hip abduction angle at initial contact was reduced by 2.7° (p= 0.018), and knee valgus angle at initial contact was also reduced by 1.7° (p= 0.029). These changes support the idea that compression tights may aid in injury prevention and rehabilitation. In the future EMG could be use to identify differences in muscle activation patterns.

KEY WORDS: compression tights, jump, knee.

INTRODUCTION: Anterior Cruciate Ligament (ACL) injuries continue to rise in college athletes, with female athletes being at greater risk than males. Women have three-times greater incidence of ACL tears than men while participating in soccer and basketball (Prodromos, Han, Rogowski, Joyce, & Shi, 2007) with 60% of all ACL tears resulting from non-contact mechanism of injury (Agel, Rockwood, & Klossner, 2016). This suggests that a large portion of injuries is due to motor-control issues rather than a result of colliding with opponents. As such, these should be preventable with proper intervention. Female soccer players have been particularly affected with significant increases in annual injury rates. The medical community has been actively trying to change this trend with new prevention protocols being studied extensively (Alentorn-Geli, Myer, Silvers, et al., 2009). Compression tights have not been included in these efforts.

Based on findings reported in the current literature, compression seems to improve proprioception (Hassan, 2002; Özdil & Anand, 2014; Sugimoto et al., 2016) and balance (Chae & Kang, 2009; Chuang et al., 2007; Hanzlíková, 2016; MacRae et al., 2011). Given the improved proprioception, it is plausible that these compression tights may be beneficial to patients at risk of injury due to poor mechanics and instability. Finally, stimulation of the cutaneous receptors at the knee joint has been shown to increase kinesthesia (Collins, 2005), which could be useful in facilitating neuromuscular mechanisms underlying improved movements (Alentorn-Geli et al., 2009; Hanzlíková, 2016; Hassan, 2002; Hewett et al., 2005; Özdil & Anand, 2014).

Chae and Kang (2009) investigated compression tights and muscle activation patterns. Their findings support the idea that compression tights are able to increase muscle activation due to an increase in cutaneous stimulation. However, their study did not address changes in either joint angles or joint moments. Therefore, the purpose of this study was to explore the effects of compression garments on dynamic valgus collapse at the knee joint, specifically investigating both kinematic and kinetic changes at the knee and hip joint. It was hypothesized that the use of compression garments would result in decreased knee valgus angle, and hip adduction angle. It is hoped that this study will be useful in setting a basis for future evaluations of compression garments as tools in ACL injury prevention and rehabilitation.

METHODS: **Participants**: A sample of 23 Division II, NCAA female athletes, aged 18 to 23 (average 19.6 ±1.3), recruited directly from the athletic teams on campus, participated in this study. Each was an active member of either the women's Volleyball, Basketball, or Soccer teams to insure participation in sports requiring jumping, landing, and cutting as fundamental skills.

Test Protocol: One model of compression tights (Knee-Tec, Opedix, Scottsdale, AZ) was used for this study. Waist circumference measurements were taken upon arrival in order to properly select the correct garment size as per manufacturer specifications. Before recording, participants were instructed on the testing procedure and 3 to 5 jumps were performed to ensure proper performance of the testing protocol. A set of 29 passive, reflective markers (9 mm DIA) was placed on the skin overlaying specific anatomical landmarks, including the medial epicondyles of the knees and the medial malleoli of the ankles, to estimate joint locations and adjacent bone segments following the Helen-Hayes model**.** Such locations are defined to estimate joint kinematics and kinetics based on previously incorporated model specifications (Aguinaldo, Buttermore & Chambers, 2007). During each movement, 3D global locations of the markers were captured using 8 visible-red cameras (*Kestrel*, Motion Analysis Corp., Santa Rosa, CA) at a sampling rate of 200 Hz. Two Accu-Gait force platforms (AMTI, Watertown, MA), recorded ground reaction force data at a sampling rate of 1200 Hz, integrated with the *Cortex v6.02* motion capture software (Motion Analysis Corp., Santa Rosa, CA). Each participant performed a drop vertical jump off a 27 cm tall box with the feet shoulder width apart.

Kinematic analysis: Valgus collapse was analyzed according to the procedures described by Hewett et al. (2005). A static capture was recorded immediately after application of the markers and used as the base template followed by a walking trial where participants were asked to walk at a normal pace for 5 meters. The participants were then instructed to step on the box and begin the test. Each participant was tested twice during the same session, a control trial without tights and an intervention trial with the compression tights. Trial order was randomized to reduce bias. The markers below the pelvis had to be removed and repositioned between conditions. New static and walking captures were recorded to ensure accuracy of the 3D modeling with the new marker placement. Kinematic points were extracted from the time-series data for subsequent statistical analysis using Cortex software

Data Analysis: Marker data were filtered using a Butterworth low-pass filter at a cutoff frequency of 12 Hz while ground reaction force data were filtered at a cutoff frequency of 50 Hz. Several kinematic parameters were extracted as dependent variables to test the hypothesis (Table 1). These parameters were previously found to have a significant relationship with the risk of an ACL injury in female soccer players and therefore were selected as the outcome measures for this study (Herrington, Simmonds & Hatcher, 2005). They were extracted from the following time points: Initial Contact (IC), representing the first contact with the force plate; Average (AVG) value across all frames; Peak (PK) value between IC and take off; Total Range of Motion (ROM). For each participant, the kinematic parameters were calculated per trial and averaged for analysis. The mean and standard deviation were calculated for each condition and paired t-tests were used to compare values with and without compression tights to determine statistical significance at an alpha level of 0.05. All statistical analysis was performed using IBM SPSS Statistics for Windows, Version 22.0. (IBM Corp. Armonk, NY).

