Ankle Landing Strategy During a Vertical Stop-Jump Maneuver Alters Knee Joint Resultant Forces

Jonathan S. Akins, Matthew A. McGinn, Nicholas R. Heebner, Timothy C. Sell, and Scott M. Lephart
University of Pittsburgh, Pittsburgh, PA, USA

INTRODUCTION

The majority of injuries among athletes are to the lower extremity with anterior cruciate ligament (ACL) injuries as one of the most common [1]. Despite prospective research, there has been no evidence of a reduction in ACL injury rates [1,2].

In an attempt to reduce the rate of ACL and other lower extremity injuries in sports, it is important to examine landing biomechanics. Previous studies have examined landing biomechanics during a stop-jump maneuver with a focus on reducing proximal tibia anterior shear force [3-5]. While ACL injuries are multi-planar, proximal tibia anterior shear force is likely the most direct loading mechanism [3]. Myers et al. demonstrated a reduction in proximal tibia anterior shear force following verbal instructions that included landing with increased knee flexion and toes first [5]. No studies were identified that specifically studied ankle joint position at landing. Landing in plantar flexion as compared to dorsiflexion allows the ankle to be an active component of the kinetic chain and may dampen the landing impact.

PURPOSE

To determine the effect of ankle landing strategy on vertical ground reaction forces (vGRFs), knee kinematics, and knee kinetics. We hypothesized that landing in plantar flexion would decrease vertical GRFs, decrease knee joint resultant forces and moments, and have no effect on knee kinematics (Figure 1).

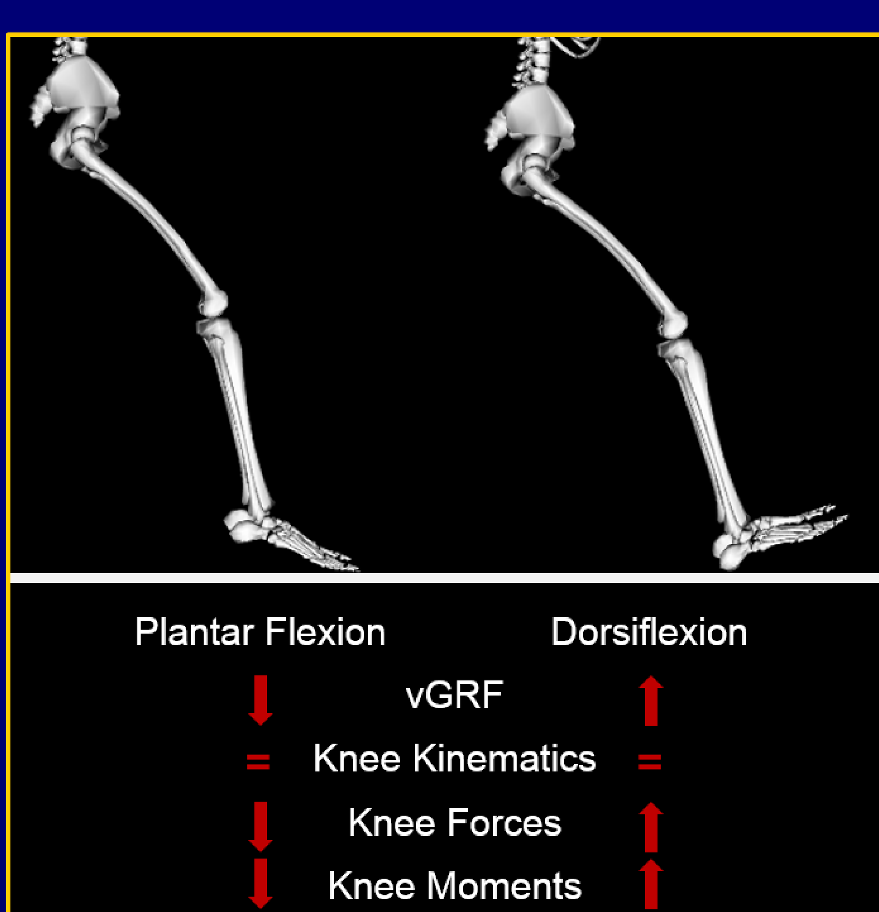

Figure 1. Hypotheses

METHODS

PARTICIPANTS

184 male military personnel

INSTRUMENTATION

Video-based motion analysis system (Vicon Motion Systems, Centennial, CO, USA) and two force platforms (Bertec, Columbus, OH, USA)

PROTOCOL

Participants performed a vertical stop-jump maneuver. Participants stood at a distance of 40% of their height from the near edge of two force platforms, jumped with both legs to the force platforms, and landed with each foot on an individual platform. Immediately after landing, subjects performed a maximum vertical jump (Figure 2).

