THE EFFECT OF MID-FLIGHT TRUNK FLEXION AND EXTENSION ON CENTER OF MASS REDISTRIBUTION AND LANDING MECHANICS

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INTRODUCTION

Anterior Cruciate Ligament (ACL) injuries are prevalent and can have devastating effects [1, 2]. While various landing conditions predispose an individual to these injuries, knee flexion angle and trunk motion appear to be significant risk factors [3, 4]. A stiff landing characterized by decreased knee and hip flexion and increased vertical ground reaction force (VGRF) is associated with increased ACL loading [5]. Mid-flight medial and lateral trunk bends influence landing mechanics [6], but the effect of trunk flexion and extension is unclear.

This study aimed to analyze the effect of mid-flight trunk flexion and extension on joint positions relative to whole-body center of mass (COM) and landing mechanics. Researchers hypothesized that mid-flight trunk extension would cause anterior motion of the hips and knees relative to the whole-body COM, resulting in a mechanically disadvantageous position for landing. Consequently, subjects would demonstrate a stiffer landing with decreased knee and hip flexion.

METHODS

Ten males and five female recreational athletes (age: 21.8 ± 1.6 years, height: 1.75 ± 0.11m; mass: 74.4 ± 28.7kg) participated. Forty-four reflective markers were attached to participants' body segments (Fig. 1). Kinetic and kinematic data were collected using eight Vicon cameras (160 Hz) and two Bertec force plates (1600 Hz).

After a static trial, participants completed three jump-landing trials in three randomly ordered conditions: reaching backward (Fig. 2), reaching up (Fig. 3), and reaching forward (Fig.4). Trials began with participant's feet on two separate force plates. The participants received instructions to jump vertically as high as possible for all conditions. Prior to jumping, participants were also instructed to reach as far backward, up, or forward as they felt comfortable after reaching their maximum jump height. A successful trial concluded when the participant landed with each foot on the force-plate on which it began.

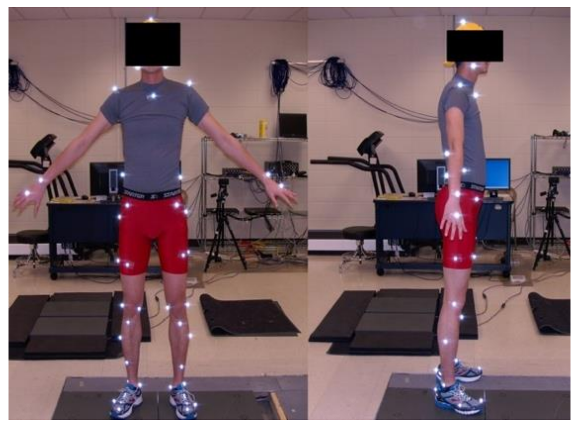

Figure 1. Marker set for data collection.

The positions of the hip, knee, and ankle joints relative to the whole-body COM at initial foot contact of landing were calculated and normalized to body height (Fig. 2, 3, 4). Positive positions represented joints anterior to whole-body COM. Hip, knee, and ankle flexion/extension angles were calculated at initial foot contact and 100 ms following initial contact of landing. Repeated-measure ANOVAs were performed for each dependent variable followed by pairwise comparisons. A type I error rate was established at 0.05 for statistical significance.

RESULTS AND DISCUSSION

ANOVAs (Table 1) showed significant differences among the three different conditions, except for VGRF. The reaching backward condition resulted in more anterior hip and knee positions from whole-body COM, smaller hip flexion angles at initial contact, and smaller hip and knee flexion angles at 100 ms of landing compared to the other two conditions. The reaching forward condition demonstrated more posterior hip, knee, and ankle positions from whole-body COM and greater hip and knee flexion angles at initial contact and 100 ms of landing compared to the other two conditions.

