

# THE EFFECTS OF AN ERGONOMIC DEVICE ON SAGITTAL PLANE LOWER EXTREMITY MOTION DURING A FULL SQUAT IN ACL-REPAIRED AND NON-INJURED FEMALES

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Each year, 250,000 Americans experience injuries affecting the anterior cruciate ligament (ACL), with women four to six times more likely to incur an ACL injury than their male counterparts. Knee Savers® (KS) are an ergonomic aid purported to lessen the risk of such injuries linked to deep squats. While widely used, KS have not been tested to determine their effect upon lower extremity kinematics. Female participants (n=20) with a history of ACL-repair (n=10) or non-injury (n=10) completed a deep squat with and without KS, while being filmed with 2D videography using methods increasingly available in clinical environments. Results from the study indicate no significant differences were found in sagittal plane lower extremity kinematics when squatting with and without KS. KS did not appear to influence lower extremity joint positions during the bottom phase of a deep squat as purported.

**Keywords:** deep-squat, softball, baseball

**INTRODUCTION:** Prolonged squatting by baseball and softball catchers is believed by many to be detrimental to the knees of these athletes. Although not universally defined, “decreased risk of knee injury” when deep squatting may be promoted through the use of ergogenic aids. Knee Savers® (KS) have been advertised as an ergonomic aid purported to reduce knee loading during squatting as well as decrease undesirable movement patterns [e.g., excessive forward trunk lean, anterior knee translation past the toes, greater degrees of peak knee flexion, etc.] (Farrago, 1991). Anecdotal evidence suggests KS are widely used in both softball and baseball, and users reportedly perceive KS to change lower extremity position, improve balance, and lessen fatigue while playing the “catcher” position in these sports. However, no known studies have evaluated the influence of such ergonomic aids on lower extremity kinematics during deep squatting.

Knee Savers® are “brick-shaped” pads which are attached to the lower leg and are positioned on the posterior portion of the limb. These pads become pinched between the posterior thighs and calves during knee flexion as the individual descends into a squatting position, and they are purported, in turn, to reduce the load placed on the knee during a prolonged deep squat. On the basis alone of the altered somatosensory input to the central nervous system, it may be hypothesized that adding a foreign object to an individual’s lower extremities when in a full squat position may alter inherent postural control strategies and lower extremity kinematics (e.g. hip, knee, ankle flexion angles). Therefore, it is valuable to understand if KS influence lower extremity joint positions when squatting. Thus, the purpose of this study was to determine if KS changed sagittal plane lower extremity joint positions when performing a dynamic deep squat. Similarly, clinicians in the field rely almost exclusively upon visual analysis when assessing human movement, which presents limitations when assessing joint kinematics, which may be influenced subtly by KS, as some wearers believe. In turn, in an effort to help bridge the “theory-practice-gap” long-noted in the kinesiology literature (Knudson, 2005), there is value in assessing lower extremity kinematics using one of the digital video software programs that have exploded on the market in recent years, and which rehab professionals are increasingly using in clinical practice. Accordingly, the secondary purpose was to assess lower extremity kinematics using video methods more commonly employed in clinical environments, as means of helping to bridge the gap between laboratory environments where sophisticated 3-D motion analysis systems predominate and the world of sport rehabilitation where vision-only qualitative motion

analysis prevails. It was hypothesized that there would be measurable differences in lower extremity kinematics (knee flexion, hip flexion, shank angle and anterior knee translation relative to the toes) when squatting with and without KS. This study of the sagittal plane motions is part of a larger study on the lower extremity kinematics of women with history of ACL-repair or non-injury, with frontal plane results reported in a companion paper (Stone et al., 2014).

