

# LOWER EXTREMITY KINEMATIC CONSEQUENCES DURING VERTICAL TO HORIZONTAL MOMENTUM REDIRECTION

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## INTRODUCTION

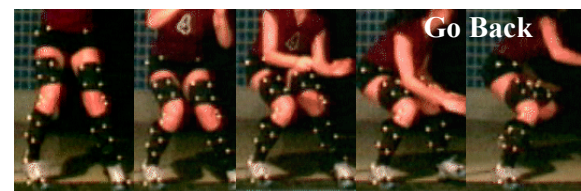
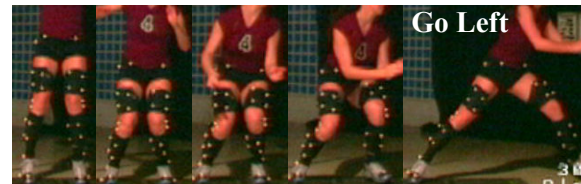
During landings, insufficient control of shank and thigh motion can result in excessive multi-axis rotation of the knee. As the complexity of tasks increases, the control system must organize its available resources to achieve the performance specifications without introducing loading conditions that put the system at risk for injury. The outcome of the control strategy is reflected in the lower extremity joint torques and the interaction forces with the environment, whereas the kinematic consequences are reflected in the degree of lower extremity joint alignment.

Factors contributing to insufficient control of the knee during foot contact are poorly understood, particularly when tasks are performed in realistic contexts. Previous studies have focused on knee flexion range of motion and knee valgus angles during drop landings as indicators for risk of injury. Lower extremity alignment measurements during task that require horizontal momentum redirection during 3D, sport-specific movements have been limited to 45° cutting and cross-over step tasks.

The goal of this study was to determine the kinematic consequences of control strategies used during landings requiring a secondary horizontal momentum redirection task. We hypothesized that the alignment of the lower extremity joint axes during both the impact and push phases of ground contact would be affected by task-specific control strategies.

## METHODS

In this pilot study, one female, collegiate volleyball player performed a standing block jump immediately followed by horizontal redirection parallel to (Go Left) or perpendicular to (Go Back) the net. A maximum vertical jump (MVJ) landing was used as a basis of comparison for kinematic results.



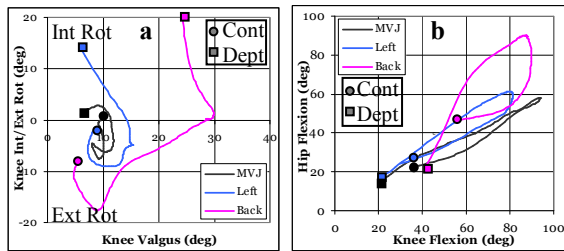
**Figure 1.** Subject-selected techniques for performing the Go Left and Go Back tasks.

High speed video from three camera views (NAC, 200 Hz) was used to obtain 3-D locations (Motus, Vicon) of four tracking markers on each segment (pelvis, thigh, shank, foot) during a calibration frame and throughout each task. All coordinates were filtered (fourth order Butterworth, 6 Hz cutoff) and imported into Matlab (The Mathworks Inc, MA) for processing. Joint coordinate systems were defined based on palpated bony landmarks (greater trochanter, femoral condyles, fibular head, malleoli).

A quaternion parameterization (Kim et al., 2001) was used to quantify segment orientations. Functional knee joint axes were calculated for each frame using the thigh and shank quaternions and reported using the anatomically-defined axes.

## RESULTS

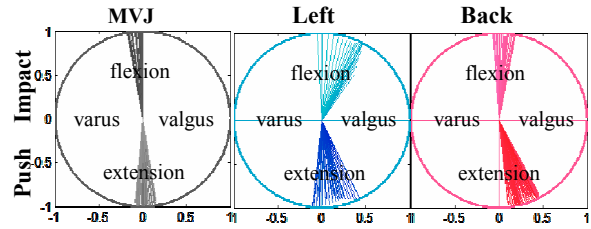
The degree of out of plane knee motion during the impact phase (touchdown to first local minimum of vertical ground reaction force (GRFv)) and the push phase (last local minimum of GRFv to toe off) increased as the direction of the horizontal Go task changed from MVJ to Left to Back (Figure 2a). External rotation of the thigh on the shank at touchdown increased across tasks as the subject modified her foot position at contact (Figure 1). During the push phase, the knee transitioned into internal rotation as the knee extended for both Left and Back. Peak knee valgus increased across tasks.



**Figure 2:** Angle-angle diagrams of the ground contact phase of representative trials of each task.

Sagittal plane knee and hip ranges of motion were also task dependent. When horizontal Go tasks were added to the block jump, maximum knee flexion angle decreased and maximum hip flexion increased (Figure 2b).

Similarly, the degree of off-axis rotation during both the impact and push phases was task dependent. While both Go tasks showed increases in knee valgus throughout the movement, the increase occurred mostly during the impact phase for Left and during the push phase for Back (Figure 3).



**Figure 3.** Knee axes of rotation for each time step for each trial. Deviations from vertical (flex (+) and ext (-)) indicate off-axis rotations toward varus (-) or valgus (+). Wider fan spread indicates increased variability over time.

## DISCUSSION/CONCLUSIONS

These results indicate that the subject employed different control strategies during the impact and push phases of the Land and Go tasks depending on the required horizontal direction. Both Go tasks resulted in differences in frontal and transverse plane knee kinematics as compared to a simple vertical jump landing. As horizontal direction deviated from Left to Back, out of plane knee motion increased in both planes simultaneously. The coordination between the knee and hip also changed based on the secondary task requirements.

Realistic landing tasks with varied secondary horizontal momentum redirection requirements provide a more complete representation of the kinematic consequences of an individual's control strategies than a standardized MVJ task. Realistic movements that result in sustained axis mal-alignment may require targeted intervention programs that consider control requirements at the whole body and local subsystem level.

## REFERENCES

- Kim, I. et al. (2001). *AAS* **01-142**, 571-586.
- Kuipers. (1999). *Quaternions and Rotation Sequences*. Princeton University Press.