Effect of a Compressive Garment on Kinematics of Jump-Landing Tasks

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Abstract

de Britto, MA, Lemos, AL, dos Santos, CS, Stefanyshyn, DJ, and Carpes, FP. Effect of a compressive garment on kinematics of jump-landing tasks. *J Strength Cond Res* 31(9): 2480–2488, 2017—During jump-landing tasks, knee kinematics such as excessive valgus have been linked to knee injury in females. We determine the influence of a compressive garment on knee valgus during landing. Physically active women ($n = 27$, mean age 23 years) performed 4 different jump-landing tasks with 2 apparel conditions (compressive garment and regular sports shorts). Kinematic data were collected to determine knee flexion and valgus angles and the maximum jump height. Results showed that the compressive garment decreased knee flexion and knee valgus range of motion, without significant changes in the maximum jump height. As a practical application, we suggest that compression could be a strategy to reduce dynamic valgus without influencing jump performance, which motivates further study of its potential for knee injury prevention.

Key Words compression, jumps, ACL injury, women, knee

Introduction

Jump-landings occur in many sports and are often associated with a risk of knee injuries (13). Excessive knee valgus during landing, which is known to be greater (17) and asymmetric (16) among women, is a potential kinematic risk factor for injury (16). Compressive garments can reduce muscle oscillation during jump-landings and may also decrease hip flexion range of motion during jumping (4). These effects are generally related to changes in sagittal plane movements but compression apparel may also be relevant in modifying frontal plane kinematics as well. Although previous studies addressed the influence of these garments on exercise recovery (11) and fatigue effects in repeated jump-landing tasks (14), evidence of its effects on joint kinematics is still limited to the sagittal plane.

Different jump-landing tasks have been investigated with the purpose of simulating sports movements for injury risk screening. One of the most common jumps analyzed in the literature is the drop jump (1). In the drop jump, the subject will drop from a box that can differ in height and land at a determined point. This type of jump can involve a countermovement, which requires the subject to jump again after falling from the box. Decreases in hip and knee flexion angles during the second drop jump landing in comparison with the first can put ligaments at higher risk (2). Another jump-landing task used for evaluation is the forward jump, which elicits higher asymmetries in knee valgus compared with drop jumps (16).

As mentioned, compressive garments influence lower-extremity kinematics during jump-landing tasks (4). Reducing knee range of motion in the sagittal plane during landing could influence knee valgus, affecting risk factors for knee injuries. This possible effect would be especially relevant for women, who are at greater risk for knee injury in landing tasks (17). In addition, altered joint stiffness due to the compression (21) could influence joint range of motion and jump height. Therefore, the aim of this study was to determine the influence of a compressive garment on knee kinematics during jump-landing tasks performed by physically active women. We hypothesized that a compressive short would decrease knee range of motion during the landing phase of jump-landing tasks (21). Practical implications of this study involve the motivation of wearing compressive garments in regular training and competition if compressive apparel can alter biomechanical variables associated with both performance and injury prevention.

Methods

Experimental Approach to the Problem

To examine the effects of the compressive garment, each subject served as their own control. The experimental treatment involved the comparison between regular sports

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shorts and a similar short that included compressive elements (84% polyester and 16% elastane, and compression level of 11.3, 10.5, and 8.3 mm Hg for sizes 44, 46, and 48, respectively, as reported by the manufacturer). Jump-landing movements were analyzed as they are frequently included in training routines and are associated with knee injury risk in sports. Female participants were selected as they have a higher incidence of lower-extremity injuries in performance of such tasks. They were requested to perform a number of jump-landing tasks using either the compressive garment or the control shorts. The tasks were verbally explained and then demonstrated before extensive familiarization with the tasks was permitted. Half of the subjects were first tested wearing the compressive garment and the other half started with the regular shorts. The order of jump-landing tasks was randomized for each participant to prevent "order" bias. Kinematic data were recorded and results were compared for each landing condition with and without wearing the compressive garment.

Subjects

Twenty-seven physically active women aged between 16 and 25 years old participated in this study, which was approved by the local ethics committee. Subjects, and their parents when suitable, were informed of the benefits and risks of the investigation before signing an institutionally approved informed consent document to participate in the study. The mean (*SD*) age of the participants was age 23 (4) years, height 1.61 (0.05) m, and body mass 60.6 (7.9) kg. The inclusion criteria were ages between 16 and 35 years and participation in a physical exercise program (volleyball, basketball, running, or weight lifting) at least twice a week with sessions lasting at least 45 minutes in the last 6 months. Participants were excluded if they had a history of lower limb injury in the past 6 months or if they received specialized training in jumping and landing techniques. Kinematic data were recorded during execution of different jump-landing tasks with or without wearing a compressive garment (further details provided below). Nutritional and hydration status were not controlled, but subjects were all instructed to avoid intense exercise 24 hours before testing, as well as to maintain their daily dietary routine.

