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Differences in Neuromuscular Strategies Between Landing and Cutting Tasks in Female Basketball and Soccer Athletes

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Context: High school female athletes are most likely to sustain a serious knee injury during soccer or basketball, 2 sports that often involve a rapid deceleration before a change of direction or while landing from a jump.

Objective: To determine if female high school basketball and soccer players show neuromuscular differences during landing and cutting tasks and to examine neuromuscular differences between tasks and between dominant and nondominant sides.

Design: A 3-way mixed factorial design investigating the effects of sport (basketball, soccer), task (jumping, cutting), and side (dominant, nondominant).

Setting: Laboratory.

Patients or Other Participants: Thirty high school female athletes who listed either basketball or soccer as their only sport of participation (basketball: n = 15, age = 15.1 ± 1.7 years, experience = 6.9 ± 2.2 years, height = 165.3 ± 7.9 cm, mass = 61.8 ± 9.3 kg; soccer: n = 15, age = 14.8 ± 0.8 years, experience = 8.8 ± 2.5 years, height = 161.8 ± 4.1 cm, mass = 54.6 ± 7.6 kg).

Main Outcome Measure(s): Ground reaction forces, stance time, valgus angles, and valgus moments were assessed during (1) a drop vertical jump with an immediate maximal vertical jump and (2) an immediate side-step cut at a 45° angle.

Results: Basketball athletes had greater ground reaction forces ($P < .001$) and decreased stance time ($P < .001$) during the drop vertical jump, whereas soccer players had greater ground reaction forces ($P <.001$) and decreased stance time ($P < .001$) during the cut. Subjects in both sports had greater valgus angles (initial contact and maximum, $P = .02$ and $P = .012$, respectively) during cutting than during the drop vertical jump. Greater valgus moments ($P = .006$) were noted on the dominant side during cutting.

Conclusions: Our subjects demonstrated differences in ground reaction forces and stance times during 2 movements associated with noncontact anterior cruciate ligament injuries. Knee valgus moment and angle were significantly influenced by the type of movement performed. Sport-specific neuromuscular training may be warranted, with basketball players focusing on jumping and landing and soccer players focusing on unanticipated cutting maneuvers.

Key Words: valgus knee angle, anterior cruciate ligament injury, ground reaction force, knee moment

The sports in which young athletes injure themselves most frequently are soccer (21%) and basketball (20%).[1] The majority of serious knee injuries in high school female athletes also occur during soccer and basketball.[2] Female athletes are 4 to 6 times more likely to sustain a noncontact anterior cruciate ligament (ACL) injury than males participating in the same sport.[3–5] Olsen et al[6] described the typical noncontact ACL injury mechanism as a combination of knee valgus, near full extension, and external rotation of the tibia with the foot firmly planted on the ground. The tasks associated with this mechanism often involve a rapid deceleration before a change of direction or while landing from a jump.[6–8] Both soccer and basketball require that the athlete perform these high-risk maneuvers during sport participation.

The proportion of ACL injuries that occur during cutting or landing varies among sports.[5,9] During basketball, female high school athletes injure their ACL more often while jumping or landing (60%) than athletes participating in soccer (25%).[9] The most frequent ACL injury mechanism in soccer appears to occur during a cutting maneuver rather than during landing.[5,9] This variation in potential injury mechanisms may be due to the nature of the specific sport or to an inherent neuromuscular strategy of the athlete. Neuromuscular strategies may develop through sport specificity and become evident when athletes perform these 2 distinct movement patterns.

Neuromuscular control relates to the activation of the dynamic restraints surrounding a joint in response to sensory stimuli.[10,11] Neuromuscular mechanisms may prove to play the largest role in the sex differences found in ACL injuries.[11] For example, injury prevention programs focusing on neuromuscular control of the lower extremity reduce noncontact ACL injuries in female athletes.[5,12] Individual sports may demonstrate unique ACL injury risk factors, depending on the type of maneuver performed. If differences in ACL injury risk factors are found, sport-specific injury prevention programs should be developed to target the neuromuscular strategies during cutting and landing.

