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ORIGINAL RESEARCH

A 5° medial wedge reduces frontal but not saggital plane motion during jump landing in highly trained women athletes

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Abstract: Lower extremity mechanics during landing have been linked to traumatic and nontraumatic knee injuries, particularly in women's athletics. The effects of efforts to mitigate these risks have not been fully elucidated. We previously reported that a 5° medial wedge reduced ankle eversion and knee valgus. In the present report we further investigated the effect of a 5° medial wedge inserted in the shoes of female athletes on frontal plane hip motion, as well as ankle, knee, hip, and trunk saggital plane motion during a jump landing task. Kinematic data were obtained from 10 intercollegiate female athletes during jump landings from a 31 cm platform with and without a 5° medial wedge. Hip adduction was reduced 1.98° (95% CI 0.97–2.99°) by the medial wedge but saggital plane motions were unaffected. A 5° medial wedge reduces frontal plane motion and takes the knee away from a position associated with anterior cruciate ligament injury and patellofemoral pain syndrome. Although frontal plane motion was not captured it is unlikely to have increased in a bilateral landing task. Thus, it is likely that greater muscle forces were generated in these highly trained athletes to dissipate ground reaction forces when a medial wedge was in place. Additional investigation in younger and lesser trained athletes is warranted to assess the impact of orthotic devices on knee joint mechanics.

Keywords: jump landing, foot orthotic, lower extremity kinematics, knee biomechanics, knee injury

Introduction

Deceleration during landing, cutting, and jumping may take the knee into a position of vulnerability for anterior cruciate ligament injury, especially in women athletes.[1,2] Thus, landing mechanics have been an experimental and theoretical focus for potential mechanisms of knee injury in women athletes.[3–7] Knee injuries also appear to be linked to limitations in neuromuscular control over the lower extremity and fatigue.[8,9] The effect of training paradigms, shoes, and foot orthoses in the prevention of lower kinetic chain motions that ultimately place the knee in a vulnerable position continue to be investigated.[4,10–12] More specifically, knee injuries in women athletes have been linked to the extent of knee valgus during landing tasks and anterior cruciate ligament (ACL) injury.[13] Joseph et al[14] reported that a 5° medial wedge decreased ankle eversion and knee valgus during jump landing from a 31 cm height in a sample of Division 1 women athletes. Of additional concern is control over closed kinetic chain hip adduction and internal rotation as greater hip adduction and internal rotation may force the knee into vulnerable positions for ligament injury and challenge control of patella tracking.[3,10,15,16]

If less motion is permitted during landing in one joint or one plane, additional motion may occur in other planes or other joints. Alternatively, it may be possible to dissipate

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greater force through muscle contraction during landing tasks. The primary purposes of this investigation were: 1) to study the hip adduction, knee flexion, ankle dorsiflexion, and trunk flexion during landing using kinematic data and 2) to examine the impact of a 5° medial wedge on lower extremity alignment during jump landing.

Material and methods

Experimental design

We used a single motion capture, laboratory-based assessment in order to characterize our subject's landing mechanics, which included the influence of a 5° medial wedge in the shoe. A three jump "blocked", balanced, and randomized treatment presentation of the two conditions was utilized. Again, it was our purpose to examine the kinematics of jump landing in highly trained competitive women athletes participating in jump-related sports. This required the recruitment and consent members of our National Collegiate Athletic Association (NCAA) Division I sports teams. We utilized high speed video analysis in order to capture kinematic data including hip adduction, knee flexion, ankle dorsiflexion, and trunk flexion during landing with and without a 5° medial wedge inserted in the subject's shoes.

Subjects

Ten NCAA Division I female athletes (basketball n = 6, volleyball n = 3, soccer n = 1; mean age 19.5 y, height 177.19 cm, mass 72.32 kg) volunteered to participate in the study. After having the risks and benefits of the study explained, each provided written informed consent to participate in the investigation. The study was approved by the Institutional Review Board for the Protection of Human Subjects at the University of Connecticut. Participants were tested during their off-season and were free of lower extremity injury symptoms. None had ever injured their ACL. Furthermore, each athlete was involved with their own sport-specific strength and conditioning programs, which included a multi-joint (eg, multiple set bench press, power cleans, pulls, squats, plyometrics) and periodized resistance training program.[17] Thus, we considered each athlete to be highly trained and fit for their respective sports, providing an important context for the results of this investigation.[18,19]

Experimental procedures

Each subject was thoroughly familiarized with the study procedures and was allowed to practice in order to eliminate any learning effects related to the experimental conditions. Each subject's height and body mass were measured during the familiarization process. Testing was performed when these athletes were well rested and between training days during an active rest phase in their periodized training program. During the familiarization phase of the investigation each subject was then fitted with a five-degree full length medial post (AliMed vinyl wedge, AliMed, Dedham MA, USA) placed inside their shoe. Subjects were asked to practice with the wedge in place to assure comfort and so that the novelty of the intervention was not a confounding factor.

