

# A Biomechanical Assessment of Ski Binding Release to Prevent ACL Tear During the Phantom Foot Ski Injury

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**INTRODUCTION:** It is estimated that one third of all injuries to skiers involves the anterior cruciate ligament (ACL).<sup>1</sup> The phantom foot ski injury mechanism, also known as flexion-internal rotation, has been reported as one of the most common injuries among recreational skiers.<sup>2</sup> This complex injury is characterized by a series of 7 forces and motions that occur almost simultaneously as a skier falls and generally produces an isolated ACL tear. In previous work, we were the first to reproduce the phantom foot ski injury mechanism in a laboratory setting using cadaveric specimens. The high frequency of ACL tears during this injury mechanism may be due to the limited release capabilities of many ski bindings. A standard ski binding is designed to release when there is a torque on the toe or upward force on the heel of the ski, not when the torque is on the heel end of the boot (dead zone). Novel binding designs have attempted to address the dead zone ski release problem by implementing a release mechanism in the heel component of the binding. This study aims to explore whether two new bindings specifically marketed to minimize ACL injury due to their added lateral heel release mechanisms, are effective against the phantom foot ski injury, as compared to a standard ski binding.

**METHODS:** Six fresh-frozen cadaveric female specimens, mid-femur to toe (average age 61, age range 46-67) were used in this study. This study was restricted to female specimens to limit the variables in this small sample study, but future work with male specimens is necessary to assess whether sex affects outcomes. Soft tissue was removed from the femur which was potted in SmoothCast casting material for fixation in the custom fixture. A nylon strap was sutured to the quadriceps tendon to allow for loading. A rod was placed behind the tibia and attached to a bracket for applying an anterior tibial load. The ACLs were removed from all specimen and a tunnel was created in line with the trajectory of ACL reconstruction for insertion of an in-line load cell to assess force across the ACL. Specimen were securely placed in an alpine Tecnica Mach 1 ski boot which was compatible with the ski bindings selected for this study. Specimen were loaded into a custom test fixture set up within the Mini Bionix 858 MTS machine equipped with a 25kN axial and 1500Nm torque load cell. The methodology for the loads applied has been previously presented at ORS. In summary, the following loads were applied to the specimen to recreate the phantom foot ski injury. A three-axis angle vise equipped with a fixation point for the potted femur was used to create: a knee flexion angle of 150° along the vertical axis, a femoral internal rotation of 20° along the horizontal axis, and an opening of the medial side of the knee by 20° by spinning the base about the vertical axis. Via the nylon strap connected to a cable/pulley system, the quadriceps tendon was loaded with 800N (~180lbs) of plate weights. The anterior tibial force of 220N (~50lbs) was applied through a cable/pulley system attached to an inline load cell and actuator. The MTS provides the final two loads, an axial load of 550N (~120lbs) and a rotation along the axis of the tibia of 95°. Three binding types, Figure 1, were assessed (KneeBinding Carbon, Look Pivot Binding, and Salomon Warden 13 Binding) at three DIN settings chosen based on the average weight of the specimen selected for this project (~120lbs). DIN settings of 4.0, 4.75, and 5.5 represented a novice, intermediate, and advanced skier. All specimen began with the KneeBinding, followed by the Pivot binding, and finally the Salomon binding. The main experimental outcomes included whether the boot released during loading and the max torque value about the axis of the tibia prior to release or at max rotation. A one-way ANOVA was used to compare means. Force across the ACL was measured as a means of determining injury potential during loading, but this data has not been analyzed at the time of submission and will serve as an additional outcome if this work is accepted. This project is a non-human subjects research study and is exempt from IRB review.

**RESULTS:** One specimen was excluded due to suffering a femur fracture on first test. The last specimen tested did not complete all testing protocol due to equipment failure that was not repaired prior to abstract submission. All specimen released from the Knee and Pivot bindings at all tested DIN settings. With the Salomon bindings, three specimen released at all DIN settings. There were no significant differences between the five specimen for max torque values,  $p=0.2$ . When comparing max torque values by DIN setting between binding types, Figure 2, there was no significant difference for DIN 4.0 and 5.5 among bindings, but there was a significant difference in max torque values for DIN setting 4.75 between binding groups,  $p=0.05$ . In all cases, the Salomon bindings released at a higher torque value for all DIN settings.

**DISCUSSION:** The phantom foot injury mechanism has the potential for isolated ACL injury when ski bindings do not release during the fall. The present study showed that the KneeBinding and Look Pivot Bindings, specifically designed with a lateral heel release mechanism to prevent ACL injury, release at a lower torque value than the traditional Salomon bindings at all tested DIN settings. While only 6 specimen were tested by the time of this submission, we aim to validate this study with 6 additional samples prior to the ORS meeting. Additional analysis of the force across the ACL will be used to determine the potential that each binding has for injury to the ACL under the applied loading conditions.

**SIGNIFICANCE/CLINICAL RELEVANCE:** Outcomes from this study can be used to inform recreational skiers on the impacts of new binding types designed to minimize injury to the ACL. These novel binding designs may reduce the overall incidence of ACL tear during the phantom foot injury model.

**REFERENCES:** [1] Posch M, Schranz A, Lener M, Tecklenburg K, Burtscher M, Ruedl G. doi:10.1007/s00167-020-06221-z. [2] Shea KG, Archibald-Seiffer N, Murdock E, Grimm NL, Jacobs Jr. JC, Willick S, Van Houten H. doi:10.1177/2325967113519741.

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Figure 1 (Left): The three bindings used in this study from left to right: Salomon Warden 13, Pivot Look, KneeBinding Carbon. All bindings pictured are for the right foot.

Figure 2 (Right): Average max torque values for each binding at each DIN setting.