Valgus moments (torques) at the knee have been reported to be significant predictors of peak ground reaction force (GRF).[13] Measures of dynamic valgus (valgus knee angles and moments) during a drop vertical jump predict noncontact ACL injury risk in female athletes with high sensitivity and specificity.[14] Hewett et al[14] also demonstrated that differences between lower extremities in those valgus knee angles and moments were key predictors of ACL injury risk. Computer simulation modeling reveals that lower extremity valgus moments at the knee are high enough to rupture the ACL, whereas knee extension moments and anterior shear forces alone are not sufficient to rupture the ligament.[15,16] Therefore, the GRF, knee valgus moments, and knee valgus angles appear to play an important role in identification of ACL injury risk in female athletes and should be investigated during dynamic movements.

Our purpose was to compare the lower extremity biomechanics of jumping and cutting in female basketball and soccer players. The general hypothesis was that female basketball and soccer players would demonstrate different neuromuscular control strategies when performing jumping and cutting tasks. The first specific hypothesis was that basketball players would have greater valgus knee moments, valgus knee angles, and vertical GRF than soccer players during a drop vertical jump (DVJ). Conversely, the second specific hypothesis was that soccer players would have increased valgus knee moments, valgus knee angles, and vertical GRF during the unanticipated cutting task. The third hypothesis was that side-to-side differences in knee valgus moments, knee valgus angles, and vertical GRF would exist in the groups of female athletes.

METHODS

Design

We used a 3-way mixed factorial (analysis of variance) design to determine the effects of 2 common athletic movement patterns in a group of female basketball and soccer players. The independent variables were the sport (2 levels: basketball and soccer), task (2 levels: jumping and cutting), and side (2 levels: dominant and nondominant). The dominant leg was defined as the leg used to kick a ball for distance. The within-subjects (repeated) factors (task and side) were randomized among subjects. The between-subjects factor was sport. The dependent variables were maximum GRF (body weight), stance time (ms), maximum valgus knee moment (Nm/[body weight·height]), valgus knee angle at initial contact (°), and maximum valgus knee angle (°).

Subjects

Thirty high school female athletes participated in this study (basketball: n = 15, age = 15.1 ± 1.7 years, experience = 6.9 ± 2.2 years, height = 165.3 ± 7.9 cm, mass = 61.8 ± 9.3 kg; soccer: n = 15, age = 14.8 ± 0.8 years, experience = 8.8 ± 2.5 years, height = 161.8 ± 4.1 cm, mass = 54.6 ± 7.6 kg). There was no difference in age between the groups ($P = .523$); however, the soccer athletes had significantly more years of experience ($P = .048$). Subjects were included within the study if they listed basketball or soccer as their only current sport of participation. Sport participation was operationally defined from a questionnaire that listed current sport participation at the high school level, as well as years of participation in that sport. Subjects were excluded if they participated in both soccer and basketball or if they listed another sport, such as cross-country or softball. Informed written consent, approved by the institutional review board, which also approved the study, was obtained from the parent or parental guardian of each subject.

Instrumentation

Thirty-six retroreflective markers were placed on the sacrum, sternum, bilateral shoulders, lateral elbow, radial styloid process, anterior superior iliac spine, greater trochanter, mid thigh, medial and lateral knee, tibial tuberosity, mid shank, distal shank, medial and lateral ankle, heel, fifth metatarsal, instep, and toe (between second and third metatarsals) of each athlete.[17] We recorded movement using a motion analysis system consisting of 8 digital cameras (Eagle cameras; Motion Analysis Corp, Santa Rosa, CA) positioned in the laboratory that defined an optimized capture volume of 4.5 × 2 × 2.5 m and sampling at 240 Hz. Before data collection, the motion analysis system was calibrated with a 2-step process, first using a static calibration frame to orient the cameras with respect to the laboratory coordinate system and, second, using dynamic wand data to fine-tune camera positions and calculate the lens distortion maps and the lens focal length. Two force platforms (AMTI, Watertown, MA) were sampled at 1200 Hz, and time was synchronized with the motion analysis system so that every fifth force data sample occurred at a single corresponding video sample. Data were collected with EvaRT (version 4; Motion Analysis Corp) and imported into KinTrak (version 6.2; Motion Analysis Corp) for data reduction and analysis.