Procedures

Each evaluation session started with an anamnesis concerning personal information and anthropometric measurements. According to the Plug-in-Gait template (Vicon Motion Systems, Oxford, United Kingdom), 39 spherical reference markers of 14-mm diameter were placed at anatomical reference sites on the participant's body. Markers were firmly attached with tape to minimize movement artifact, and their positions were marked to help the researchers replicate the marker positions when wearing the different garments. Kinematic data were sampled at 100 Hz using 15 infrared cameras (Bonita B10, Vicon Motion System, Oxford, United Kingdom). Two force plates (OR6 2000; AMTI Inc., MA, USA) embedded in the floor sampled data at 1,000 Hz to detect the start of touchdown.

The participants performed 5 different jump-landing tasks. For each task, 3 valid trials were recorded while wearing a compressive short or a control (noncompressive) short, and the order of testing was alternated between the participants. The order of the jump-landing tasks was randomized for each participant and garment condition. The compressive garment used in this study was a brand new Adidas TechFit short, and the noncompressive short was a generic brand (Figure 1). The shorts had similar color and length; they were fitted for the participants according to the size they wear in their regular clothes.

The jump-landing tasks investigated were:

- *Forward jump*: starting 20 cm from the force plates, the participant was instructed to jump forward and as high as possible and land on the force plates;
- *Forward jump with countermovement*: starting 20 cm from the force plates, the participant was instructed to jump

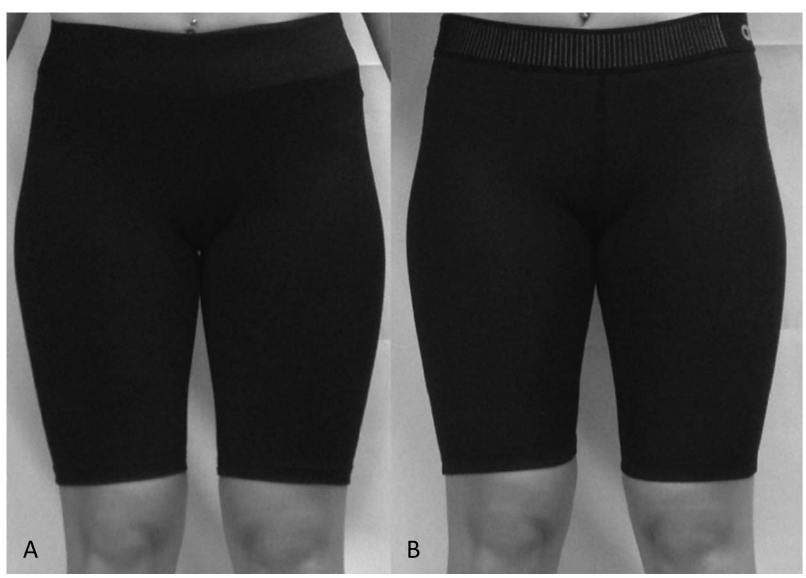

Figure 1. Garments: control (noncompressive) short (A) and compressive short (B) used in this research.

forward and as high as possible and land on the force plates then immediately jump again after touchdown, in the same spot of landing, as high as possible;

- *20-cm drop jump with countermovement*: from the top of a 20-cm-high box, and 20 cm away from the force plates, the participant was instructed to drop from the box onto the force plates and then jump again after touchdown, in the same spot of landing, as high as possible;
- *40-cm drop jump with countermovement*: from the top of a 40-cm-high box, and 20 cm distant from the force plates, the participant was instructed to drop from the box onto the force plates and then jump again after touchdown, in the same spot of landing, as high as possible;
- *Vertical jump*: standing on the force plates, the participant was instructed to jump as high as possible.

During the performance of the tasks, participants were instructed to keep their hands on the waist, and for a valid trial, they had to land with one foot on each force plate, without losing balance. Experiments were performed during a 3-week summer season, always in the afternoon. Audience effects were strictly controlled in the laboratory.

The kinematic variables determined were knee flexion angle at initial ground contact and peak knee flexion angle during landing; knee valgus angle at initial ground contact and peak knee valgus during landing; and maximum jump height. The maximum jump height was defined by the height of the center of mass subtracting the center of mass height during standing. Angular variables were determined bilaterally during the landing cycle, which was defined as the time between initial contact and peak knee flexion (16).

