EXPLORING KNEE BIOMECHANICS IN DEFENSIVE SPORTS: A COMPARATIVE STUDY OF FORWARD AND BACKPEDAL SIDESTEP CUTS WITH AND WITHOUT A KNEE BRACE

Taliah J. Carlson[1], Zachary Jenkins[1], Joshua T. Weinhandl[1]
[1]University of Tennessee Knoxville, TN, U.S.A

Cutting, a key movement in dynamic sports, is associated with increased anterior cruciate ligament injuries. The influence of knee braces, commonly used for injury prevention, on knee mechanics requires further analysis. The purpose of this study was to examine the impact of knee braces on knee biomechanics during forward and backpedal cutting. Ten healthy males performed forward and backpedal cutting tasks, with and without a dual-hinged brace, simulating offensive and defensive movements. Compared to forward cuts, backpedal cuts showed increased knee flexion and decreased abduction and internal rotation. Knee internal extension moments and adduction moments increased, while knee internal rotation moments decreased during the backward cut. The lack of significant effect from knee braces highlights the need for continued research to aid in developing injury prevention strategies for athletes.

KEYWORDS: ACL Injury, Backpedal Cut, Forward Cut

INTRODUCTION: Anterior cruciate ligament (ACL) injuries are common in sports, with about 250,000 yearly cases (Collins et al., 2013). ACL injuries are predominantly (70%) non-contact, often occurring during sidestep cuts or jump landings, when the knee is near full extension, abducted, and externally rotated (Griffin et al., 2006). It is imperative to examine motion in three planes due to the multifactorial nature of ACL injuries (Griffin et al., 2006), particularly in agility-focused sports like football and soccer (Maniar et al., 2019).

Within these sports, defensive players experience 73% of ACL injuries and roughly 44% of those were non-contact (Brophy et al., 2015). Effective defense relies on the ability to backpedal and quickly change directions. However, limited research focuses on backpedaling into a 45° forward side cut, with current research focusing on ankle and metatarsophalangeal joint biomechanics (Ford et al., 2016). Examining game-like movements, such as backpedaling into a forward side cut, could provide insight into the higher ACL injury risk in defensive players.

For non-contact ACL injuries, knee braces have been considered as a preventative measure. Braces are thought to restrict or stabilize the knee in an effort to decrease injuries and promote healing. However, their role in reducing ACL injury risks remains controversial, with some studies showing minimal impact (Sinclair et al., 2017), potentially due to non-game-like movement tasks being examined (Moon et al., 2018). This study aimed to assess the effect of knee bracing on knee joint kinematics and kinetics in forward and backpedaling sidestep cutting. It was hypothesized that wearing a knee brace would decrease knee joint range of motion and reduce knee joint moments, and that backpedaling into a forward sidestep cut would result in higher peak knee flexion angles and internal extension moments compared to forward running into a 45° sidestep cut.

METHODS: Ten healthy, recreationally active males (age: 24.6 ± 4.47 years, height: 1.82 ± 0.08 m, mass: 84.23 ± 8.80 kg) voluntarily participated after providing informed consent. Exclusion criteria included past lower extremity surgery, lower extremity injury in the past 6 months, or a score of 71 or less on the Lower Extremity Functional Scale. Participants wore lab-provided spandex shorts and running shoes (Nike Air Zoom Pegasus 34; Nike, Beaverton, OR), and a bilateral dual dampening hinge knee brace (Donjoy Bionic FullStop, Vista, CA) on their dominant limb. Participants completed a self-selected treadmill warm-up and then performed four activities: forward and backpedal sidestep cuts, both with and without a knee brace. Forward cuts involved running at 4.0-4.5 m/s, striking a force plate with the dominant leg, and making a 45° cut. Backpedal cuts started with four steps backwards at a self-selected speed, striking a force plate with their dominant leg, and making a 45° forward cut. After practice trials, participants completed five successful trials per condition, with rests to limit the effect of fatigue. Three-dimensional knee kinematics and internal joint moments were calculated using Visual3D (C-Motion, Germantown, MD, USA), with data filtered via a 4^{th} order low-pass Butterworth filter with a cut-off frequency of 10 Hz (Kristianslund et al., 2012). Stance phase was defined as initial contact, when vertical GRF is greater than 10 N, to toe-off, when vertical GRF is less than 10 N. Statistical analysis used two-way ANOVAs in a custom R script (R Foundation v4.2, Vienna, Austria) to evaluate differences in peak knee joint angles and internal knee joint moments during stance phase, with normality and variance homogeneity assessed by Shapiro-Wilk and Levene’s tests.