We utilized the drop-jump testing protocol as described by Hewett et al.[20] Briefly, each subject was positioned on a 31 cm box with their feet 35 cm apart and was asked to drop off of the box, land onto two force platforms and then perform a maximal vertical jump. Important to this study design, the data from the force platforms were used to identify only the initial contact. Each subject performed six drop-jumps, three with medial posting and three without medial posting. The three trials of each condition were "blocked" together, but the order in which the drop-jump blocks were performed was balanced and randomized. Using the same procedures the reliability of kinematic data obtained through this drop-jump protocol has been reported to be good to excellent.[21]

Kinematics data acquisition

Kinematic data were collected with a Qualisys, seven-camera, 3D motion analysis system (Qualisys, Inc., Gothenburg, Sweden) at a sampling frequency of 240 Hz. The cameras were interfaced to a microcomputer (Dell Computer Corp, Los Angeles, CA, USA) and placed around two force platforms (Advanced Mechanical Technologies, Inc., Newton, MA, USA).

Ankle, knee, hip, and trunk kinematics were recorded for each trial by securing 36 retro-reflective markers to anatomical landmarks.[22] A stationary calibration trial was recorded to align the participant with the global coordinate system in order to account for individual variability of anatomic alignment. Markers on the iliac spine, greater trochanters, medial and lateral ankle, and knee were removed for the movement trials. Marker coordinates were filtered with a low-pass Butterworth digital filter with a cut-off frequency of 8 Hz and transformed into global coordinates for knee abduction/adduction and ankle inversion/eversion. Maximum and contact kinematic values were recorded for hip adduction, trunk flexion as well as knee flexion, hip flexion, and ankle dorsiflexion. Knee valgus and ankle eversion data have been previously reported. Visual 3D (C-Motion, Inc, Rockville, MD, USA) was used to compute knee and ankle angles.

Statistical analyses

Means and standard deviation values were calculated for each of the independent variables. An analysis of variance with repeated measures was used to analyze each dependent variable to identify differences between landing with and without the 5° medial wedge in place. The data were tested for linear assumptions, corrected if an assumption was not met, and reanalyzed. Statistical power in this study ranged from 0.81 to 0.91 for the various variables (nQuery Advisor, Statistical Solutions, Saugus, MA). The criterion for significance in this investigation was set at $P \leq 0.05$.

Results

As noted in Table 1 and Table 2, the placement of the medial wedge significantly reduced the point of maximum hip adduction (mean difference 1.98° [95% confidence interval [CI]: 0.97–2.99°]). Additionally, there was a reduction in the total adduction movement (mean difference 2.75° [95% CI: 1.77–3.72°]) during jump landing. We observed nonsignificant differences in total dorsiflexion range of motion (mean difference 0.14° [95% CI: –1.41–1.70°]), knee flexion (mean difference 1.01° [95% CI: –1.54–3.56°]), hip flexion (mean difference 1.34° [95% CI: –0.64–3.31°]), or trunk flexion (mean difference 0.06° [95% CI: –1.97–2.09°]). We also found, nonsignificant differences in the point of maximum ankle dorsiflexion (18.6° with, and 17.7° without medial wedge), knee flexion (87.1° with, and 87.3° without medial wedge) hip flexion (70.07° with, 71.16° without medial wedge), or trunk flexion (14.85° with, 13.80° without medial wedge).

Discussion

The primary finding in this investigation was that the introduction of a 5° medial wedge consistently reduces hip adduction during a jump landing task. Adduction range of motion excursion was 2.75° less while wearing the medial wedge. While wearing the medial wedge the hip was maintained in a greater amount of abduction throughout the landing motion. The reduction in hip adduction, and the previously reported reduction in knee valgus and ankle eversion,[14] was not matched by changes in saggital plane motion at the ankle, knee, hip, or trunk in this analysis. Upon reflection of our findings, it is not surprising that the addition of the medial wedge reduced hip adduction since hip adduction is known to influence the total amount of knee valgus that is experienced under landing conditions.[11,20]

We think the more interesting finding from this investigation is that the constraint of frontal plane motion induced by the introduction of the wedge was not accompanied by an increase in motion in the saggital plane at the ankle, knee, hip, or trunk. Reduced saggital plane motion however, has been shown to increase knee valgus in jump landing.[23] There are two potential explanations as to how ground reaction forces are dissipated when a 5° medial wedge medial wedge is introduced.

First, reduction of motion in the frontal or saggital motion may increase motion in the transverse plane. Our study opens the experimental opportunity to further examine the transverse plane of motion at the ankle or knee and hip. However, we suggest that increased motion in the transverse plane is unlikely to account for motion restraint in the frontal and saggital planes during a closed kinetic chain landing task. Under these conditions increased tibial and femoral rotation would be accompanied by increased genu valgum and femoral adduction respectively.[16,20] Since we observed reduced knee valgus and hip adduction, the only plausible explanation remaining is that the introduction of the 5° medial wedge resulted in greater ground reaction force dissipation through eccentric muscle actions. However, further studies will have to verify this hypothesis as our experimental set-up did not allow collection of such data.