**METHODS:** This study was approved by the Western Kentucky University Institutional Review Board. It was completed as a laboratory-controlled, quasi-experimental design. Upon arrival for participation, individuals were briefed on the study and completed the consent form. Participants' body mass and height were collected using standardized procedures (Table 1); they were then instructed to don standardized testing attire. The females were grouped into either the ACL-repaired (n=10) or non-injured group (n=10). Participants' body mass and height were collected using a digital scale and stadiometer. Participants' body measurements were quantitatively similar (Stone, 2014). Participants were then asked to change into proper testing attire (dark compression clothing). Reflective tape (1x1 inch) was affixed bilaterally to the participants' anterior patellae and left lateral femoral condyle, lateral malleolus, greater trochanter, and acromioclavicular joint.

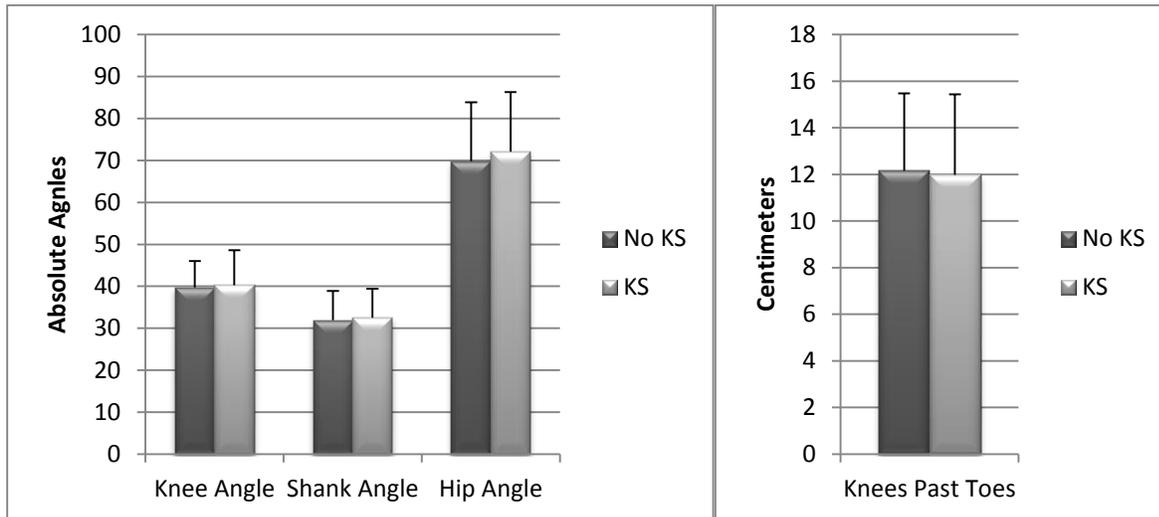
Once markers were placed, the participant began a standardized warm up of treadmill walking and deep squats. Squatting without KS served as the control (CON) condition, and squatting with KS was the experimental (EXP) condition, with conditions counterbalanced to prevent testing order effects. Participants performed three practice trials by squatting to the greatest depth possible while balancing on the toes. The participants remained in the squat for seven seconds, then the investigator gave a count down by speaking, "3, 2, 1, up". The participant then stood as quickly as possible. After performing each trial, the participant rested for 15-20 seconds before each subsequent trial.

Sagittal plane motion was captured (30Hz) using digital video cameras (Panasonic PV-GS300, Secaucus, NJ, USA), and markers were digitized from when to when in the squat using Dartfish 7<sup>©</sup> software (Dartfish USA, Atlanta, GA, USA). Angle measures were made by visually identifying frames at the bottom phase of the squat prior to ascent. Analysis of hip and knee flexion angles and absolute shank angle (horizontal reference) were assessed using the angle calculation tool in Dartfish. The hip flexion angle was defined anteriorly from the left acromioclavicular joint, greater trochanter, and femoral condyle markers. The knee flexion angle was defined posteriorly from the left greater trochanter, femoral condyle, and lateral malleolus markers. The absolute shank angle was comprised of the vertex of a line running through the left femoral condyle and malleolus markers and another line parallel with the ground. Anterior translation of the patella past the toes was assessed immediately prior to ascent by measuring the horizontal distance from the patella marker to the toe marker. Statistical analysis was conducted using four factorial analyses of variance (ANOVA) with repeated measures (n=20) with an alpha level of  $p \leq 0.05$  denoting a statistically significant difference. Given the exploratory nature of this study, inflation of the type I error rate for testing of numerous dependent variables was not controlled.