Procedures

Before data collection, each subject performed a series of submaximal vertical jumps and cuts in order to warm up. The subject was instructed to stand still, and a static trial was collected to align the joint coordinate system to the laboratory before data were collected. Medial markers were removed before subjects completed the tasks. The subject was shown each maneuver and allowed to practice each task as many times as necessary in order to perform the task as instructed, typically 2 or 3 times. The first task was a DVJ off a 31-cm box onto 2 force plates with an immediate maximal vertical jump.[18] We chose the DVJ in order to examine a landing that might be related to similar movements in both soccer and basketball. The DVJ consisted of the subject's starting on top of a box with the feet positioned 35 cm apart (distance measured between toe markers). She was instructed to drop directly down off the box and immediately perform a maximum vertical jump, raising both arms as if jumping for a basketball rebound. The 2 force platforms were embedded into the floor and positioned 8 cm apart so that each foot contacted a different platform. The first landing on the platforms (ie, the drop from the box) was used for analysis. Three successful trials were recorded for each subject.

The second task was the cut, in which the athlete performed an immediate jump forward with both feet, landed on both feet, and followed with a side-step cut at an approximately 45° angle.[19] Each subject was shown by demonstration the unanticipated cut (left or right) and allowed to practice first without observing the visual unanticipated direction cue. We selected this maneuver in order to examine a common athletic and potentially high ACL injury risk movement that occurs in basketball and soccer.[7] Each subject was positioned on the ground in an athletic "ready" position to react to a randomized, unanticipated direction cue (left or right). A custom computer program simulated a stoplight on a monitor (red, yellow, and then green) and was used to cue the subject when to initiate the forward jump (0.4 m); immediately after this cue, the subject jumped off both feet and landed on both feet before the cut. After the green ("go") light (0.3 seconds), an arrow directing the subject which way to cut was displayed on the same computer monitor. The subject was instructed to perform a side-step cut at a 45° angle and run past a marker 2.5 m away. For example, when cutting to the right, the subject pushed off with her left limb and led with her right. Trials were excluded if the subject performed a crossover cut or if the entire foot did not land on the force plate. The direction of the arrow was randomized over 6 trials (3 in each direction). The 2 force platforms were positioned as stated previously, so that each foot would contact a different platform. Three trials were collected for each cut direction.

Data Analysis

We estimated the 3-dimensional Cartesian marker trajectories from each trial using the direct linear transformation method and filtered through a low-pass, 2nd-order Butterworth digital filter at a cutoff frequency of 15 Hz.[20] Knee joint valgus angles for the dominant and nondominant legs were calculated from an embedded joint coordinate system.[21] Valgus knee angle was reported with 0° representing the subject's static standing position. Positive numbers represented varus orientation, and negative numbers represented valgus orientation (abduction: distal tibia moving away from midline). Initial contact with the ground and at toe-off was determined using vertical GRF. The initial contact was operationally defined as the time when vertical GRF exceeded 10 N, with toe-off defined as the time when vertical GRF dropped below 10 N. Stance time was calculated as the time between initial contact and toe-off. Valgus knee angle was recorded at initial contact, and maximum angle was recorded during stance. Knee valgus moments were calculated from the motion and force data using inverse dynamics and filtered through a low-pass Butterworth digital filter at the same cutoff frequency of 15 Hz to minimize possible impact peak errors.[20,22,23] Net external moments represent the external load on the joint. Maximum knee valgus moments during the stance phase were calculated during the maneuver and normalized to body weight (N) times height (m). Maximum vertical GRF was also calculated during the stance phase and normalized to body weight (N).

Statistical Analysis

We calculated statistical means and standard deviations from 3 trials for each variable for each subject. Separate mixed 2 $\times$ 2 $\times$ 2 factorial analyses of variance (2 within, 1 between factors) with repeated measures on task and side were performed to assess the interaction of sport, task, and side and their main effects on GRF, stance time, maximum knee valgus moment, knee valgus angle at initial contact, and maximum knee valgus angle. The within-subjects (repeated) factors (task and side) were randomized among subjects. The between-subjects factor in this study was sport. Simple main effects testing (independent *t* tests) was used post hoc to locate specific group differences after a significant 2-way interaction. No significant 3-way interactions were noted. The level of significance was established at $P < .05$. Statistical analyses were conducted in SPSS for Windows (version 10.0.7; SPSS Inc, Chicago, IL).