RESULTS: There was no significant main effect nor interaction of brace for peak knee joint angles**.** There were, however, significant task differences. Participants displayed 10.36º decreased flexion (p=0.005), 3.14º increased abduction (p=0.035), and 6.23º increased internal rotation angles (p=0.018) during forward compared to backpedal cutting (Table 1, Figure 1).
Similarly, peak joint moments were significantly different between forward and backward cutting, but there was no brace-x-task interaction or brace effect. Participants exhibited 1.84 Nm/kg greater peak knee extension (p<0.001) and 0.20 Nm/kg adduction (p=0.019) moment with 0.09 Nm/kg decreased peak internal rotation moment (p=0.005) during forward sidestep cuts compared to backpedal sidestep cuts (Table 1).

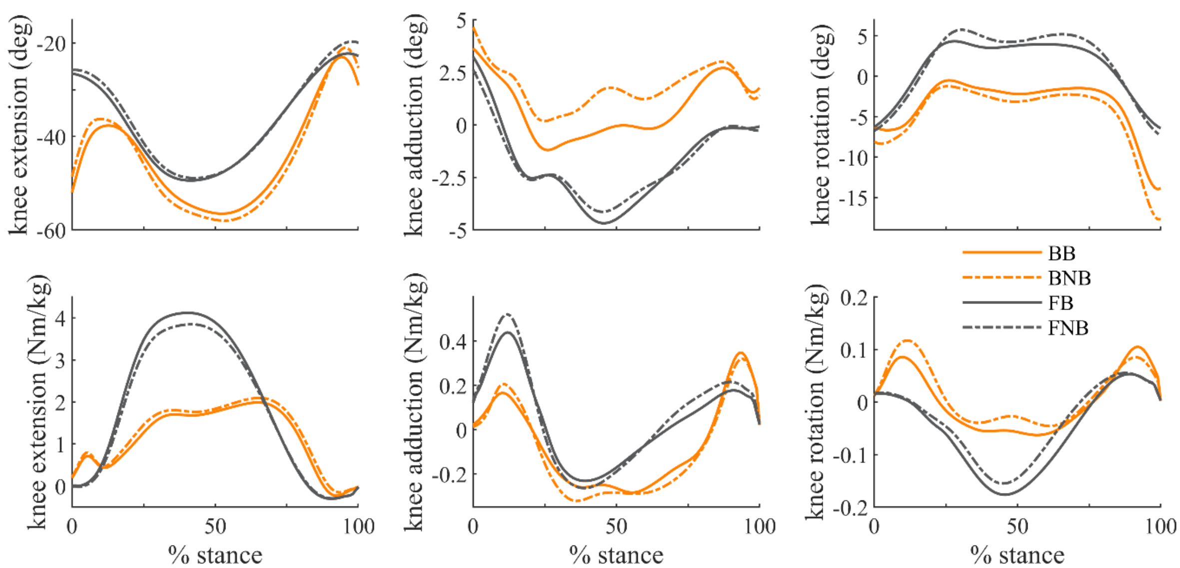

Figure 1: Mean knee joint angles (top) and moments (bottom) (sagittal x, frontal y, transverse z) in stance phase for backward brace (BB), backward no brace (BNB), forward brace (FB), and forward no brace (FNB). Positive values indicate knee extension, adduction, and internal rotation.

DISCUSSION: Athletes in sports like basketball and soccer often use knee braces to aid ACL injury risk reduction (Najibi & Albright, 2005). While a dual-hinged brace is thought to reduce ACL injury risk by increasing knee flexion angles (Yu et al., 2004), this study saw no significant differences in peak knee angles or moments with the brace, contradicting the first hypothesis. While prior research has shown knee flexion angles increase with use of a similar brace (Liu et al., 2014), that study differed in skill learning from prolonged brace wearing. Furthermore, those who have suffered knee ligament injuries may depend on the brace more than uninjured individuals (Lee et al., 2016). Thus, suggesting knee braces may be more effective at reducing injury risk when mechanics are altered due to injury, and that there may be an adaptation period before mechanics are altered. Therefore, further investigation is warranted with injured individuals over prolonged brace wearing is warranted to fully understand the effect of the brace at reducing injury risk during backpedal sidestep cutting.

