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# Knee moments during run-to-cut maneuvers are associated with lateral trunk positioning

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ABSTRACT

Non-contact anterior cruciate ligament (ACL) injuries account for approximately 70% of ACL ruptures and often occur during a sudden change in direction or pivot. Decreased neuromuscular control of the trunk in a controlled perturbation task has previously been associated with ACL injury incidence, while knee abduction moments and tibial internal rotation moments have been associated with ACL strain and ACL injury incidence. In this study, the association between movement of the trunk during a run-to-cut maneuver and loading of the knee during the same activity was investigated. External knee moments and trunk angles were quantified during a run-to-cut maneuver for 29 individuals. The trunk angles examined were outside tilt (frontal plane angle of the torso from vertical), angle between the ground reaction force (GRF) and the torso in the plane containing the GRF and shoulders (torso–GRF_shoulders); and angle between GRF and torso in the plane containing the GRF and pelvis (torso–GRF_pelvis). Significant positive associations were found between torso angles and peak knee abduction moments (outside tilt, $p=0.002$; and torso-GRF_shoulders, $p=0.036$) while a significant negative association was found between peak tibial internal rotation moment and outside tilt ($p=0.021$). Because the peaks of these moments occur at different times and minimal axial rotation moment is observed at peak knee abduction moment ($-0.29 \pm 0.46$%BW*ht), the positive association between peak knee abduction moment and torso lean suggests that increasing torso lean may increase ACL load and risk of injury.



## 1. Introduction

Anterior cruciate ligament (ACL) rupture is one of the most common knee injuries for athletes competing in field and court sports. Hewett et al. (1999) reported that more than 2200 ACL ruptures are expected to occur in female American National Collegiate Athletic Association (NCAA) athletes each year and that a conservative estimate for orthopedic care for this group alone would amount to over $37 million. When one considers that these injuries occur to males and females participating in sport at all levels from junior to elite to adult recreational, the total direct medical costs reach into the billions (PearlDiver Technologies, Inc., 2010a, b). The consequences of ACL rupture also go beyond the medical costs of initial treatment. Injured athletes also face the potential loss of the remainder of the season, long-term disability, increased risk of osteoarthritis, elevated pain levels during sport, and, for collegiate athletes, lowered academic performance and possible loss of a scholarship (Freedman et al., 1998; Ruiz et al., 2002).

Approximately 70% of ACL ruptures are non-contact in nature, meaning that they occur without a direct blow to the leg by an object or opposing player, and most of these occur during sudden changes in direction and pivoting (Boden et al., 2000; Griffin et al., 2000; McNair et al., 1990). Previous studies have shown that both knee abduction moments and tibial internal rotation moments load the ACL and that these moments have an interaction effect at physiologic load levels, creating strains approaching the reported range of ACL rupture (Fleming et al., 2001; Kanamori et al., 2002; Shin et al., 2009, 2011). One prospective cohort study has shown that peak knee abduction moment during a drop–jump activity could predict ACL rupture with 73% specificity and 78% sensitivity in a population of 205 female athletes, further implicating increased peak knee abduction moments as a factor in ACL injury risk (Hewett et al., 2005).

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A prospective study by Zazulak et al.(2007) found that deficits in lateral trunk control, measured using an isolated trunk perturbation test, were correlated with ACL injury incidence. During this test the subject's pelvis was secured to isolate the torso and upper extremity. The subject then isometrically pulled against a cable until the cable was randomly released. Those subjects with increased angular deviation of the trunk after the release were observed to have a higher relative risk of ACL injury than those that had better neuromuscular control of the trunk. While this study suggested that a relationship does exist between trunk control and ACL injury risk, it did not address the underlying cause of this observed relationship. One potential explanation for this result is that control of the trunk in the isolated trunk perturbation test is a good indication of dynamic trunk control during certain cutting and pivoting tasks and that the resulting trunk position directly influences the dynamic loading of the knee. However, an alternative explanation is that this relationship is merely coincidental—athletes who are in better overall physical condition may display better trunk control, but they may be less apt to sustain an ACL injury due to lower-extremity factors that are also associated with being in better overall physical condition.

**Table 1**
Subject demographic data as well as means, standard deviations, and ranges for variables of interest split by gender (15 males, 14 females).