RESULTS

Differences were observed in the way female basketball and soccer players performed the 2 maneuvers (Table). Basketball players had a greater peak vertical GRF (task $\times$ sport, $F_{1,28} = 10.2$, $P = .003$) and decreased stance time (task $\times$ sport, $F_{1,28} = 18.0$, $P < .001$) during the jump (Figure 1) than soccer players. Compared with soccer players, basketball players had 15.4% greater peak normalized vertical GRF on the dominant side and 10.5% greater force on the nondominant side during the DVJ. Conversely, soccer players demonstrated greater peak vertical GRF (task $\times$ sport, $F_{1,28} = 10.2$, $P = .003$) and decreased stance time (task $\times$ sport, $F_{1,28} = 18.0$, $P < .001$, Figure 2) during the cut. In soccer players, the GRF during cutting was approximately 15% greater than in basketball players.

Measures of knee valgus were not different between sports ($P > .05$). Knee valgus angles at initial contact ($F_{1,28} = 6.1$, $P = .02$) and maximum ($F_{1,28} = 7.1$, $P = .012$) were greater during the cutting maneuver in both sports (main effect of task) (Figure 3). Mean valgus angle was 27.7% greater at maximum during the cut than the landing.

In both groups of athletes, side-to-side differences were observed during the cut (task $\times$ side, $F_{1,28} = 8.7$, $P = .006$). Greater valgus moments occurred during cutting on the dominant side (Figure 4). The mean valgus moment was 31.8% greater on the dominant side than on the nondominant side during the cut. Side-to-side differences were also found in peak vertical GRF during both movement tasks. Similar to the side-to-side differences found in valgus knee moments, the dominant side exhibited larger GRF during the cut (task $\times$ side, $F_{1,28} = 213.2$, $P < .001$; see Table 1). The GRF mean for the cut was 41.4% greater on the dominant side than the nondominant side. Interestingly during the DVJ, the side-to-side differences were the opposite of what we found in the cut. The nondominant side had greater force than the dominant side (task $\times$ side, $F_{1,28} = 213.2$, $P < .001$). For the DVJ, the means differed by 37.7%, with the nondominant side exhibiting greater force.

DISCUSSION

Our findings support our hypothesis that basketball and soccer players would demonstrate differences in neuromuscular control patterns during landing and cutting tasks. Basketball players had greater GRF and decreased stance time during the

Ground Reaction Force, Stance Time, Valgus Moment, Valgus Angle Initial Contact, and Maximal Valgus Angle in Basketball and Soccer Players During the Drop Vertical Jump and Cutting Tasks*

	Drop Vertical Jump			Cutting		
Dependent Variable	Basketball	Soccer	Sport Total	Basketball	Soccer	Sport Total
Ground reaction force (× body weight)†‡						
Dominant	1.5 ± 0.3	1.3 ± 0.2	1.4 ± 0.3	1.9 ± 0.3	2.2 ± 0.2	2.0 ± 0.3
Nondominant	2.1 ± 0.4	1.9 ± 0.4	2.0 ± 0.4	1.3 ± 0.2	1.5 ± 0.1	1.4 ± 0.2
Side total	1.8 ± 0.5	1.6 ± 0.4		1.6 ± 0.4	1.8 ± 0.4	
Stance time (ms)†						
Dominant	347 ± 62	408 ± 70	377 ± 72	408 ± 72	333 ± 60	371 ± 75
Nondominant	347 ± 57	412 ± 72	379 ± 72	420 ± 66	328 ± 62	374 ± 79
Side total	347 ± 58	410 ± 70		414 ± 68	331 ± 60	
Valgus moment (Nm/[body weight × height])‡						
Dominant	−0.012 ± 0.019	−0.014 ± 0.011	−0.013 ± 0.015	−0.019 ± 0.009	−0.027 ± 0.009	−0.023 ± 0.009
Nondominant	−0.018 ± 0.015	−0.019 ± 0.009	−0.018 ± 0.012	−0.016 ± 0.005	−0.019 ± 0.006	−0.018 ± 0.006
Side total	−0.015 ± 0.018	−0.016 ± 0.010		−0.017 ± 0.008	−0.023 ± 0.009	
Valgus angle initial contact (°)§						
Dominant	−0.8 ± 2.6	−0.3 ± 2.9	−0.6 ± 2.7	−1.2 ± 3.3	−1.7 ± 4.5	−1.4 ± 3.9
Nondominant	−0.2 ± 2.3	−0.9 ± 3.8	−0.5 ± 3.1	−0.8 ± 2.3	−1.4 ± 5.1	−1.1 ± 3.9
Side total	−0.5 ± 2.5	−0.6 ± 3.3		−1.0 ± 2.8	−1.6 ± 4.7	
Maximal valgus angle (°)§						
Dominant	−6.5 ± 4.8	−5.5 ± 4.4	−6.0 ± 4.5	−7.4 ± 3.0	−7.2 ± 3.5	−7.3 ± 3.2
Nondominant	−6.0 ± 4.1	−5.1 ± 5.8	−5.6 ± 4.9	−7.5 ± 2.3	−7.4 ± 3.2	−7.4 ± 3.2
Side total	−6.3 ± 4.4	−5.3 ± 5.1		−7.4 ± 2.6	−7.3 ± 3.7	

