

## FRONTAL PLANE KNEE MOTION OF ACL-REPAIRED AND NON-INJURED FEMALES WHEN USING KNEE SAVERS®

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Women are four to six times more likely to sustain ACL injuries compared to male counterparts. Few investigations have explored if ergonomic devices may alleviate the stress placed on the ACL during deep squatting. The purpose of the study was to determine if Knee Savers® (KS) influenced the frontal plane knee motion when previously-injured and healthy participants completed a squat. Female participants (ACL-repaired:  $n=10$ ; healthy:  $n=10$ ) completed a deep squat with and without KS using 2-D videography methods. Results indicated a greater medial motion of the patella in the frontal plane in the right leg of non-injured participants when compared to the ACL-repaired group ( $p = 0.04$ ). When squatting with KS, the non-injured group experienced more frontal plane motion at the knee, compared to the ACL-repaired group.

**KEYWORDS:** varus, valgus, deep-squat, baseball, softball

**INTRODUCTION:** Serious knee injuries, such as anterior cruciate ligament (ACL) rupture are a concern for athletes participating in contact and non-contact sports (Gilchrist et al., 2008), with women four to six times more likely to sustain ACL injuries compared to their male counterparts (Hewett et al., 2010). Recent research links valgus knee postures, and the associated risk of injuries such as ACL ruptures, to poor neuromuscular coordination patterns of the trunk and lower extremities (Hewett et al., 2010; Shirey et al., 2012). As a consequence of such research, it is now common for sports medicine professionals to screen individuals for dynamic lower extremity postures during functional movements, such as squats (Willson, Ireland, & Davis, 2006).

Not with standing surgical restoration of the ACL, functional performance may never be fully achieved after an ACL injury (Villadsen, Overgaard, Holsgaard-Larsen, Christensen, & Roos, 2013). Researchers have quantified such differences in lower extremity kinematics when comparing women who have undergone ACL reconstruction with non-injured controls (Hewett et al., 2005). Both those without ACL injury and those who have endured ACL reconstruction demonstrate a more quadriceps-dominant movement strategy (Hewett et al., 2010), which typically plays in a lower extremity valgus posture during functional activities, such as squatting. Despite understanding how dynamic lower extremity valgus posture contributes to ACL injuries, clinicians in the field face challenges in assessing such movements due to reliance upon qualitative motion analysis. Nonetheless, technology applications are prompting shifts in the clinical world, away from solely relying on visual qualitative motion analysis and instead incorporating 2-D motion analysis software applications. Thus, sport science researchers can help to bridge this “theory-practice-gap” long-noted in the Kinesiology literature (Knudson, 2005), by conducting studies, e.g., lower extremity kinematics during functional tests, using such methods which clinicians increasingly have at their disposal. The use of these software applications might provide practitioners with a way of ascertaining the subtle impact ergonomic aids may have upon movement patterns of the body.

Knee Savers® (KS) are dense foam pads used as an ergonomic aid to reduce the loading placed on the knee (Farrago, 1991). Athletes wear KS by strapping them over the belly of the calves, providing a wedge between the calves and posterior thighs when in a deep squat position. Some authors have posited that during a sustained deep squat, the connective tissues within the lower extremity may be exposed to creep phenomenon, thereby plausibly contributing to increased joint laxity in the lower extremities (Ryan et al., 2012). Proponents of KS posit that these ergonomic aids lessen the tensile load on the connective tissues within the knee’s ligaments and joint capsule (Farrago, 1991), based on the premise that

these wedges limit end-range motion and thus prevent “bottoming out” during a deep squat. In turn, some authors suggest that due to the effects of menstrual cycle hormonal fluctuations upon joint connective tissue laxity women may be at some degree of greater risk of creep phenomenon during sustained deep squatting (Renstrom, et al., 2008). Nonetheless, while KS are used widely by softball and baseball catchers, no known empirical evidence exists to support the claim that this aid reduces the risk for knee injury by preventing the end-range lower extremity kinematics that some believe may increase the risk of knee injury (Farrago, 1991).

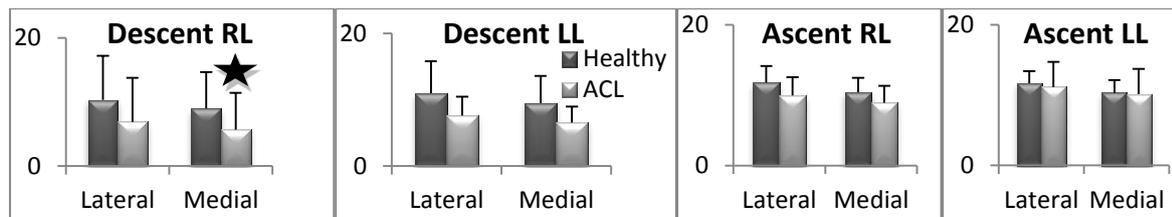
Potential risk to the ACL has been widely linked to poor frontal plane alignment of the lower extremity, as the dynamic valgus posture, which is truly a 3-D movement disorder, presents as a medial drift of the knee when viewed in the frontal plane, or 2-D condition (Hewett et al., 2005). This apparent 2-D phenomenon has been operationally defined as a medial drift of the patella in the frontal plane during either standing or dynamic activities (Shirey et al., 2012). Therefore, the purpose of this study was to determine if KS influence frontal plane lateral and/or medial drift of the knee, in ACL-repaired and non-injured individuals, when descending into and ascending from a deep squat. This report is part of a larger study with sagittal plane data presented in a companion paper (Stone et al., 2014). We hypothesized that lower extremity kinematics when squatting with KS would be different between individuals who had a history of ACL-repair, compared to non-injured individuals. A secondary aim was to use widely available motion analysis software to study a functional task widely assessed in sports medicine environments.