Trunk flexion and extension resulted in altered joint positions related to whole-body COM and subsequent landing mechanics. In the reaching backward condition, the whole-body COM is placed posterior of the hip, resulting in an external hip extension moments. Consequently, an active internal hip flexion moment is needed to flex the hip and move the whole-body COM forward during early-landing. In addition, because of a posteriorly positioned whole-body COM, actively knee flexion may not be performed to avoid further moving the whole-body COM posteriorly to prevent falling. On the other hand, in the reaching forward condition, the whole-body COM is placed anterior of the hip, causing an external hip flexion moment to facilitate hip flexion. In the meantime, as the whole-body COM is moving forward due to hip flexion, an active knee flexion may be achieved during early-landing while postural stability is maintained.

CONCLUSIONS

COM redistribution elucidated by the reaching backward condition may predispose an individual to a stiffer landing posture that renders them at risk for ACL injury. The findings may provide information for understanding ACL injury mechanisms associated with trunk motion and developing effective landing strategies to decrease ACL injury risk after trunk perturbation.

REFERENCES

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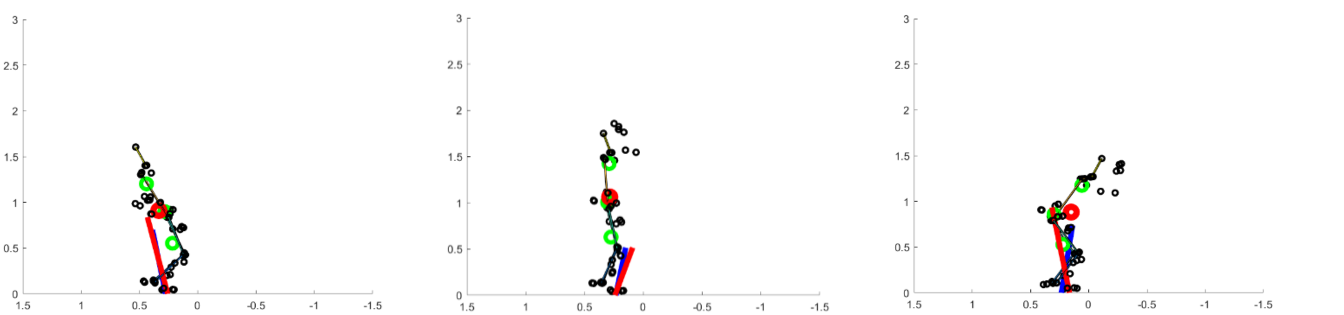

Figures 2, 3, and 4. Stick figures of participant with COM locations (red and green dots) and VGRF (red and blue lines) for reaching backward, up, and forward conditions respectively.

Table 1. Means ± Standard Deviations of Dependent Variables.

	VGRF (body weight)	Hip position at contact (body height %)	Knee position at contact (body height %))	Ankle position at contact (body height %))	Hip flexion at contact (degrees)	Knee flexion at contact (degrees)	Ankle plantar flexion at contact (degrees)	Hip flexion at 100 ms (degrees)	Knee flexion at 100 ms (degrees)	Ankle dorsiflexion at 100 ms (degree)
Backward	4.2±1.1	3.0 ± 1.6^{A}	4.6 ± 1.7^{A}	-0.6 ± 1.7^{A}	2.7 ± 8^{C}	13.5 ± 8.3^{B}	36.5 ± 6^{B}	23.0 ± 14^{C}	56.6 ± 10^{C}	26.9 ± 6.4^{A}
Up	4.4±1.0	-0.3 ± 1.7^{B}	2.7 ± 1.1^{B}	-1.3 ± 1.2^{A}	12.8 ± 7^{B}	13.5 ± 8.9^{B}	37.2 ± 10^{B}	37.0 ± 12^{B}	60.6 ± 11^{B}	25.7 ± 4.8^{A}
Forward	4.4±1.0	-7.1 ± 2.6^{C}	0.2 ± 2.5^{C}	-2.5 ± 1.8^{B}	34.8 ± 13^{A}	21.7 ± 9.5^{A}	40.3 ± 9^{A}	60.6 ± 17^{A}	66.5 ± 12^{A}	20.5 ± 6.4^{B}

Note: A>B>C at a significance level of $p < 0.05$.