*Group means and marginal means ± SD for each variable.
†Significant task × sport interaction ($P < .05$).
‡Significant task × side interaction ($P < .05$).
§Significant main effect of task ($P < .05$).

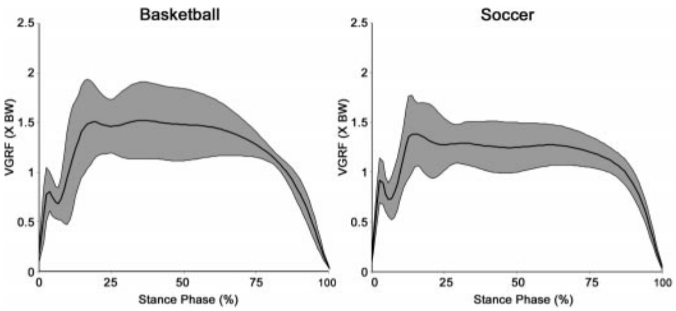

Figure 1. Ensemble average of dominant-side vertical ground reaction force (VGRF) during a drop vertical jump (mean ± SD).

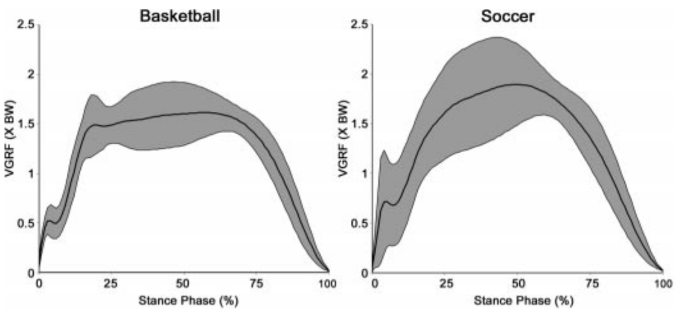

Figure 2. Ensemble average of dominant-side vertical ground reaction force (VGRF) during an unanticipated cut (mean ± SD).

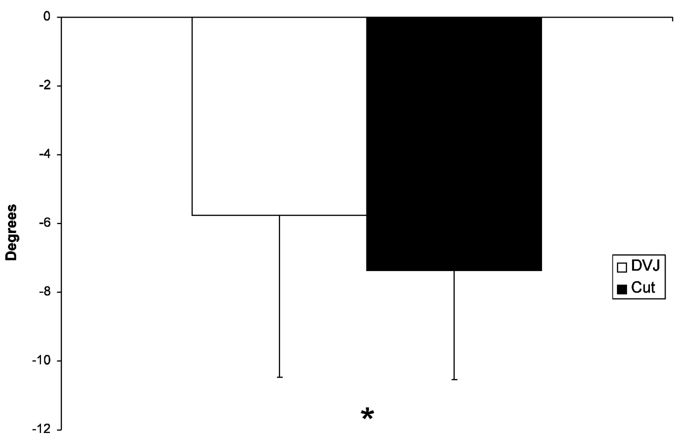

Figure 3. Comparison of the drop vertical jump (white) and cut (black) in maximum knee valgus angle (mean ± SD). Significant task effect was noted ($P < .05$), with greater valgus angle during the cut. DVJ indicates drop vertical jump.