Positional data were processed using Nexus 1.5.2 software and custom-written MATLAB codes. They were low-pass filtered with a fourth-order zero-lag Butterworth filter with cutoff frequency of 10 Hz. For all the jump-landing tasks that involved a countermovement, the analysis was made for the second landing.

Statistical Analyses

A Shapiro-Wilk test was used to determine whether the data were normally distributed. For parametric data, a paired t test was used to compare the garment conditions. For nonparametric data, Wilcoxon's test was used. Where appropriate, Cohen's d effect size was calculated to quantify differences between the garment conditions (20). Test-retest reliability was analyzed by determining the intraclass correlation coefficient between the trials in the same condition and between the 2 conditions. The level of significance selected was 0.05, and all analyses considered a confidence interval of 95%.

Results

The interclass correlation coefficient (ICC) for the trials, considering the average for all variables analyzed, with the control shorts was 0.79, 0.77, 0.80, 0.73, and 0.80 for the forward jump, forward jump with countermovement, 20-cm drop jump, 40-cm drop jump, and vertical jump, respectively. For the compressive garment, the ICCs for the same order of jumps tasks were 0.74, 0.68, 0.80, 0.72, and 0.79.

The use of a compressive garment did not affect jump height in the forward jump ($p = 0.092$), forward jump with countermovement ($p = 0.781$), 20-cm drop jump ($p = 0.740$), 40-cm drop jump ($p = 0.333$), and vertical jump ($p = 0.289$). Supplemental Digital Content 1 (see File 1, http://links.lww.com/JSCR/A20) for complete jump height values and Supplementary File 2 for effect sizes. The use of a compressive short resulted in smaller knee valgus and knee flexion angles. For most of the tasks, such effects were found in both legs, and effect sizes ranged between medium to large (see File 2, Supplemental Digital Content 2, http://links.lww.com/JSCR/A21, for a full report of effect sizes).

Knee valgus angle at initial ground contact was smaller during the use of the compressive garment for all the tasks (Figure 2, left column): in the forward jump for both the right ($p = 0.0009$; $d = -0.67$) and left ($p = 0.002$; $d = -0.58$) legs; in the forward jump with countermovement for the right ($p < 0.001$; $d = -0.61$) and left ($p = 0.033$; $d = -0.41$) legs; in the 20-cm drop jump for the right ($p = 0.003$; $d = -0.58$) and left ($p = 0.008$; $d = -0.51$) legs; in the 40-cm drop jump for the right ($p < 0.001$; $d = -0.67$) and left ($p < 0.001$; $d = -0.50$) legs; and in the vertical jump for the right ($p = 0.006$; $d = -0.50$) and left ($p = 0.028$; $d = -0.36$) legs.

The peak knee valgus angle during the landing phase was smaller during the use of the compressive garment for all the tasks (Figure 2, right column): in the forward jump for the right ($p < 0.001$; $d = -0.61$) and left ($p = 0.013$; $d = -0.47$) legs; in the forward jump with countermovement for the right ($p = 0.001$; $d = -0.22$) and left ($p = 0.018$; $d = -0.25$) legs; in the 20-cm drop jump for the right ($p = 0.0004$; $d = -0.55$) and left ($p = 0.039$; $d = -0.39$) legs; in the 40-cm drop jump for the right leg ($p = 0.011$; $d = -0.50$); and in the vertical jump for the right ($p = 0.011$; $d = -0.51$) and left ($p = 0.035$; $d = -0.37$) legs.

Knee flexion angle at initial ground contact (Figure 3, left column) was smaller when wearing compressive shorts in the forward jump for the left leg ($p = 0.011$; $d = -0.63$); in the forward jump with countermovement for the left leg ($p = 0.002$; $d = -0.60$); in the 20-cm drop jump for the right ($p = 0.024$; $d = -0.43$) and left ($p = 0.007$; $d = -0.47$) legs; in the 40-cm drop jump for the right ($p = 0.027$; $d = -0.35$) and left ($p < 0.001$; $d = -0.37$) legs.