Table 1: Peak Joint Angles and Moments During Forward and Backward Cut: Mean ± SD

	Forward Cut		Backward Cut	
	Brace	No Brace	Brace	No Brace
Joint Angles				
Knee Flexion (deg)	-54.46 ± 6.23	-54.21 ± 4.91	-63.97 ± 16.36*	-65.42 ± 12.51*
Knee Abduction (deg)	-6.10 ± 5.11	-5.70 ± 5.41	-2.99 ± 4.24*	-2.54 ± 2.95*
Knee Rotation (deg)	7.42 ± 5.17	8.32 ± 10.13	1.65 ± 4.41*	1.63 ± 10.13*
Joint Moments				
Knee Extension (Nm/kg)	4.25 ± 0.41	4.01 ± 0.37	2.25 ± 0.44*	2.33 ± 0.29*
Knee Adduction (Nm/kg)	0.60 ± 0.23	0.66 ± 0.38	0.41 ± 0.14*	0.46 ± 0.20*
Knee Rotation (Nm/kg)	0.08 ± 0.07	0.09 ± 0.07	0.16 ± 0.09*	0.20 ± 0.15*

*Indicates a significant difference from forward cut.

In backpedal versus forward cutting, participants exhibited approximately 10º greater peak knee flexion angles and 45% smaller extension moments in backpedal cutting, partially supporting the second hypothesis (Table 1). It was expected that there would be increased peak knee flexion angles during backpedal cutting due to the greater knee flexion at initial contact (Uthoff et al., 2018). While backpedaling, there is increased knee flexion at initial contact followed by extension for the first 15% of stance to prepare for backward propulsion. During the backpedal sidestep cut, this extension phase is followed by knee flexion as they alter their mechanics to prepare for the cut's forward motion. In this study, the smaller knee extension moments in backpedal cutting compared to forward cutting, contradict prior findings of higher knee extension moments in backwards running due to greater quadriceps activations (DeVita & Stribling, 1991; Uthoff et al., 2018). This may be due to the slower speed of the backpedal cut compared to the forward cut, with peak knee extension moments occurring during loading in forward running and near push-off in backpedal cutting. Significant decreases in peak knee abduction and internal rotation angles and peak knee adduction moments during the backpedal cut were also observed. This may be due to increased lower limb muscle activation during backpedaling, which reduces stress on the knee joint (Uthoff et al., 2018). Research associates greater ACL injury risk with increased knee abduction and adduction moments (Hewett et al., 2005), and suggests that ACL injuries result from multifactorial mechanisms (Cronstrom et al., 2020). Thus, it appears that backpedaling into a forward cut increases knee flexion angles and reduces extension moments however, further research is needed to fully understand the risk associated with sustaining an ACL injury during a backpedal sidestep cut. Further research is needed on the use of knee braces as an ACL injury prevention technique on individuals with a previous knee ligament injury, in a fatigued state, or in a female population, due to their increased ACL injury risk (Brophy et al., 2015). Research shows an increased injury prevalence in defensive players (Brophy et al., 2015), suggesting a need for future research on defensive movements to better understand ACL injury risks.

CONCLUSION: The results of the current study indicate there are differences in knee mechanics between forward and backpedal sidestep cutting, but no knee brace effect. Backpedal sidestep cut showed altered knee kinematics and kinetics in variables commonly associated with ACL injury risk compared to forward cutting. To our knowledge, this was the first study to examine lower extremity biomechanical differences between a backpedal and forward sidestep cut on knee biomechanics, but further research is needed with larger studies with different populations and perspective studies to truly assess injury risk differences between forward and backpedal cuts.

REFERENCES:

Brophy, R. H., Stepan, J. G., Silvers, H. J., & Mandelbaum, B. R. (2015). Defending Puts the Anterior Cruciate Ligament at Risk During Soccer: A Gender-Based Analysis. *Sports Health*, *7*(3), 244-249. https://doi.org/10.1177/1941738114535184

Collins, J. E., Katz, J. N., Donnell-Fink, L. A., Martin, S. D., & Losina, E. (2013). Cumulative incidence of ACL reconstruction after ACL injury in adults: role of age, sex, and race. *Am J Sports Med*, *41*(3), 544-549. https://doi.org/10.1177/0363546512472042

Cronstrom, A., Creaby, M. W., & Ageberg, E. (2020). Do knee abduction kinematics and kinetics predict future anterior cruciate ligament injury risk? A systematic review and meta-analysis of prospective studies. *BMC Musculoskelet Disord*, *21*(1), 563. https://doi.org/10.1186/s12891-020-03552-3