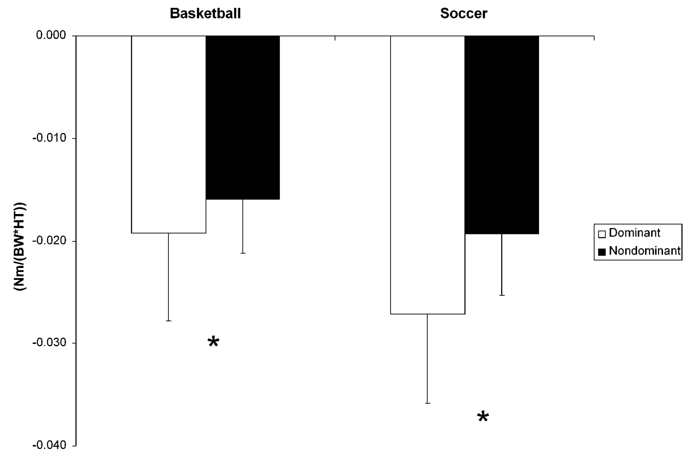

Figure 4. Dominant- and nondominant-side maximum knee valgus moment (mean ± SD) during the cut. * The dominant side was greater in both sports during the cut (significant side × task interaction, $P < .01$). BW indicates body weight; HT, height.

DVJ than did soccer players, whereas soccer players had increased GRF and decreased stance time during cutting. These higher forces over a shorter time period may allow an athlete to perform the skill more quickly but may concomitantly increase the risk for injury due to the higher forces and moments.[24] Injury rates may also be influenced by the speed at which an athlete performs a skill, given that most noncontact ACL injuries occur at high velocity.[6] Furthermore, increased force during athletic maneuvers may be related to ACL injury rates, as Hewett et al[5] identified the link between increased forces[13] and injury rates. Specifically, a decrease in peak vertical GRF during landings was found in high school female athletes after they participated in neuromuscular training.[13] The same training was conducted during the preseason and shown to reduce the rate of noncontact ACL injuries in trained versus untrained female athletes.[5] Therefore, a reduction in peak GRF appears to be an important factor in preventing injuries. We found an average increase of 15.6% in peak vertical GRF and a 20.5% decrease in stance time in soccer players during the cut compared with basketball players. In contrast, the basketball players during the landing had 12.5% greater GRF and a decrease of 14.6% in stance compared with soccer players. The differences in the way these 2 tasks were executed, specifically in stance time and GRF magnitudes, may relate to different injury mechanisms between the 2 groups of females.

The mechanisms of injury for soccer and basketball players may differ due to specific demands of each sport. Piasecki et al[9] reported that landing accounted for 60% of ACL injuries in high school basketball players, whereas landing was responsible for only about 25% of ACL injuries in soccer. Hewett et al[5] recorded injuries for a single season in high school basketball, soccer, and volleyball athletes. The noncontact ACL injuries observed in soccer players involved cutting and twisting, whereas basketball injuries involved either a landing or a cutting and twisting mechanism.[5] Similarly, Powell and Barber-Foss[25] found that a jumping and landing task associated with rebounding the ball was the most often cited maneuver associated with ACL injuries to female basketball players. Although an ACL injury may result from multiple factors, our results suggest that differences in force and stance time during cutting and landing may account for differences in injury mechanisms between these sports.

We hypothesized that differences would exist in knee valgus between sports. However, valgus moments and angles of similar magnitudes were found in soccer and basketball players. Both groups demonstrated increased knee valgus moments and angles during the cut versus the DVJ. Increased knee valgus angles or torques have been previously considered a risk factor for ACL injuries.[14,17,18,26,27] The ACL loading, deformation, and subsequent rupture may occur more often during a cutting movement, when large valgus moments may be combined with external flexion loads.[28,29] Females exhibit greater knee valgus angles and/or moments than males in both cutting and landing maneuvers.[13,17,18,27,30] Furthermore, even small changes in valgus motion can considerably increase the valgus load on the knee. For example, McLean et al[17] reported that a difference of only 2° of knee valgus can lead to a 40 Nm change in valgus moment.[17] Individual tasks can also influence the amount of valgus load that occurs at the knee. Compared with a straightforward run, a cutting task may double the valgus load on the knee.[29]

The amount of valgus observed during a sport movement suggests an inability of the athlete's musculature to control the GRF.[18] As a result, ligaments may absorb the additional force and this overreliance on the ligaments to control motion may constitute a greater risk factor for ACL injury. The lack of coordinated muscle control of the lower extremity may lead to high forces and potentially irrevocable loads on the knee ligament.[31] Recent injury modeling work also supports the importance of coronal-plane biomechanics during sport movements. McLean et al[15] induced random neuromuscular perturbations on forward dynamic models and found valgus loads, which could injure the ACL, occurred more often in females. The increased lower extremity valgus angles and moments we found during the cut suggest that both groups of females may have difficulty controlling knee motion during the single-leg cut compared with the double-leg jump. The inability to control valgus may contribute to a cutting mechanism of ACL injury that occurs in both soccer and basketball. Even though most basketball ACL injuries occur during landing,[9] the increase in valgus and inability of the musculature to control the movement may still contribute to a portion of cutting-related injuries within basketball players.

