SPINAL MECHANICS DURING DROP LANDING: EFFECTS OF GENDER AND LANDING TECHNIQUE

Soo-An Park [1] John W. Chow [2], and Mark D. Tillman [2]

[1] SUNY – Upstate Medical University, Syracuse, NY, USA
[2] University of Florida, Gainesville, FL, USA
E-mail: parkso@upstate.edu

INTRODUCTION

The mechanics of spine during activities that demand vigorous spinal movements has rarely been studied. The purpose of this study was to determine the effects of gender and landing techniques on spinal column kinematics and loads to the lumbosacral (L/S) and cervicothoracic (C/T) junctions during drop landings.

METHODS

Thirteen male (21.4 ± 1.3 yrs) and 13 female (21.1 ± 1.3 yrs) healthy individuals participated in this study. A sagittal plane 5-segment (3 lower extremity and 2 spinal segments) mechanical model was used. A set of reflective markers was placed on the lower extremity, pelvis and trunk, and another set was placed on skin over selected spinous processes to track the kinematics of different spinal regions (Figure 1).

Data were collected using a 3-D motion capture system (Motion Analysis Corp., Santa Rosa, CA) and a Bertec forceplate. Each subject performed 3 drop landings using his/her own landing technique (NL) and 3 soft landings with instruction (SL). During each trial, the subject descended from a 50- cm high platform and landed on a forceplate with the left foot at the center of forceplate. Assuming bilateral symmetry in lower extremity mechanics, GRFs were doubled when applied to the model.

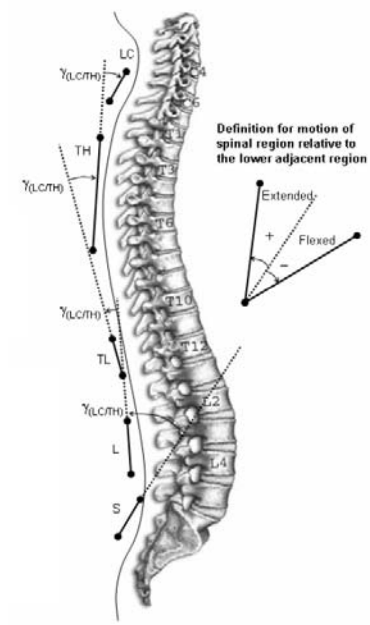

Figure 1: Ten markers on the spine were used to define different spinal regions – sacral (S), lumbar (L), thoracolumbar (TL), thoracic (TH), and lower cervical (LC) regions.

Dependent variables were divided into 5 groups. One group of landing variables was peak vertical GRF, time for landing phase, touchdown angles and flexion ROMs of knee and hip joints after touchdown. Two groups of spinal kinematics included touchdown (TD) angle and initial extension ROM of different spinal regions. The angle of a spinal region was defined as the angle between the spinal region and its lower adjacent region. Two groups of spinal kinetics included joint resultants at L/S and C/T junctions computed using an inverse dynamics approach. The 5 groups of dependent variables were submitted to 5 separate 2 × 2 (Gender × Landing type) MANOVAs with repeated measures on the last factor and follow-up univariate analyses of variance were conducted when appropriate.

RESULTS AND DISCUSSION

MANOVA and follow-up univariate tests revealed that, when going from NL to SL condition, significant increases in the landing phase (0.22±0.08s to 0.36±0.14s, $p<0.001$), TD angles (knee: 7.3±6.8° to 10.5±6.4°, $p<0.001$; hip: 61.5±12.0° to 66.6±12.3°, $p<0.001$), flexion ROMs of knee (53.0±10.4° to 69.9±14.2°, $p<0.001$) and hip (33.3±13.7° to 51.2±10.8°, $p<0.001$) joints, extension ROMs in TH (4.6±3.7° to 8.0±5.1°, $p<0.001$) and LC (10.3±7.8° to 16.3±10.4°, $p=0.006$) regions, and decreases in peak vertical GRF (23.91±3.87 $N\cdot kg^{-1}$ to 15.77±3.03 $N\cdot kg^{-1}$, $p<0.001$) and all joint resultants for L/S ($p<0.001$) and C/T junctions ($p<0.001$) were observed (Table 1.A).

Females exhibited significantly greater TD angle of TL region ($p=0.003$), flexion ROM of hip ($p=0.001$) and extension ROM of TH region ($P=0.012$) than males across both landing conditions. Greater TL TD angle means that TL region was extended and increased the lumbar lordosis by the definition of variable. The significant interaction in TH TD angle between gender and landing type ($p=0.032$) means that males demonstrated more flexed TH region at TD from NL to SL condition, while females did not (Table 1.B).

The model used in this study showed reasonably matched values of spinal kinetics and kinematics comparing with the landing variables. Spinal kinetics during drop landing significantly decreased from NL to SL in each gender, but some gender differences were shown in kinematics. Females demonstrated extended TL region and increased lordosis at TD and compensated for it by using greater motion at the hip joint and TH region during the landing phase, whereas males showed more flexed TH posture at TD from NL to SL condition.

SUMMARY/CONCLUSIONS

Gender differences in spinal kinematics at TD and compensatory motions during drop landing (an activity demands vigorous spinal movements) may be one of the reasons for the gender disparity in knee joint injury. Regardless of gender, the increased motions of TH and LC regions from NL to SL, in addition to the increased motions of lower extremity joints, suggest that the spinal column is actively involved in energy absorption during drop landings.

Table 1: A. Spinal kinetics with significant main effect for landing type. B. Dependent variables showed significant gender main effect (*) and interaction (+). (mean ± SD)

A		**AxF** ($N\cdot kg^{-1}$)	**ShF$_{ant}$** ($N\cdot kg^{-1}$)	**ShF$_{post}$** ($N\cdot kg^{-1}$)	**FlxM** ($N\cdot m\cdot kg^{-1}\cdot BH^{-1}$)	**ExtM** ($N\cdot m\cdot kg^{-1}\cdot BH^{-1}$)
L/S	NL	20.91 ± 6.04	3.24 ± 1.60	21.75 ± 7.29	2.72 ± 0.90	7.06 ± 2.30
	SL	13.97 ± 3.84	1.84 ± 1.03	10.16 ± 4.92	1.84 ± 0.88	3.91 ± 1.40
C/T	NL	21.95 ± 8.23	10.35 ± 3.99	10.35 ± 3.99	5.65 ± 1.68	6.94 ± 2.66
	SL	9.75 ± 5.04	8.70 ± 3.49	8.70 ± 3.49	4.11 ± 1.62	3.64 ± 1.33

B		**TD angle of TL/L (°)***	**TD angle of TH/TL (°)+**	**Ext ROM of TH/TL (°)***	**Flx ROM of Hip (°)***
Male	NL	7.6 ± 5.1	-23.1 ± 6.2	3.3 ± 2.8	24.8 ± 11.5
	SL	7.2 ± 6.1	-25.1 ± 8.2	5.4 ± 3.9	47.0 ± 7.2
Female	NL	16.1 ± 7.8	-20.7 ± 7.6	6.0 ± 4.2	41.7 ± 10.2
	SL	16.7 ± 8.4	-20.1 ± 6.9	10.6 ± 4.9	55.5 ± 12.3

Note: A positive TD angle indicates the spinal region is in an extended state or extension motion relative to the lower adjacent region (see Figure 1). Abbreviations: AxF (axial force), ShF (shear force), FlxM (flexion moment), ExtM (extension moment)