The peak knee flexion angle during the landing phase (Figure 3, right column) was smaller with the use of compressive shorts in the forward jump for the right ($p = 0.006$; $d = -0.42$) and left ($p = 0.015$; $d = -0.51$) legs, in the forward jump with countermovement for the left leg ($p = 0.010$; $d = -0.49$), in the 20-cm drop jump for the right ($p = 0.020$; $d = -0.38$) and left ($p = 0.008$; $d = -0.37$) legs, in the 40-cm drop jump for the right ($p = 0.010$; $d = -0.38$) and left ($p < 0.001$; $d = -0.55$) legs, and in the vertical jump for the right leg ($p = 0.011$; $d = -0.45$). Figures 4 and 5 show responders

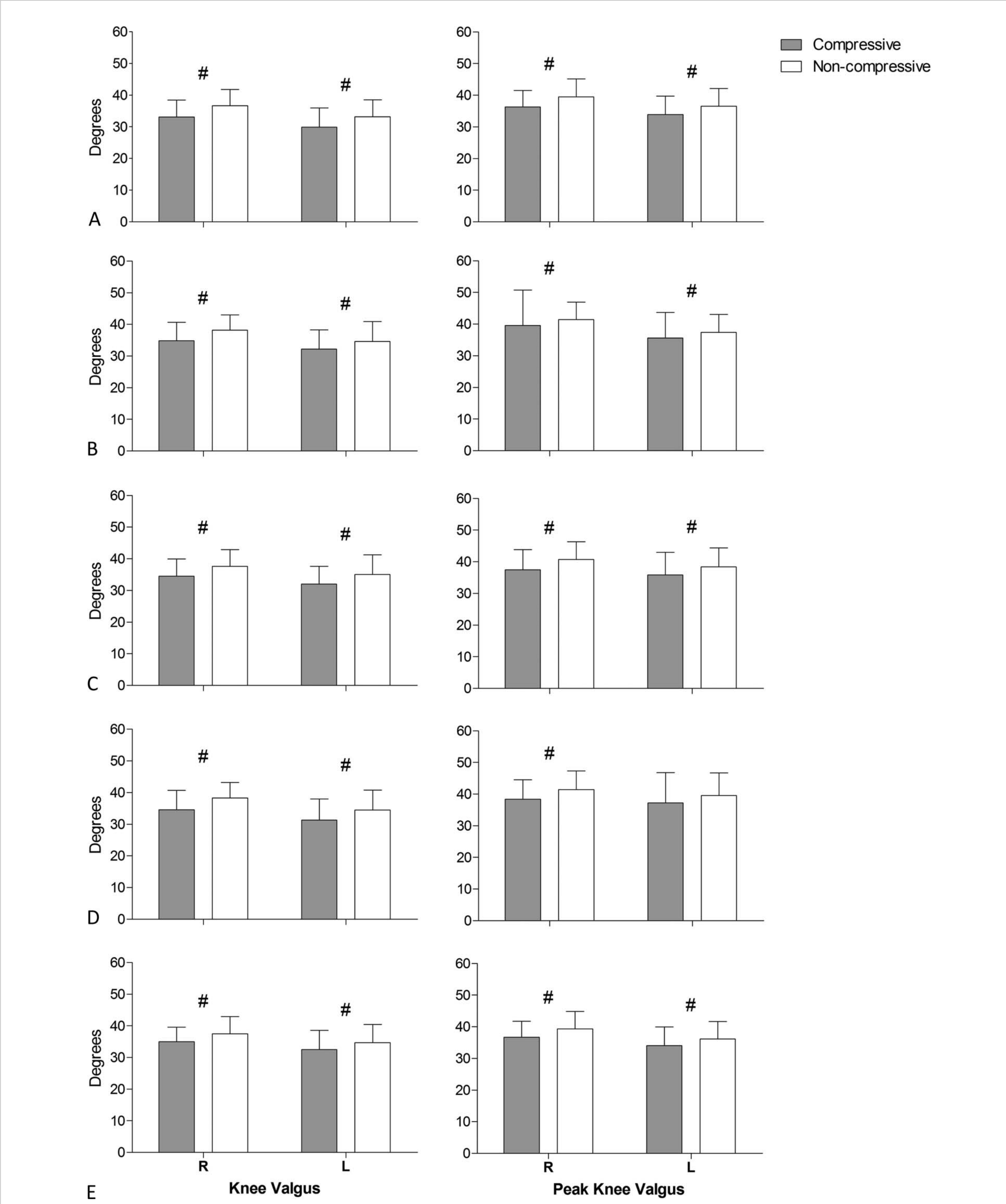

Figure 2. Knee valgus angle at initial ground contact (left columns) and peak knee valgus angle (right columns) during the landing phase in the 5 jump-landing tasks: forward jump (A), forward jump with countermovement (B), 20-cm drop jump (C), 40-cm drop jump (D), and vertical jump (E). Data are presented as mean (bars) and SD (vertical lines) for the right (R) and left (L) legs. #Significant difference between the compressive and noncompressive shorts.