| | Mean ± st.dev. | Range |
|---|---|---|
| Age [yr] | | |
| M | 26.7 ± 7.6 | 18–45 |
| F | 25.5 ± 6.2 | 20–42 |
| Height [m] | | |
| M | 1.79 ± 0.08 | 1.61–1.87 |
| F | 1.67 ± 0.07 | 1.57–1.78 |
| Mass [kg] | | |
| M | 75.5 ± 12.9 | 52.2–101.6 |
| F | 60.7 ± 6.0 | 49.8–69.8 |
| pKAbM [%BW*ht] | | |
| M | 3.09 ± 2.30 | −0.30–9.58 |
| F | 3.01 ± 2.66 | 0.37–11.23 |
| pTIRM [%BW*ht] | | |
| M | 0.93 ± 0.68 | −0.01–2.85 |
| F | 0.87 ± 0.50 | 0.09–1.89 |
| Outside tilt [deg] | | |
| M | 10.3 ± 10.1 | −6.0–34.7 |
| F | 6.4 ± 3.3 | −0.57–13.6 |
| Torso–GRF_shoulders angle [deg] | | |
| M | 25.3 ± 4.9 | 13.0–33.4 |
| F | 24.8 ± 4.2 | 15.3–34.5 |
| Torso–GRF_pelvis angle [deg] | | |
| M | 33.4 ± 9.4 | 15.7–57.5 |
| F | 31.1 ± 7.7 | 17.2–49.5 |
| Approach speed [m/s] | | |
| M | 2.85 ± 0.31 | 2.29–3.68 |
| F | 2.66 ± 0.27 | 2.23–3.10 |
| Cut angle [deg] | | |
| M | 44.3 ± 5.5 | 34.3–63.0 |
| F | 45.6 ± 4.2 | 35.0–53.0 |

The goal of this study was to determine if control of the trunk during a run-to-cut maneuver was correlated with the loading of the knee during the same activity. It was hypothesized that increased torso motion away from the cutting direction would have a significant, positive association with both knee abduction moments and tibial internal rotation moments.

## 2. Methods

### 2.1. Subjects

Thirty healthy subjects participated in this study after providing IRB approved consent. Subjects had no prior history of lower extremity surgery or serious injury nor did they have a previous history of open abdominal surgery. All subjects were pain free at the time of testing and were fit enough to comfortably jog for more than 10 min. Excess torso marker occlusion prevented the calculation of torso angles for one female subject. The remaining 29 subjects (Table 1) were included in the analyses presented.

### 2.2. Unanticipated run-to-cut maneuver

Subjects started on a pressure-sensitive mat then ran 3 steps at a self-selected pace before planting their dominant foot within a target area defined by a force plate 40 cm wide by 60 cm long [Bertec 4060-10; Bertec Corp; Columbus, Ohio] embedded in the floor to record the ground reaction forces acting upon the foot during stance. During the approach, before the subjects planted for their cut, an arrow pointing either straight ahead or away from the planting foot, instructing the subjects to either continue running straight or to perform a side-step cut. The direction of the arrow (straight or cut) was chosen at random. A successful cut was one in which the plant foot was completely within the 40 cm wide by 60 cm long target area and the subject's change of direction took him/her over top of a line drawn on the floor at a 45° angle to the approach direction, originating at the middle of the force plate and progressing away from the plant foot side. The distance between the pressure mat and the plant foot target as well as the time between when the subject left the pressure mat and when an arrow would be illuminated were adjusted for each subject to account for stride length, speed, and reaction time differences between subjects. Dominant foot was established as the foot the subject would prefer to use to kick a ball. Fig. 1 shows the laboratory set-up for the unanticipated cutting maneuver.

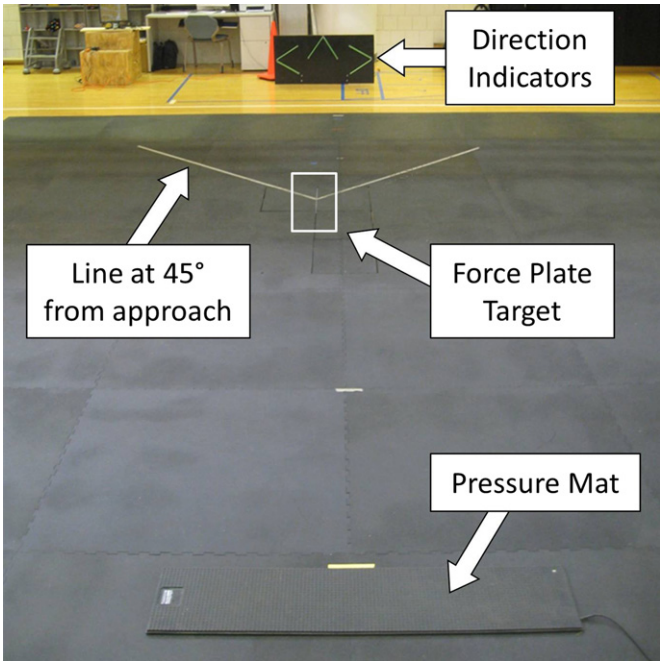


**Fig. 1.** Unancipated run-to-cut set-up. Subject started on the pressure-sensitive mat, took three steps at a self-selected jog pace before planting their fourth step within the force plate target area. A direction indicator arrow would illuminate before the plant indicating whether to perform a side-step cut or continue straight. Right and left foot plants are possible with this set-up.