THE EFFECT OF A RAISED SURFACE ON FRONTAL PLANE KNEE LOADING AND MUSCLE ACTIVATION DURING A SIDECUT IN RECREATIONAL FEMALE SOFTBALL PLAYERS

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INTRODUCTION

Fast-pitch softball has increased in popularity, with 19,628 NCAA Division I female athletes participating in the 2014-15 season [1]. However, increased participation results in increased number of potential injuries. Base running is a major component of the sport, occurring in almost every play of the game. To get from one base to the next, players have to “round the base” by performing a sidecut to the left by planting their right foot on a raised base. Unfortunately, this specific movement has resulted in approximately 187 game-day injuries [2].

This dynamic sidecut movement has been shown to place large loads on the knee ligaments, potentially resulting in anterior cruciate ligament (ACL) injuries [3]. Noncontact ACL injuries account for nearly 31% of all game-day softball knee injuries [2]. Biomechanical and neuromuscular abnormalities have been associated with an increased likelihood of this injury to occur. Specifically, increased frontal plane loading [4] and unbalanced quadriceps-to-hamstring co-contraction indices (Q:H CCI) [5] have been identified as primary risk factors in the occurrence of noncontact ACL injuries.

To date, no study has analyzed the effect of rounding a base on noncontact ACL injury risk factors in softball players. Therefore, the aim of this study was to determine the effect of a raised surface (i.e. base) during a sidecut on frontal knee loading and muscle activation in recreational softball players.

METHODS

Nine recreationally active females (age: 21.8±2.0 yrs, 1.70±0.03 m, 63.7±5.0 kg) completed two base running conditions, five trials per condition. In the first condition, a sidecut simulating rounding first base was performed with no base (NB) present on the force plate. For the second condition, the same route was performed with a base (WB) present on the force plate. Participants were instructed to stay within a range of 90°-120°during the entrance of the sidecut. Entrance and exit speeds were monitored at 4.0 m/s ± 0.25 m/s and 3.75 m/s ± 0.25 m/s, respectively. During each trial, right leg 3-D kinematics and kinetics were collected using a 12-camera Vicon motion capture system (200 Hz), ground reaction forces (GRF) were measured with one mounted AMTI force plate (2000 Hz), and muscle activations were measured using a Delsys Trigno wireless electromyography (EMG) system (2000 Hz). Muscles included biceps femoris (BF), semitendinosus (MH), vastus lateralis (VL), and vastus medialis (VM).

Raw EMG data were pre-amplified and band-pass filtered using a 4th order Butterworth filter (10 Hz, 350 Hz), full-wave rectified and low-pass filtered (5 Hz) to create a linear envelope. Peak maximum voluntary isometric contraction values for each muscle were used to normalize the filtered EMG signals for comparisons (%MVIC). Raw 3D marker coordinate and GRF data were both low-pass filtered using a 4th order, Butterworth filter (20 Hz). A time frame of 50 ms prior to initial contact and 100 ms after initial contact were used during EMG analysis. Peak internal knee adduction moment was computed in the joint coordinate system and normalized to body mass (Nm/kg).

Dependent *t*-tests were used to compare differences between NB and WB initial contact knee abduction angle, peak knee abduction angle, and peak knee adduction moment. A repeated measures 2x2 ANOVA was used to compare Q:H CCI between the condition (NB and WB) and contact time (pre- and post-contact). The alpa level was set at $p \leq 0.05$.

RESULTS AND DISCUSSION

This study compared frontal knee kinematics and kinetics during two base running conditions. It also compared muscle activations during two base running conditions pre- and post-contact. Our results suggest that performing a sidecut with a raised surface does not significantly alter both peak and initial contact knee abduction angle. Peak knee adduction moment was significantly greater in the NB condition compared to the WB condition (Table 2). A main effect involving contact time was identified for Q:H ratio, indicating a greater Q:H ratio post-contact than pre-contact ($F_{1,7} = 16.113$, $p = 0.005$, Table 1).

It is interesting to note that while participants landed with larger initial contact and peak knee abduction angles in the WB condition, peak knee adduction moments were significantly larger in the NB condition (Figure 1). These findings contradict what McLean et al. [4] found regarding the causal link between increased initial contact knee abduction angles and the subsequent increased peak knee adduction moments. This suggests contacting a raised surface provides a more optimal surface to perform and complete the sidecut, causing a more medially directed GRF compared to cutting on a flat surface.

Q:H CCIs showed that prior to initial contact, activation between the two muscle groups were somewhat balanced (Table 1). Previous literature has shown that reduced hamstring pre-activation places the ACL at an increased risk of injury due to the inability to properly scale the hamstrings to the same level as the quadriceps [6]. Significantly greater quadriceps activation was seen post-contact. The quadriceps act to prevent the knee from collapsing during any sort of dynamic task, thus explaining the increased activation. Unfortunately, an unbalanced Q:H ratio, with significantly greater quadriceps activation, creates a large anterior shear force, thus increasing the stress on the ACL [5]. Neuromuscular training to improve Q:H CCI could decrease the load applied to the ACL and decrease the risk of injury.

CONCLUSIONS

These findings suggest that rounding a base, with a controlled foot placement, may reduce ACL injury risk by decreasing the knee adduction moment. Examining movement patterns at the ankle and abnormal foot strikes may provide a better explanation for ACL injuries that occur when rounding a base.

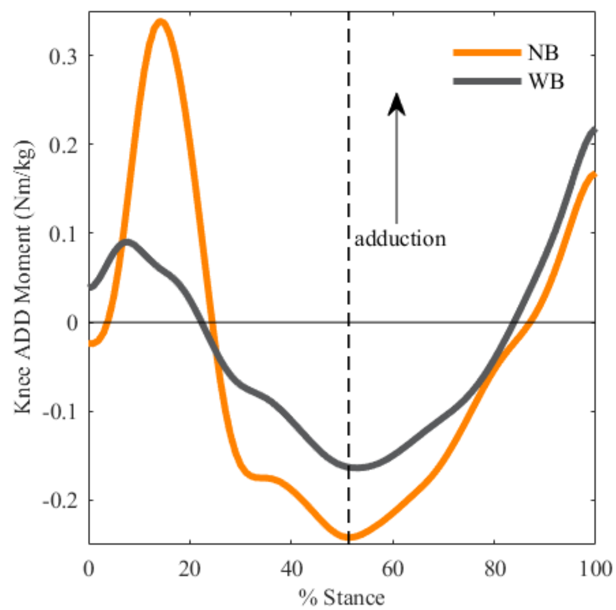

Figure 1: Knee adduction moments during NB and WB conditions. Dotted line represents 100 ms after initial contact.

Table 1: Mean %MVIC values of Q:H CCIs between conditions and between contact times.

		NB	WB
Q:H CCI	**Pre**	0.92	1.13
	Post	4.22	4.17

Pre: 50 ms prior to initial contact, Post: 100 ms after initial contact
Q: VM+VL, H: BF+MH

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Table 2: Knee abduction angles and adduction moments during the two base running conditions (mean±SD).

	NB	WB	*p*-value	ES
IC Knee ABD Angle (deg)	-1.01±5.98	-1.72±5.02	0.550	0.14
Peak Knee ABD Angle (deg)	-9.31±4.47	-9.68±3.99	0.632	0.09
Peak Knee Adduction Moment (Nm/kg)	0.54±0.48	0.33±0.32	0.041	0.55