Table 1. Group Demographics

Group	Age (years)			Height (cm)			Height (cm)		
Plantar flexion (≤ 0°)	29.8	±	7.1	177.7	±	6.2	86.0	±	8.8
Dorsiflexion (> 0°)	29.6	±	5.9	178.7	±	5.9	86.5	±	8.5

Table 2. Group Comparisons

Biomechanical Variable	Plantar Flexion Group (n=97)			Dorsiflexion Group (n=87)			p-value
Ankle Flexion at IC (°) *	-16.3	±	8.1	6.8	±	4.1	< 0.001
Knee Flexion at IC (°)	25.4	±	8.8	27.3	±	8.2	0.052
Knee Valgus at IC (°)	9.8	±	6.0	9.8	±	6.2	0.791
Peak Knee Flexion (°)	93.5	±	19.0	95.8	±	16.1	0.216
Peak Vertical Ground Reaction Forces (%BW)	202.6	±	55.2	192.1	±	59.9	0.063
Proximal Tibia Anterior Shear Force (BW) *	0.783	±	0.177	0.694	±	0.127	< 0.001
Proximal Tibia Lateral Shear Force (BW) *	0.368	±	0.152	0.309	±	0.136	0.003
Proximal Tibia Compression Force (BW) *	1.627	±	0.462	1.524	±	0.501	0.033
Knee Flexion Moment (BW)	193.4	±	46.2	180.3	±	35.7	0.129
Knee Varus Moment (BW)	30.2	±	14.7	36.2	±	23.4	0.288
Knee Internal Rotation Moment (BW)	4.16	±	4.16	3.31	±	3.37	0.147

* Significant difference (p < 0.05)

Figure 2. Stop-jump maneuver

DATA REDUCTION

Lower extremity kinematics and kinetics were calculated using the Plug-In Gait biomechanical model (Vicon Motion Systems, Centennial, CO, US).

- Vertical GRFs were used to identify initial contact of subjects with the force platforms; initial contact was identified as the time when vGRFs exceeded 5% body weight
- Knee kinematic data were calculated at initial contact and the peak values during the landing phase of the maneuver
- Peak kinetic data were calculated during the landing phase of the maneuver and normalized by body weight
- Means from three successful trials of the right leg were used for data analysis
- Subjects were categorized based on ankle joint position in the sagittal plane at initial contact (Table 1)

STATISTICAL ANALYSIS

Data were not normally distributed therefore a Mann-Whitney U test was used to identify significant differences between vGRFs, knee kinematics, and knee resultant forces and moments. All statistical analyses were performed using SPSS (Version 20, IBM, Armonk, NY, US) with alpha set as 0.05 *a priori* for all analyses

RESULTS

No significant differences were identified between vGRFs or knee kinematics (Table 2). Landing in plantar flexion resulted in significantly greater proximal tibia anterior shear force (p<.001), proximal tibia lateral shear force (p=.003), and proximal tibia compressive force (p=.033). No significant differences were identified for knee resultant moments (p=.129-.288).

DISCUSSION

Landing in plantar flexion, as compared to dorsiflexion, allows the ankle to be an active component of the kinetic chain. We hypothesized that landing in plantar flexion would decrease vertical GRFs, decrease knee joint resultant forces and moments, and have no effect on knee kinematics.

A plantar flexed position allows the gastoc-soleus complex to absorb GRFs prior to heel contact, but resulted in significantly greater knee joint resultant forces. Landing toes first shifts the GRF anteriorly with respect to the long axis of the tibia. This anterior shift creates a moment arm that the GRFs act upon. With similar vGRFs between groups, the moment arm likely increased the resultant forces acting about the knee.

Knee resultant force and moment magnitudes from this study were similar to previous studies [3,4]. Sell et al. and Yu et al. identified biomechanical (hip and knee kinematics, GRFs) and neuromuscular (vastus lateralis activation) variables that are related to proximal tibia anterior shear force [3,4], but did not study ankle position during landing.

The results of this study identified that landing in dorsiflexion may reduce proximal tibia anterior shear force. Clinicians and coaches can use these results to assist in training of maneuvers similar to stop-jumps such as basketball rebounds, volleyball spikes, and related athletic maneuvers. Future research should determine if ankle joint position at initial contact alters the distribution of ankle, knee, and hip joint kinetics, and the impact on maximal vertical jump height performance.

CONCLUSIONS

Landing in dorsiflexion significantly reduced proximal tibia anterior shear force, lateral shear force, and compressive force in military personnel during a stop-jump maneuver.

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