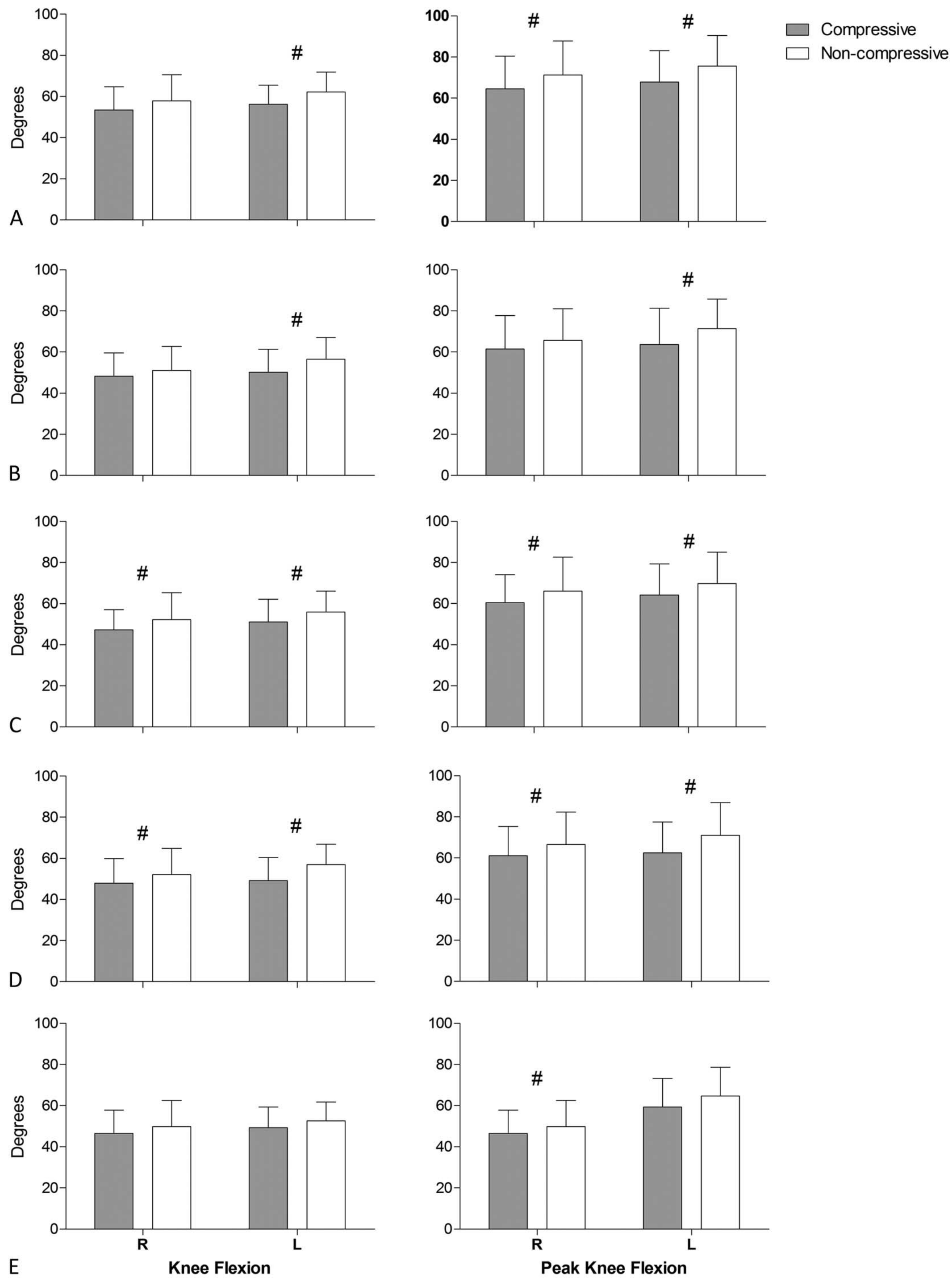

Figure 3. Knee flexion angle at initial ground contact and peak knee flexion angle, for the 5 jump-landing tasks: forward jump (A), forward jump with countermovement (B), 20-cm drop jump (C), 40-cm drop jump (D), and vertical jump (E). Data are presented as mean (bars) and SD (vertical lines) for the right (R) and left (L) legs. #Significant difference between the compressive and noncompressive shorts.