DeVita, P., & Stribling, J. (1991). Lower extremity joint kinetics and energetics during backward running. *Med Sci Sports Exerc*, *23*(5), 602-610. https://www.ncbi.nlm.nih.gov/pubmed/2072839

Ford, K. R., Taylor, J. B., Baellow, A. L., Arpante, A. K., Wright, K. E., & Nguyen, A. D. (2016). Effects of plate stiffness on first metatarsophalangeal joint motion during unanticipated cutting and resisted sled pushing in football players. *Footwear Science*, *8*(2), 75-82. https://doi.org/https://doi.org/10.1080/19424280.2016.1175518

Griffin, L. Y., Albohm, M. J., Arendt, E. A., Bahr, R., Beynnon, B. D., Demaio, M., Dick, R. W., Engebretsen, L., Garrett, W. E., Jr., Hannafin, J. A., Hewett, T. E., Huston, L. J., Ireland, M. L., Johnson, R. J., Lephart, S., Mandelbaum, B. R., Mann, B. J., Marks, P. H., Marshall, S. W., . . . Yu, B. (2006). Understanding and preventing noncontact anterior cruciate ligament injuries: a review of the Hunt Valley II meeting, January 2005. *Am J Sports Med*, *34*(9), 1512-1532. https://doi.org/10.1177/0363546506286866

Hewett, T. E., Myer, G. D., Ford, K. R., Heidt, R. S., Jr., Colosimo, A. J., McLean, S. G., van den Bogert, A. J., Paterno, M. V., & Succop, P. (2005). Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. *Am J Sports Med*, *33*(4), 492-501. https://doi.org/10.1177/0363546504269591

Kristianslund, E., Krosshaug, T., & van den Bogert, A. J. (2012). Effect of low pass filtering on joint moments from inverse dynamics: implications for injury prevention. *J Biomech*, *45*(4), 666-671. https://doi.org/10.1016/j.jbiomech.2011.12.011

Lee, H., Ha, D., Kang, Y. S., & Park, H. S. (2016). Biomechanical Analysis of the Effects of Bilateral Hinged Knee Bracing. *Front Bioeng Biotechnol*, *4*, 50. https://doi.org/10.3389/fbioe.2016.00050

Liu, H., Wu, W., Yao, W., Spang, J. T., Creighton, R. A., Garrett, W. E., & Yu, B. (2014). Effects of knee extension constraint training on knee flexion angle and peak impact ground-reaction force. *Am J Sports Med*, *42*(4), 979-986. https://doi.org/10.1177/0363546513519323

Maniar, N., Schache, A. G., Cole, M. H., & Opar, D. A. (2019). Lower-limb muscle function during sidestep cutting. *J Biomech*, *82*, 186-192. https://doi.org/10.1016/j.jbiomech.2018.10.021

Moon, J., Kim, H., Lee, J., & Panday, S. B. (2018). Effect of wearing a knee brace or sleeve on the knee joint and anterior cruciate ligament force during drop jumps: A clinical intervention study. *Knee*, *25*(6), 1009-1015. https://doi.org/10.1016/j.knee.2018.07.017

Najibi, S., & Albright, J. P. (2005). The use of knee braces, part 1: Prophylactic knee braces in contact sports. *Am J Sports Med*, *33*(4), 602-611. https://doi.org/10.1177/0363546505275128

Sinclair, J. K., Vincent, H., & Richards, J. D. (2017). Effects of prophylactic knee bracing on knee joint kinetics and kinematics during netball specific movements. *Phys Ther Sport*, *23*, 93-98. https://doi.org/10.1016/j.ptsp.2016.08.005

Uthoff, A., Oliver, J., Cronin, J., Harrison, C., & Winwood, P. (2018). A New Direction to Athletic Performance: Understanding the Acute and Longitudinal Responses to Backward Running. *Sports Med*, *48*(5), 1083-1096. https://doi.org/10.1007/s40279-018-0877-5

Yu, B., Herman, D., Preston, J., Lu, W., Kirkendall, D. T., & Garrett, W. E. (2004). Immediate effects of a knee brace with a constraint to knee extension on knee kinematics and ground reaction forces in a stop-jump task. *American Journal of Sports Medicine*, *32*(5), 1136-1143. https://doi.org/10.1177/0363546503262204