INTRODUCTION
Anterior cruciate ligament injury is a traumatic sports related injury arising via combined modifiable and non-modifiable risk factors. Current prevention strategies focus largely on modifiable factors, and in particular neuromuscular control, as it directly influences joint mechanics and is amenable to training. In spite of the increased quality and quantity of such programs, however, injury rates and the associated sex-based disparity in these rates have remained. Knee joint anatomy has been commonly linked to ACL injury risk and also governs resultant joint mechanics. By failing to consider the integrative impact of this critical non-modifiable factor within the ensuing neuromechanical profile, we thus propose that prevention efforts will remain substantially compromised. With this fact in mind, the current study examined the association between key knee joint anatomical indices and resultant in vivo knee load states elicited during dynamic sports landing postures.

METHODS
Twenty healthy female subjects (aged 20.2 ± 1.7 years) initially had 3D knee joint kinematic and kinetic data quantified during execution of a dynamic single leg landing task. Prior to testing, approval for the research was gained through the Institutional Review Board of the University of Michigan and written informed consent for all subjects was obtained. Subjects performed ten successful land and jump trials on the dominant limb, with the landing necessarily being on a force plate (AMTI, MA), within the field of view of a high speed motion analysis system (Vicon Corp, CO). Upon landing, they immediately pushed off as quickly and aggressively as possible in opposition to the landing foot. Normalized (bw x ht) peak stance phase anterior tibial shear force and external peak external knee flexion, abduction and internal rotation moments were calculated from the raw force and video (marker) data, from which, mean subject-based values were determined.

In addition to biomechanical data, subjects also had explicit knee joint anatomical indices quantified via high-resolution sagittal, coronal and transverse plane magnetic resonance (MR) images obtained within an Achieva 3.0 Tesla Philips Magnetic Resonance system (Philips Medical Systems, Netherlands). Specifically, inter-condylar distance (ICD), tibial width (TW), the ratio of these two measures (TW/ICD), and lateral (LTS) and medial (MTS) posterior tibial slopes and their ratio (LTS:MTS) were calculated (Figure 1). Individual correlation coefficients were then computed between these indices and the subject-based mean peak knee loads and compared for strength of association.

RESULTS
Dominant limb knee joint stance phase kinetic profiles quantified during the landing tasks were consistent with those reported previously for similar movements. Moderate positive correlations were observed between MTS (r = 0.55), LTS (r = 0.71) and the resultant peak anterior shear force, where increases in slope promoted concomitant increases in the load state (Figure 2). Increases in peak knee abduction moment also occurred with associated decreases in TW/ICD (r = -0.72). Finally, peak knee internal rotation moment was moderately positively correlated with LTS:MTS (r = 0.76).

DISCUSSION
An increased posterior tibial slope, and particularly LTS, increases the potential for large anterior tibial shear loads during dynamic landings. Considering a greater portion of this load is also transferred along the ACL as the slope increases, analogous increases in ligament injury risk seem plausible. An increased TW/ICD ratio possibly promotes an imbalance between the externally applied and opposing medial hamstring moment arms, perpetuating concomitant increases in the abduction moment. A smaller ICD may also present a dangerously small lever arm between the lateral condyle compressive load and the ACL tensile load during such load states. Increases in the internal tibial rotation moment during landing, arising with similar increases in the LTS:MTS ratio, may stem from a possible lateral to medial discrepancy in relative anterior tibial translation magnitudes. A more detailed assessment of explicit joint mechanical responses in our ongoing in vivo and in vitro work will provide greater insights into the interaction between anatomical and mechanical risk factors.

The current results indeed suggest that knee neuromechanical profiles elicited during dynamic sports landings are directly influenced by the underlying anatomy of the joint. Specifically, key anatomical indices, and in particular LTS and TW:ICD directly impact the potential for high risk sagittal and frontal plane knee load states. Current ACL injury prevention methods should thus necessarily consider individual knee joint structural vulnerabilities within the training strategy. Additional assessment of the processes directly governing knee joint structural adaptation and modulation, such as maturation and habitual loading phenomena, now also appears well warranted.

REFERENCES