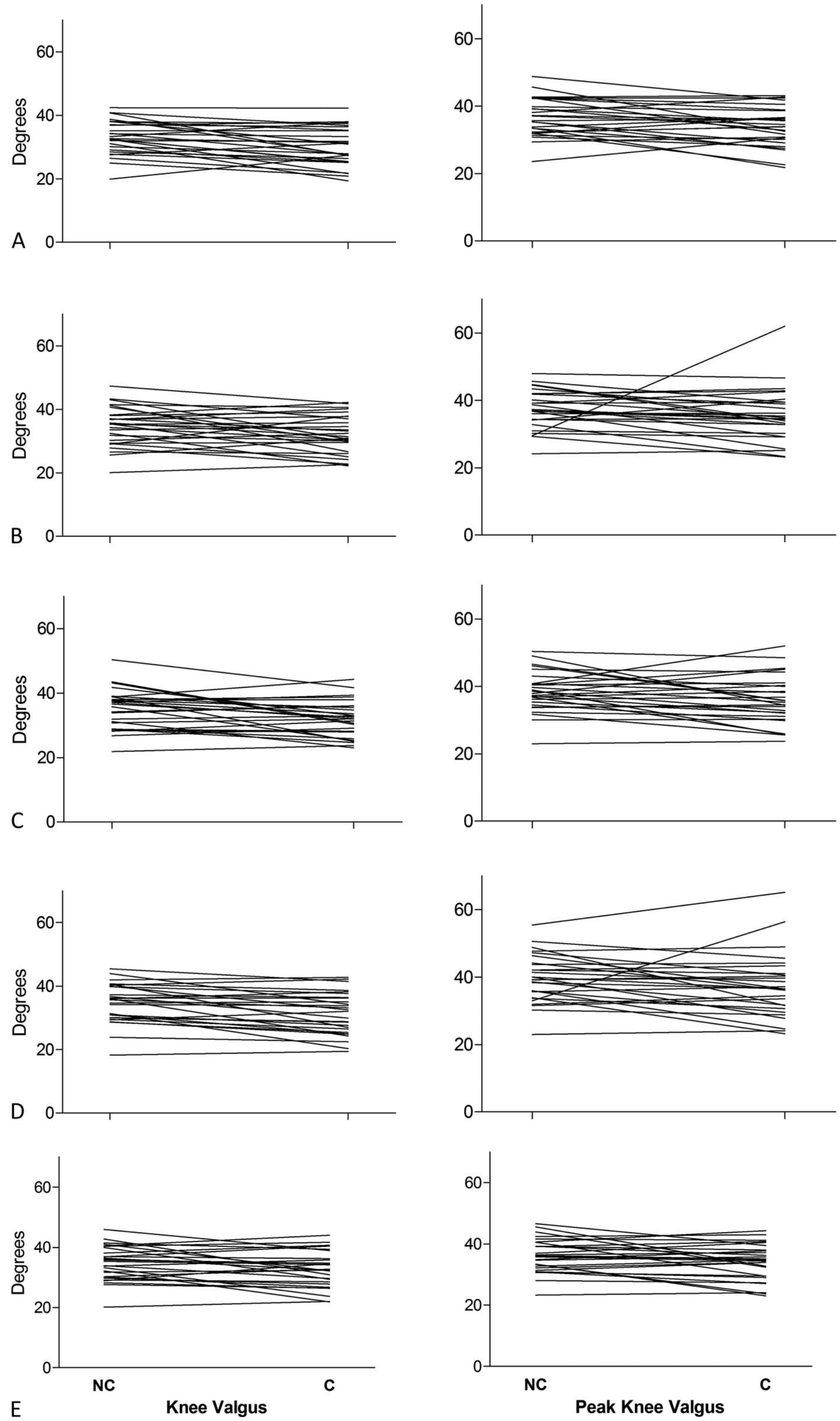

Figure 4. Responders and nonresponders in the noncompression (NC) and compression (C) conditions of testing. Knee valgus angle at initial ground contact (left columns) and peak knee valgus angle (right columns) during the landing phase in the 5 jump-landing tasks: forward jump (A), forward jump with countermovement (B), 20-cm drop jump (C), 40-cm drop jump (D), and vertical jump (E).