Table 1 Maximum range of motion (mean ± standard deviation in degrees) through the joints of the lower extremity and trunk from landing of 31 cm depth jump through squat jump for women athletes (N = 10), while wearing 5° medial wedge orthotic and without wearing 5° medial wedge orthotic

Joint of analysis	Motion of interest	With 5° medial wedge	Without 5° medial wedge	Average difference
Hip	Flexion	70.1 ± 17.8	71.2 ± 16.5	–1.1
	Adduction[a]	–3.7 ± 5.2*	–1.7 ± 5.3	–2.0*
Knee	Flexion	87.1 ± 11.1	87.3 ± 9.7	–0.2
Ankle	Dorsiflexion	29.3 ± 4.4	30.1 ± 4.5	–0.8
Trunk	Flexion	16.7 ± 6.3	16.7 ± 6.4	<0.1

Notes: *Indicates statistically significant differences in joint motion within the group of athletes wearing 5° medial wedge orthotic versus when not wearing 5° medial wedge orthotic, $P \leq 0.05$; [a]adduction is given in values where a negative value indicates an abducted posture at the hip.

Table 2 Total excursion (mean ± standard deviation in degrees) through the joints of the lower extremity and trunk from the landing of 31 cm depth jump through squat jump for female athletes (N = 10), while wearing 5° medial wedge orthotic and without wearing 5° medial wedge orthotic

Joint of analysis	Motion of interest	With 5° medial wedge	Without 5° medial wedge	Average difference
Hip	Flexion	39.1 ± 15.1	40.4 ± 13.7	−1.3
	Adduction[a]	3.1 ± 2.1*	5.9 ± 2.1	−2.8*
Knee	Flexion	62.2 ± 10.1	63.2 ± 9.9	−1.0
Ankle	Dorsiflexion	47.9 ± 5.6	47.8 ± 6.2	0.1
Trunk	Flexion	14.9 ± 8.4	13.8 ± 7.1	1.1

Notes: *Indicates statistically significant differences in joint motion within the group of women athletes wearing 5° medial wedge orthotic versus when not wearing 5° medial wedge orthotic, $P \leq 0.05$; [a]adduction is given in values where a negative value indicates an abducted posture at the hip.

An additional consideration is that the subjects in this investigation were highly trained collegiate athletes, capable of generating larger forces in the muscles crossing the hip, knee, and ankle. Interestingly, it has been shown that thigh strength and activation do not predict hip and knee joint excursions. Greater activation does, however, predict larger anterior tibial shear forces, but this effect is relatively small in response to jump landing.[24] It may not have been just strength per se, but more a function of the training status and the strength training protocols of these athletes that permitted the observed adaptations when the 5° medial wedge was in place. Our findings, therefore, must be placed into context.[25] The athletes we studied were all involved in strength and conditioning programs where recent strategies for ACL injury prevention were incorporated.[6,11] One might call into question the ability to generalize the response to a 5° medial wedge across all populations where hip adduction and genu valgum during landing poses a threat of ACL injury or stresses to the patellofemoral joint. Further investigation of younger and lesser trained athletes is warranted to assess the potential to generalize these findings.

One must also place these results into the context of the research setting. The 5° medial wedge was chosen because it could be conveniently placed in the athletes' shoes to study lower extremity kinematics. While none of the subjects reported any discomfort with the medial wedge in place, they did not experience the medial wedge during athletic activities. It is however, possible to post an orthotic that is fit to the individual for the purpose of controlling motion during sport activities. Callahan et al[26] reported in a study of 14 athletes with lower extremity injuries, that all continued to use the devices after 4 months of intervention. All involved some degree of medial posting. Thus, while the 5° medial wedge used in this study might not be suited for wear during practice and competition it is possible to post with orthotic devices that are well tolerated during sport activities. The extent of posting required to alter lower extremity mechanics, the potential of posting to increase the risk of other injuries such as a lateral ankle sprain as well as the effect of posting on the incidence and management of knee conditions warrant continued investigation. Should the potential benefits of medial posting in protecting the knee be realized, implementation of posting through commercially available orthotics would be cost-effective and generally well-tolerated.

Conclusion

In conclusion, our further analysis of kinematic data first reported by Joseph et al[14] has revealed that hip adduction in a sample of Division I women athletes participating in sports involving repetitive landing and associated with a high risk of ACL injury is reduced by a 5° medial wedge. Saggital plane motions at the ankle, hip, knee, and trunk were not significantly different with or without the 5° medial wedge in place. It is unlikely that the introduction of a 5° medial wedge resulted in increased frontal plane motion, thus it is likely that greater muscle forces were generated to dissipate ground reaction force under the posted condition. It is unclear, however, if lesser-trained athletes would exhibit a similar response if they are unable to generate the additional muscle force to dissipate ground reaction force. Further investigation of this phenomenon is warranted as these data suggest that a 5° medial wedge can alter lower extremity kinematics in a manner that moves the knee away from a position associated with tear of the ACL.

Disclosures

The authors report no conflicts of interest in this work.

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