**RESULTS:** No significant differences were found between injury condition when evaluating peak knee angle ( $p=0.8$ ), absolute angle of the shank ( $p= 0.34$ ), anterior knee translation past the toes ( $p= 0.18$ ), or peak hip flexion ( $p= 0.17$ ). Means and SD of these data are illustrated in Figures 1 and 2.

**Table 1: Participant descriptive statistics**

Group	Age (years)	Height (cms)	Weight (kgs)	Years post-surgery	Injured Leg
Healthy	22.4 ± 2.07	132.08 ± 12.04	61.33 ± 5.89	---	---
ACL	20.9 ± 1.85	165.65 ± 5.82	68 ± 8.14	3.56 ± 2.19	R: 3; L: 5; Both: 2



**Figure 1 and 2: Mean and SD knee flexion angle, absolute angle of the shank or hip flexion angle horizontal distance of the knee from the toe in squats with and without Knee Savers®.**

**DISCUSSION:** Based on the present findings, it is speculated that KS did not significantly alter lower extremity kinematics when deep squatting. It was anticipated that the addition of KS would affect the measures of knee and hip flexion, absolute angle of the shank, and distance the knees translated pasted the toes. With the present findings, we rejected the primary hypothesis that KS would change squatting mechanics when compared to squatting without KS. Related to this notion, analyses were conducted to determine if there were differences between ACL-repaired and non-injured participants when squatting with and without KS. The results also indicated no significant difference in kinemechanics between the ACL-repaired and non-injured groups. Previous research may prove helpful for interpreting the present findings. When evaluating a dynamic balancing task between ACL-repaired participants and healthy controls, researchers found no significant differences in postural control between groups (Goetschius, Kuenze, Saliba, & Hart, 2013). However, literature has also shown a significantly diminished ability of ACL-repaired participants to maintain center of pressure during a dynamic balancing task compared to healthy controls (Davids, Kingsbury, George, O'Connell, & Stock, 1999). The lack of variability between groups in the present study may be because KS are minimally invasive to the athlete's postural control. Future studies may evaluate ergonomic wedges that provide greater support and less knee flexion in order to delineate differences in postural control when squatting with and without the aid. This study is limited as lower extremity kinematics were assessed at a single time point during squat performance. Additionally, postural variability throughout the squat cannot be determined, as forces were not measured.

No differences were found between KS and no KS in the dependent variables. Therefore, it may be suggested that there are no differences in multi-joint muscle recruitment synergies when stabilizing in the bottom phase of a deep squat between these conditions. However, future study is necessary before drawing such a conclusion. Although not investigated, KS may have instead

caused changes in other biomechanical factors, such as joint torque and muscle activation patterns. Additionally, KS appear to neither help nor hinder position of the knee relative to the foot. Although KS are suggested to reduce the forces exerted on the knee joint while squatting, the present data would suggest there is no difference when squatting with or without KS in regards to sagittal plane kinematics. Future study on this topic is certainly warranted before drawing conclusions about the purported benefits of KS. Finally, given the ease of use of the Dartfish® software employed in this study, the present findings suggest motion analysis software may be a reasonably easy tool for rehabilitation professionals to embrace as an adjunct to the qualitative motion analysis that predominates in clinical environments.

**CONCLUSIONS:** KS use appeared to provide no significant change in sagittal plane kinematics when performing a deep squat, compared to no KS.. The Dartfish® analysis platform proved capable of analyzing posture of the lower extremity when squatting. Practitioners may use this software to analyze sagittal plane movement while in the field.

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