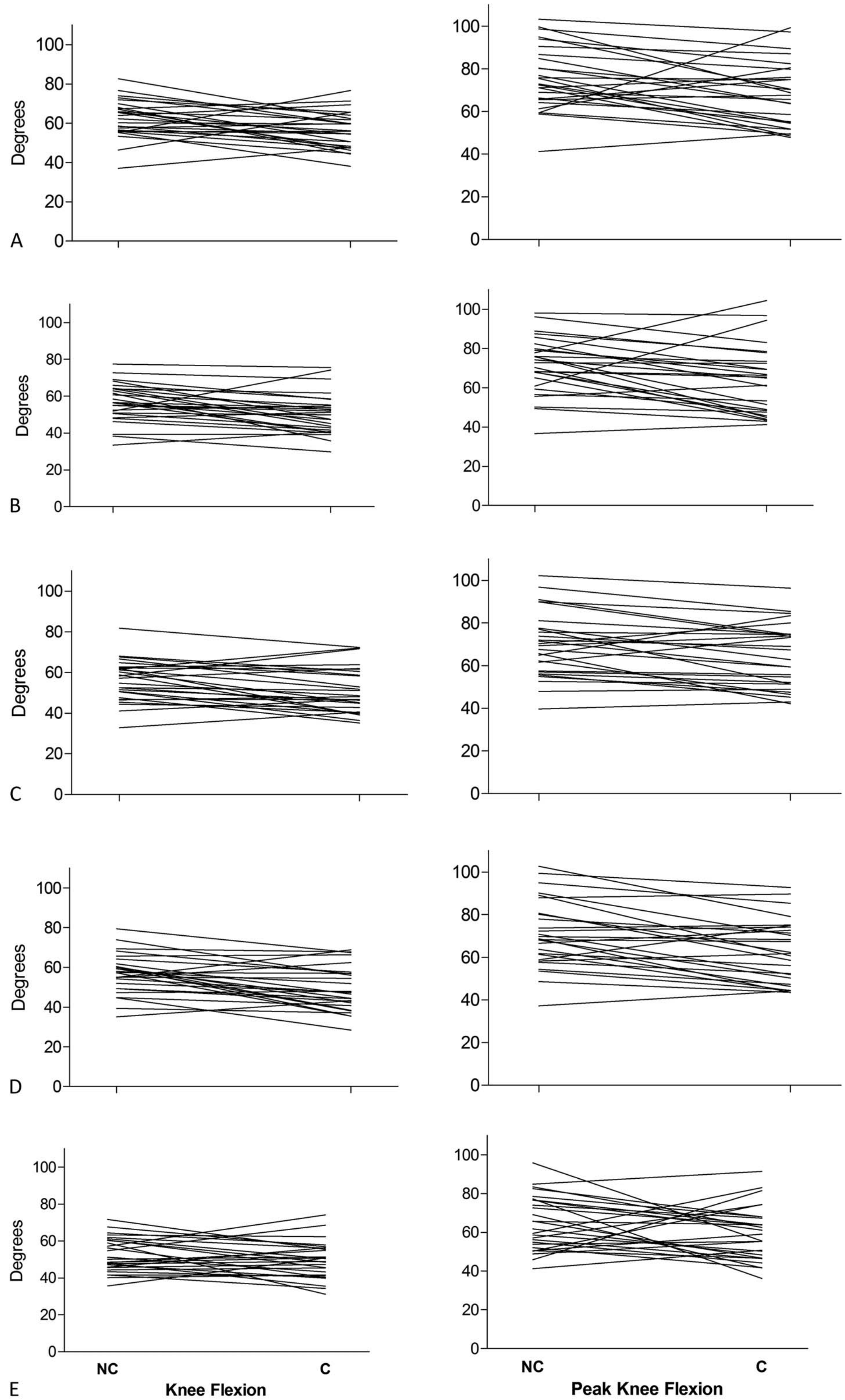

Figure 5. Responders and nonresponders in the noncompression (NC) and compression (C) conditions of testing. Knee flexion angle at initial ground contact (left columns) and peak knee valgus angle (right columns) during the landing phase in the 5 jump-landing tasks: forward jump (A), forward jump with countermovement (B), 20-cm drop jump (C), 40-cm drop jump (D), and vertical jump (E).

and nonresponders detailed in spaghetti graphs for knee valgus (Figure 4) and knee flexion (Figure 5) data.

Discussion

The goal of this study was to determine whether wearing a compressive garment would influence kinematic variables during jump-landing tasks in physically active women. We hypothesized that the compressive short would decrease range of motion at the knee joint. Our results showed that the compressive shorts decreased knee joint angles, which supports our hypothesis that the compressive garment can influence jump-landing kinematics. The novelty and an important aspect of this study are the findings for the frontal plane kinematics.