Table 1
Extracted Variables

Average Knee Valgus Average Hip Internal Rotation Average Knee Valgus Average Knee External Rotation Hip Abduction Range of Motion Knee Valgus Range of Motion Knee External Rotation Range of Motion	Knee Valgus at Initial Contact Hip Abduction at Initial Contact Knee External Rotation at Initial Contact Peak Knee Valgus Peak Hip Abduction Peak Knee External Rotation

RESULTS: **Kinematics:** Table 2 shows four variables statistically significant at an alpha level of 0.05. The hip joint was the most affected by wearing compression tights. Average hip internal rotation was reduced by 1.9° (p= 0.005), hip abduction range of motion was 2.4° less than control (p= 0.002), and hip abduction angle at initial contact was reduced by 2.7 (p= 0.018).

Knee valgus angle was also affected at initial contact, with compression showing a reduction of 1.7 (p= 0.029).

Table 2
Kinematic Parameters

Kinematic Parameter	Control (degrees)	Tights (degrees)
Average Hip Internal Rotation	4.6 ± 2.9	2.7 ± 2.7*
Average Knee Valgus	1.8 ± 1.4	1.1 ± 1.1
Average Knee External Rotation	11.4 ± 7.9	10.5 ± 6.3
Hip Abduction Range of Motion	12.6 ± 5.5	10.2 ± 4.6*
Knee Valgus Range of Motion	5.6 ± 2.1	6.9 ± 3.0
Knee External Rotation Range of Motion	13.7 ± 4.0	14.2 ± 3.6
Knee Valgus at Initial Contact	4.1 ± 6.9	2.4 ± 6.2*
Hip Abduction at Initial Contact	11.9 ± 6.6	9.2 ± 4.5*
Knee External Rotation at Initial Contact	1.6 ± 26.9	1.6 ± 26.0
Peak Knee Valgus	2.9 ± 2.1	2.2 ± 2.5
Peak Hip Abduction	3.0 ± 5.1	2.7 ± 4.4
Peak Knee External Rotation	18.3 ± 8.9	18.7 ± 8.9

* $p < 0.05$

DISCUSSION: Mechanical versus physiological changes: The purpose of this study was to evaluate the effects of compression tights on dynamic knee motion. It was hypothesized that specifically designed garments would be able to improve proprioception and therefore increase movement control. Historically, two modalities have been used when there is a need to control excessive joint motion athletic taping, and braces. Mechanical knee braces have been used extensively to reduce or control joint motion and have been proposed as a preventative measure in sports such as American football (American Academy of Orthopaedic Surgeons, 1997). Sugimoto et al. (2016) conducted a systematic review on ACL braces and joint position sense and found that the current evidence is inconclusive. Furthermore, a recent study suggested that the use of mechanical restraints such as ACL braces cannot effectively prevent ACL injuries due to their inability to reduce anterior tibial translation beyond anterior forces of 140 N and internal torques of 8 Nm (Prodromos et al., 2007; Smith et al., 2013).

Recent studies on knee sleeves and silicon braces have shown promising results. Schween et al. (2015) showed that elastic knee sleeves reduced knee adduction angle at ground contact by 1.9 ± 2.1°, and peak knee adduction angle by 1.5 ± 1.6°during gait. Knee adduction moment was also reduced by 10.1% and positive knee adduction impulse by 12.9%. Hanzlíková et al. (2016) found that silicone web braces reduced knee valgus and internal rotation angles during single leg drop jumps.

The tights tested in the study were designed using a combination of fabrics with different elasticity and tensile strength in an effort to increase support at the knee joint. Our results show the possible efficacy of compression garments as functional injury prevention aids and are consistent with the findings of Hanzlíková et al. (2016) and Schween et al. (2015). The hip joint showed 41% less average internal rotation, 19% less frontal plane motion, and more neutral ground contact with 23% less adduction at initial contact. The knee also benefited of the compression tights showing 41% less valgus at initial contact. These changes could be the result of increased proprioceptive stimulation of the hip musculature leading to better movement patterns, as proposed by Hooper et al. (2015).

CONCLUSION: The results of this study showed a significant, positive change in hip and tibio-femoral motion as a result of wearing compression tights with reductions of key kinematic variables ranging between 20% and 40%. These changes support the idea that compression tights may aid in injury prevention and rehabilitation, but it is not possible to clearly identify the mechanisms by which they occur. Further research should focus on two main areas: muscle activation patterns and adaptations over time. Electromyography (EMG) recordings have shown an increase in muscle activation when compression is applied to a body segment (Chae & Kang, 2007) and could help identify the relationship between compression, proprioception and movement patterns. The use of this technology has been a staple of gait analysis and is well validated (Türker & Sözen, 2013).

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