THE EFFECTS OF DYNAMIC LIMB ALIGNMENT ON KNEE MOMENTS DURING SINGLE LIMB LANDING: IMPLICATIONS FOR THE ANALYSIS OF THE NON-CONTACT INJURY TO THE ANTERIOR CRUCIATE LIGAMENT

Ajit M Chaudhari (1), Brenna K Hearn (1), Lise A Leveille (1), Emilie R Johnson (1), Thomas P Andriacchi (1,2)

(1) Biomechanical Engineering Division
Mechanical Engineering Department
Stanford University
Stanford, CA

(2) Department of Orthopaedic Surgery
Stanford University Medical Center
Stanford University
Stanford, CA

INTRODUCTION

Non-contact injuries to the anterior cruciate ligament are most frequently reported during the deceleration phase of landing after a jump or in preparation for a cutting maneuver. Video observation and patient accounts have demonstrated that the knee is most often in a position near full extension and there is typically a valgus collapse of the knee associated with landing or deceleration [1]. While many authors in the past have suggested that static limb alignment may influence ACL injury rates [e.g. 2,3], studies have shown that subjects can dynamically alter their alignment [4,5]. Therefore, the dynamic limb alignment during high-risk activities may be more relevant in predicting injury than the static alignment.

The purpose of this study was to observe the effects of dynamic limb alignment on moments sustained at the knee during single limb landing. It was hypothesized that the alignment of the knee at landing (valgus, varus, or neutral position) influences the joint moments and therefore can be used to predict risk of ACL injury.

METHODS

Twenty-one subjects (9 males and 12 females, ages 18-29) without a history of lower limb injury and who exercise regularly were tested after providing informed consent. All subjects performed a 90-degree lateral run-to-cut maneuver. The subjects' frontal-plane lower limb alignment was measured using digital video (video-based method). Joint kinetic data was obtained using a three-dimensional opto-electronic system and a previously described 6-marker link model of the lower extremity (kinetic method) [6].

The kinetic and video-based methods were used simultaneously to evaluate the run-to-cut motion of the subjects. For the video-based method, a digital video camera was used to capture the motion of each subject in the frontal plane. After video data were collected, the tapes were viewed at normal and reduced speeds. Each subject was categorized as valgus, varus or neutral by observing the angle between the shank and thigh in the frontal plane during weight acceptance (Figure 1).

Two kinetic values were selected for study: peak external knee abduction (valgus) moment and peak external knee adduction (varus) moment. For each subject, a single trial was randomly selected for inclusion in the overall group mean. Student's t-tests (α=0.05) were done to compare the mean values of the kinetic quantities for the different groups.

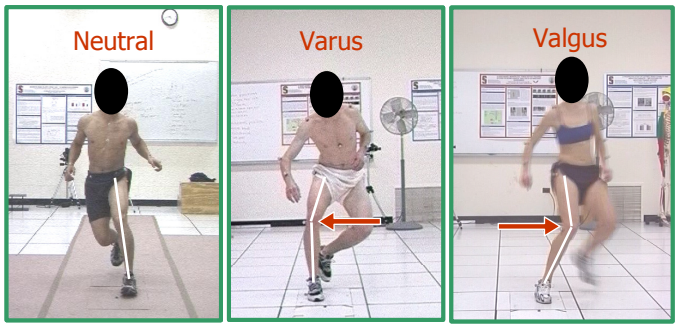

Figure 1. Limb alignment categorizations.

RESULTS

The visual classification of limb alignment shows that there were similar numbers of valgus landers and neutral landers, while varus landing was much more rare. Women were more likely to be valgus landers than men (Table 1).

	Total	Men	Women
Valgus	10	2	8
Neutral	9	5	4
Varus	2	2	0

Table 1. Visual classification of dynamic limb alignment.

For each of the kinetic quantities examined, the valgus group was significantly different from both the neutral group and from the neutral and varus groups combined ($p<0.01$). In all cases, the valgus group mean was higher, or more toward abduction (Figure 2).