A side-to-side difference in external valgus moment was prominent in both soccer and basketball players. In a previous investigation,[18] side-to-side differences in valgus angle were found in adolescent females versus males during a box DVJ. This may suggest a neuromuscular imbalance between contralateral lower extremities. Previous authors[13,14,26,32] have shown that side-to-side differences in strength, flexibility, and coordination may be predictors for increased injury risk. When an imbalance is present, the risk for noncontact ACL injury may be increased for both limbs. Limb asymmetry appears to differ between tasks in female athletes. During the cut, both basketball and soccer athletes had greater force on the dominant side. Conversely, the nondominant side had larger peak vertical GRF during the DVJ. This interesting finding was consistent across the majority of subjects, even when the variables were adjusted for the left-side dominant athletes. The differences between tasks in side-to-side GRF suggest that an athlete's ''preferred'' leg, which receives the majority of the GRF, may change depending on the type of movement. Asymmetries between sport movements and athletes should be further investigated. Training programs should focus on addressing side-to-side as well as other neuromuscular imbalances in female athletes.[14,33–35]

Previous researchers[13] demonstrated that females may benefit from neuromuscular training programs that are designed to decrease GRF, control lower extremity frontal-plane motion (especially knee valgus), and decrease side-to-side imbalances.[13] The GRF and side-to-side strength differences were reduced in female athletes who underwent a neuromuscular training program that included plyometrics and strength training. Prapavessis and McNair[36] showed that GRF could be decreased with instruction. However, neuromuscular control differences between basketball and soccer players during the cut and DVJ may suggest a specific mechanism of injury for different types of athletes. If the different risk variables can be identified, then training programs can become increasingly efficient and sport specific in nature. Hewett et al[14] and Myer et al[37] demonstrated that neuromuscular training can be used to decrease coronal-plane moments, which are related to future ACL injury in both basketball and soccer female athletes. However, the results of our study suggest that sport-specific neuromuscular training may be warranted. Basketball players may be better served with training that includes depth jumping focused on reducing landing forces and valgus knee collapse.[18] Soccer athletes may reduce their injury risk by training to decrease valgus loads when performing unanticipated cutting maneuvers.[19,28] A recent investigation of school-age (6–21 years) athletes identified soccer and basketball as the most common sports that resulted in injuries.[1] The authors also found that the highest occurrence of sports injuries was at the onset of and during puberty.[1] Therefore, targeted, sport-specific neuromuscular training at or near the onset of puberty may simultaneously improve lower extremity strength and power and reduce potentially dangerous landing and cutting biomechanics related to ACL injury that begin to emerge with female maturation.[14,26]

Our study has several possible limitations that need to be considered. First, there is a limit to the generalizability of this study, as we investigated only young female high school athletes. The results may not translate to collegiate or elite athletes with different experience and training backgrounds. Second, a comparison between the sexes was not performed. Male athletes may exhibit similar differences during the movements. Finally, the differences between several biomechanical variables, although statistically significant, were relatively small and may be difficult to measure clinically. We must also be aware of the possible variations found between subjects, as these are typically high in biomechanical measures. However, similar differences and variations have been noted elsewhere during landing- and jumping-type movements in female athletes.[14,17,19,37]

In conclusion, although female basketball and soccer players share certain injury risk factors, they demonstrate differences in GRF and stance time during 2 major movements associated with noncontact ACL injuries. Both groups of athletes also had differences in knee valgus moments and angles between the types of movement (landing and cutting). Sport-specific neuromuscular training may be warranted, with basketball athletes focusing on jumping and landing and soccer athletes focusing on performing unanticipated cutting maneuvers. Further research is needed to explore the possibility that the changes in performance during these tasks between sports may be related to different mechanisms of noncontact ACL injuries. Universal approaches to injury prevention programs for female athletes should include both landing and cutting technique training, with a focus on reducing valgus knee moments and motion.[14,15] However, the differences between single-sport athletes demonstrated in this study may warrant further investigation in sport-specific neuromuscular training programs for these athletes.

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