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Lower extremity biomechanics during the landing of a stop-jump task

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Abstract

Background. Literature shows that landing with great impact forces may be a risk factor for knee injuries. The purpose of this study was to examine the relationships among selected lower extremity kinematics and kinetics during the landing of a stop-jump task.

Methods. Landmark coordinates and ground reaction forces during a stop-jump task were collected. Lower extremity joint angles and resultants were reduced. Pearson correlation coefficients among selected lower extremity kinematics and kinetics were determined.

Findings. The hip flexion angular velocity at the initial foot contact had significant correlation with peak posterior and vertical ground reaction forces ($r = -0.63$, $P < 0.001$, $r = -0.48$, $P < 0.001$) during the landing of the stop-jump task. The knee flexion angular velocity at the initial foot contact also had significant correlation with peak posterior and vertical ground reaction force ($r = -0.49$, $P < 0.001$, $r = -0.06$, $P < 0.001$) during the landing of the stop-jump task. Peak proximal tibia anterior shear force and peak knee extension moment during landing of the stop-jump task had significantly correlation with the corresponding posterior and vertical ground reaction forces ($r > 0.51$, $P < 0.001$).

Interpretation. A large hip and knee flexion angles at the initial foot contact with the ground do not necessarily reduce the impact forces during the landing of the stop-jump task, but active hip and knee flexion motions do. Hip joint motion at the initial foot contact with the ground appears to be an important technical factor that affects anterior cruciate ligament loading during the landing of the stop-jump task.

Keywords: ACL; Landing; Impact; Knee joint motion; Hip joint motion

1. Introduction

Landing is a frequently performed task in sports. The performances of landing tasks in sports are important not only for the performances of the tasks following the landing but also for the prevention of lower extremity injuries. Literature shows that landings with great impact forces may be a risk factor for knee injuries, especially anterior cruciate ligament (ACL) tear (Devita and Skelly, 1992; Malinzak et al., 2001; Chappell et al., 2002, 2005; Decker et al., 2003). Many studies have been conducted on the biomechanics of landing in an attempt to determine the biomechanical factors that can minimize the impact forces and knee loading during landing. Devita and Skelly (1992) reported that subjects had

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increased knee flexion angle when performing a landing with reduced ground reaction forces in comparison to that when performing a landing with increased ground reaction forces. Chappell et al. (2002) found that female recreational athletes had increased peak proximal tibia anterior shear force and peak knee extension moment and decreased knee flexion angle during landings of stop-jump tasks in comparison to their male counterpart. Chappell et al. (2005) also found that both male and female recreational athletes decreased their knee flexion angle at initial foot contact with the ground and had increased proximal tibia anterior shear force during landings of stop-jump tasks when fatigued. These results appeared to indicate that increasing knee flexion angle at initial foot contact with the ground may decrease impact forces and knee loading in landing tasks. Yu et al. (2004), however, reported that a 5° increase in knee flexion angle at initial foot contact with the ground did not significantly affect the magnitudes of ground reaction forces in a stop-jump task. Decker et al. (2003) also reported significant gender difference in ankle, knee, and hip kinematics but no significant gender difference in lower extremity kinetics during a vertical drop landing task.

The discrepancy in the literature on the biomechanics of landing may be largely due to a lack of information on the relationships among lower extremity kinematics and kinetics during landing. Previous studies on the lower extremity kinematics and kinetics (Devita and Skelly, 1992; Malinzak et al., 2001; Chappell et al., 2002; Decker et al., 2003; Yu et al., 2004) only compared the lower extremity kinematics and kinetics between groups or conditions, but did not actually examined the relationships among lower extremity kinematics and kinetics. The lack of understanding the relationships among lower extremity kinematics and kinetics during landing would be an obstacle to our understanding of lower extremity biomechanics in prevention of knee injuries. The purpose of this study was to examine the relationships among selected lower extremity kinematics and kinetics during the landing of a stop-jump task that is frequently performed in sports and associated with non-contact ACL injuries in women basketball, volleyball, and gymnastics (Boden et al., 1996; Yu et al., 2002). We hypothesized that there would be at one significant gender difference in the lower extremity kinematics and kinetics during the landing of the stop-jump task. We also hypothesized that the knee and hip kinematics would significantly correlate to the peak ground reaction forces and knee kinetics in the sagittal plane during the landing of the stop-jump task. We further hypothesized that the peak ground reaction forces in the sagittal plane would significantly correlate to the peak proximal tibia anterior shear force and peak knee extension moment during the landing of the stop-jump task.

2. Methods

2.1. Subjects

Thirty male and thirty female healthy college students between 18 and 26 years of age without known history of knee disorders were recruited as the subjects for this study (Table 1). Each subject regularly played sports and exercise two to three times/week for a total of 2–3 h without following a professionally designed training scheme. All subjects were recruited from the general student population in the University of North Carolina at Chapel Hill campus through advertising. The use of human subjects was approved by the Institutional Review Board of the School of Medicine of the University of North Carolina at Chapel Hill. Written consent was obtained from each subject before data collection.

2.2. Data collection

The athletic task tested in this study was a vertical stop-jump task frequently performed in basketball and volleyball games. This task consists of an approach run with up to five steps, and a two-footed landing followed by a two-footed takeoff for the maximum height (Fig. 1). A recent review of over 100 ACL injury cases on videotapes (Boden et al., 1996) revealed that 70% of non-contact ACL injuries occurred in stop-jump related tasks.

Table 1
Subject characteristics

	Male ($N = 30$)	Female ($N = 30$)
Age (years)	22.4 (1.6)	22.1 (1.4)
Body mass (kg)	72.8 (10.1)	55.9 (7.1)
Standing height (m)	1.78 (0.07)	1.67 (0.05)

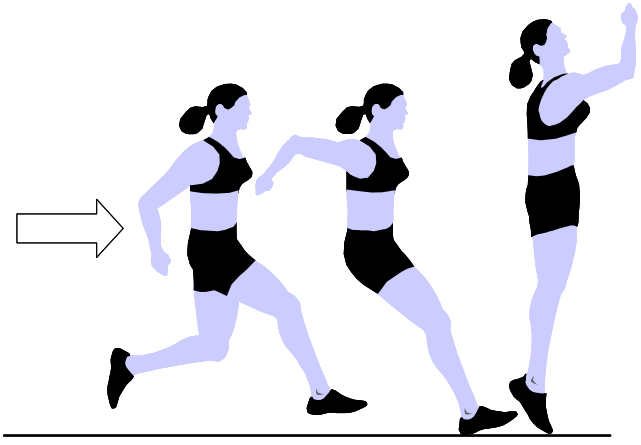

Fig. 1. Stop-jump task with up to five steps of approach run and a two-footed landing followed by a two-footed takeoff.