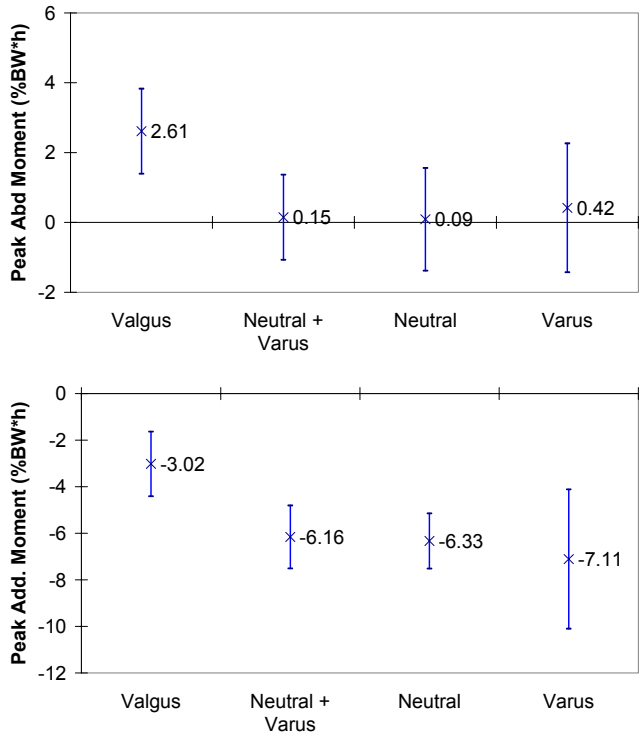

Figure 2. (top) Peak external knee abduction moment and (bottom) peak external knee adduction moment. The valgus group was significantly more positive than the neutral+varus and neutral groups for all values ($p<0.01$). Error bars denote the 95% confidence intervals of the group means.

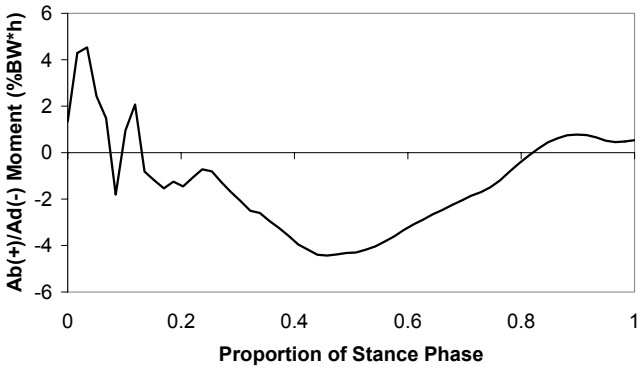

Figure 3. External knee abduction (+) and adduction (-) moments for a typical trial.

DISCUSSION

ACL injuries frequently occur in conjunction with an excessive knee abduction angle, suggesting that an extreme valgus position imposes an above-ultimate strain on the ligament. Moreover, previous studies have shown that valgus opening of the joint is more likely to rupture the ACL than varus, since the ACL becomes tense before the MCL in valgus [7]. The likelihood that such a position will result during a run-cut maneuver is related both to the initial angle and moment at the knee, with larger angles and higher moments increasing risk.

As most non-contact ACL injuries occur upon landing, the moments that occur during early stance phase are the most relevant to predicting injury. Since the abduction moment peak occurs during this period (Figure 3), abduction moments should be considered more dangerous than adduction moments. In addition, Besier et al. showed that unanticipated cutting maneuvers created higher abduction moments than anticipated maneuvers [8]. Such an increase would be most dangerous to those who already exhibit high abduction moments.

In our study, valgus alignment correlated with higher peak abduction moments, suggesting that this group is at elevated risk of an ACL injury. The neutral and varus groups had a similar range of moments, but were shifted more towards adduction, suggesting a lower risk of injury. The larger proportion of women in the valgus group is consistent with the higher incidence of non-contact ACL injury in women [9].

CONCLUSIONS

This study has demonstrated that moment at the knee is directly related to the dynamic alignment of the lower limb at landing. This validates the use of the shank-thigh angle observed during weight acceptance as a predictor for ACL injury.

The ability to accurately access ACL injury risk based on dynamic knee position greatly increases the number of people that can be evaluated. Analysis can be based solely on video data, which is easily obtained in the gym or on the practice field. Those determined to be at high risk could subsequently undergo more rigorous testing and evaluation as well as training to correct the more dangerous valgus alignment.

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