Compression-induced changes in tissue blood flow and perfusion seem to result in improved oxygenation during short-term exercise (7). This may explain the effects of wearing compressive garments on exercise recovery and performance sustenance during repeated bouts of exercise. However, it may not explain acute effects such as the changes in knee kinematics observed in our study. In upper limbs, researchers showed that a compressive garment improved the joint position sense of participants after a series of exercises (18). Furthermore, the compressive garment may provide resistance to joint angular motion, decreasing knee joint movements due to an increased joint stiffness as previously suggested (21). In addition, other studies with compressive garments found decreased muscle oscillation during dynamic tasks (9,15), which could influence force production allowing a better control of joint position.

Maximum jump height was not influenced by the compression apparel in any of the 5 tasks examined in our study. In a previous study, in which participants of both sexes performed a similar vertical jump, there was an increase in maximum jump height with the use of compressive shorts (9). A review by MacRae et al. (15) found mixed results considering performance improvement in jump-landing tasks due to compression. No previous study addressed this question exclusively in women as was done in this study, and this perhaps may influence the comparison with previous research that reported an increase in jump height among men. In the context of our research, the lack of difference in jump height strengthens the practical implications of our findings as differences in jump height could influence lower-extremity kinematics (1), which could limit our comparisons between the apparel conditions.

Compression was related to smaller knee valgus angles at initial ground contact and peak knee valgus angles during landing, for both legs except the left leg in the 40-cm drop jump. This effect on knee valgus has important practical implications, because valgus is considered a major predictor of anterior cruciate ligament (ACL) injury during landing (12).

Knee flexion angle at initial ground contact was smaller when wearing the compressive shorts, except for the vertical jump. In most cases, both legs presented similar results. Compressive shorts led to smaller peak knee flexion angles when compared with the noncompressive short. In a previous study, participants performed a 40-cm drop jump and the peak knee flexion angle after initial ground contact was approximately 93° (17). When drop jumps were performed from 60 cm, female participants showed peak knee flexion of approximately 98° (8). Our results showed a peak knee flexion after initial ground contact of 64 to 75°. However, in the study by Pappas et al. (17) and Decker et al. (8), participants did not perform the countermovement phase. In other words, they only dropped from the box. In our study, the participants jumped again immediately after the first landing (dropping from the box), and this could be a factor for decreased peak knee flexion in this study. Perhaps stepping down from the box would increase knee flexion angles because the initial height is probably greater when compared with a second jump (countermovement).

Knee flexion angle is an important factor to analyze during landing, because it is related to injury risk. Women tend to land with a straighter leg, with more quadriceps than hamstrings contraction putting the ACL at greater risk (12). Female soccer athletes showing a low knee flexion angle during landing also showed greater peak knee valgus, and greater knee adductor moment (19). In other words, landing characteristics considered of greater risk for the ACL may be influenced by the use of compression.

In our study, the compressive shorts decreased knee flexion angles during landing, which may not be ideal for avoiding some injury risk factors. Compressive shorts might provide little advantage for women who already present small knee flexion values, but can be used by other athletes with the tendency to exaggerate knee flexion during landings. The decrease in knee flexion angle during landing could be interesting for people who tend to flex their knees excessively, perhaps better controlling the movement, without forgoing the dissipation of impact forces. These inferences need further research.

Our data also suggest that the differences between the garment conditions occurred more often in the left leg than the right leg, with smaller values in the left leg. This is an interesting finding because the majority of the participants had preference for the right leg. Additionally, ACL injury is more common to occur unilaterally (5), and it has been shown that the first leg to touch the ground during landing is the preferred leg (10). Future investigations may want to consider comparisons between the legs, asymmetries, and the use of compressive garments.

The mechanism by which the compressive garment led to decreased range of motion remains uncertain. The pressure over the skin by the compressive shorts can affect the mechanoreceptors in this area, providing more afferent information for the nervous system and facilitating the movement response, because slow adapting mechanoreceptors can be influenced by skin pressure and provide more sensory information (22). However, previous studies showed that compression effects are not associated with the magnitude of pressure applied (3), which may depend on the fact that the pressure applied by sports compression garments is significantly affected by garment type, size, and posture assumed by the wearer (6). Finally, it is also important to remember that this study investigated the effect of the compressive shorts acutely; it does not provide information about the persistence of this effect and the long-term consequence for sports performance, which will certainly require further investigations.

Conclusion

Compressive shorts led to smaller knee flexion and valgus angles in jump-landing tasks. Future intervention studies should determine the long-term effects of this influence on performance and injury prevention.

Practical Applications

- Compressive shorts led to smaller knee flexion and valgus angles in jump-landing tasks.
- Smaller valgus angles during jump-landing using compressive apparel may reduce risk for knee injury.
- Effects of compression were very consistent across different jump-landing tasks in women.
- Using compressive shorts may have potential to reduce risk factors for ACL injury.

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