**METHODS:** This study was approved by the Western Kentucky University Institutional Review Board. Female participants were grouped into either the ACL-repaired group (n=10) or non-injured group (n=10). Upon arrival to the laboratory, participants were briefed on study procedures and asked to sign the consent form. Participants’ body measurements were quantitatively similar (Stone, 2014). Reflective tape (1x1 inch) was affixed bilaterally to bony landmarks; acromioclavicular joint, anterior superior iliac spine, and patellae. During the data collection phase, participants squatted with the KS affixed on the posterior portion of the lower extremity, following manufacturer’s instruction. All participants squatted with and without KS during the testing session following a counter-balanced design. Prior to each condition, participants received a minimum of three practice trials by squatting to the greatest self-selected depth allowed while remaining balanced on the toes; these depths were not equalized, as to make the findings more generalizable to actual performance. Then, the participants stood as quickly as possible. All testing trials were conducted the same as practice trials. More details concerning study methodology may be referenced in the companion paper (Stone et. al., 2014).

A digital video camera (Panasonic PV-GS300, Secaucus, NJ, USA) was used to collect frontal plane video (30 Hz), and markers were digitized using Dartfish 7<sup>®</sup> software (Dartfish USA, Atlanta, GA, USA). Researchers have found Dartfish<sup>®</sup> a valid and reliable 2D kinematic analysis instrument for both static and dynamic evaluations (Mier, 2011). Variables under observation were horizontal displacements of the right and left legs when individuals descended into and ascended out of a deep squat. Each participant’s data sequence was time normalized to 0-100% of the squat duration to reduce variation among participants and allow direct comparison between trials. Measurements were assessed during the top phase (standing), descent, bottom phase (full squat), ascent and top phase again. Patella motion in the frontal plane were defined as horizontal displacement of the patella away/toward the body’s midline (medial motion vs. lateral motion), using the methods described by Shirey et al., 2012. All deviation scores were standardized to body height and are reported in cm/m. The statistical analysis was conducted using an analysis of variance (ANOVA), with an alpha level of  $p \leq 0.05$  denoting a statistically significant difference.

**RESULTS:** No significant differences were observed between ACL injured and healthy groups when evaluating the ascent phase. However, statistically significant mean differences

were observed in the right leg with medial knee motion being greater ( $p=0.04$ ) in the healthy group, compared to the ACL group.



**Figures 1, 2, 3, & 4:** (1) Mean and SD horizontal motion of the patella of the right leg (and left leg during squat descent and ascent). Statistical significance ( $p \leq 0.05$ ). Descent: right lateral ( $p=0.06$ ) right medial ( $p=0.17$ ), left lateral ( $p=0.7$ ), left medial ( $p=0.07$ ), Ascent: right lateral ( $p=0.12$ ), right medial ( $p=0.17$ ), left lateral ( $p=0.7$ ), left medial ( $p=0.9$ ).

**DISCUSSION:** The ACL-repaired and non-injured individuals in this study showed only one significant increase in medial knee motion when descending into a deep squat. This finding is consistent with many reports that females frequently demonstrate greater deficiencies in neuromuscular coordination patterns during the eccentric phase of many closed kinetic chain activities, when compared to male counterparts (Salem, Salinas, & Harding, 2003). The ACL-repaired group had significantly less medial deviation of the right leg in the frontal plane, compared to the non-injured group. As explained by Hewett et.al. (2010), females are much more likely to be asymmetric in lower extremity movement patterns, or one-leg dominant, than their male counterparts. Therefore, the data from this study suggest that the non-injured group may have adopted a leg dominance approach when descending into a deep squat. Due to past traumas, the lower magnitude of medial deviation demonstrated by the ACL group may be attributed to heightened proprioception of the lower extremity, plausibly gained through rehabilitation. There is evidence that trauma to the ligament will result in modified motor programs (Johansson, Sjolander, & Sojka, 1991). Through physical therapy, the ACL participants may have refined motor programs to better recruit motor units bilaterally (Mulder & Hulstyn, 1984), whereas the non-injured group may not have attuned these neural pathways. Yet, as information on muscle strength, leg dominance, and muscle recruitment patterns were not collected within this study, it may be surmised from the difference between groups that the non-injured group may have adopted the reported “leg dominant” approach during the descent phase of squatting, compared to the ACL-repaired group. However, this observation is speculative in lieu of this information. Still, sports medicine professionals should be mindful of lower extremity movement asymmetry and evaluate each female participant for unilateral strength disparities. These findings also suggest that statistically significant differences in lower extremity frontal plane motions may be detected using technology widely available to clinicians. Thus, the findings of the present study have clinical meaningfulness in helping rehabilitation professionals bridge the gap between measurement methods used in laboratory conditions and those widely used in the field. Limitations of the study include the lack of data smoothing, analyzing data through instantaneous calculations in Dartfish©, and the inability to quantitatively delineate varus or valgus deviations with the 2D videography analysis system; however, it should be noted that there are high correlations between 2D and 3D videography when evaluating dynamic valgus motions (McLean et al., 2005).

**CONCLUSION:** Knee Savers® do not appear to elicit a change in frontal plane lower extremity kinematics when standing from a deep squat. Furthermore, a history of ACL-repair does not appear to negatively affect knee motion with, or without, these devices. However, these findings support previous studies showing that non-injured females often demonstrate poor lower extremity kinematics associated with increased risk of ACL injury. These findings also suggest the Dartfish© platform may allow sport professionals to help detect clinically meaningful measures – such as abnormal frontal plane motion – when working in the field (McLean et al., 2005; Mier, 2011)

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