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THE EFFECT OF FATIGUE ON PEAK GROUND REACTION FORCE AND LOWER EXTREMITY KINEMATICS DURING SINGLE-LEG LANDING IN DANCERS

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The purpose of this study was to examine the effect of fatigue on peak vertical ground reaction force and lower extremity kinematics during single-leg landing in dancers and non-dancers. Subjects (n=20) were divided into two groups; Dance group (n=10) and Control group (n=10). Subjects performed single-leg drop landing from a 30 cm platform before and after fatigue protocol. Before fatigue protocol, dancers showed significant longer time between initial contact and the maximum ground reaction force achieved compared with the controls. After fatigue protocol, there was significant increase in peak ground reaction force during landing for both dancers and controls. Both groups also showed significant increase in hip and knee flexion after fatigue protocol.

KEY WORDS: dancer, drop landing, fatigue, ground reaction force, lower extremity kinematics.

INTRODUCTION: Previous study reported that dance has been shown to have much lower incidence of ACL injuries compared with team sports (Liederback et al., 2008). Other study indicated that there was no gender disparity in dancers for landing biomechanics (Orishimo et al., 2009). Considering previous reports, it is speculated that dance training would induce unique landing biomechanics. On the other hands, fatigue would be one of the risk factors for injury during landing from a jump. Several studies demonstrated that fatigue would influence landing biomechanics or muscle activities that would induce larger stress or deteriorate shock attenuation on landing. However, the effect of fatigue on biomechanical risk factors during landing for dancers had not been fully elucidated. So the purpose of this study was to examine the effect of fatigue on peak vertical ground reaction force and lower extremity kinematics during single-leg landing in female Japanese dancers and non-dancers.

METHODS: Subjects were ten dancers who had been performing dance training more than ten years as the dance group and ten female university students who had no experience of dance training as well as intense physical training including jumps or landings as the age-matched control group. They had no history of surgery to the lower extremities and no lower extremity injuries within the past years. Subjects performed 3 single-legged drop jumps from 30-cm platform on to a force plate with barefoot. All landings were performed on the dominant leg. Eight reflective markers were placed right calcaneus, third and fifth metatarsal, lateral malleolus, great trochanter, and anterior superior iliac spine. Video images were recorded from the front and the side of the subject at 60Hz. Kinematic variables were calculated by a motion analysis software (Frame Dias, Japan). Ground-reaction forces were recorded at 1000Hz with a force platform (Kistler, Switzerland). Landings were defined from initial contact with the force plate to the maximum amount of knee flexion achieved during each trials. After three drop jumps, subjects performed fatigue protocol consisted from repetitive 100 counter movement jumps with maximal efforts at 90bmp and 100 consecutive jumps over 5cm obstacles. This fatigue protocol was designed in previous studies (Pappas et al, 2007). All subjects completed all post-fatigue trials within three minutes after the completion of the fatigue protocol.

RESULTS: There was no significant difference in the subjects` height, while there was significant difference in the body weight between two groups. Figure 1 showed typical

example of vertical ground reaction force with time during a single-leg drop landing. There was a significant increase in peak vertical ground reaction force during landing from 3.6 (SD 0.4) BW to 4.0 (SD 0.9) BW after fatigue protocol for the dancers, while there was a significant increase in peak ground reaction force during landing from 4.1 (SD 0.9) BW to 4.2 (SD 1.0) BW for the controls. Before fatiguing protocol, dancers showed significant longer time from initial contact to the achievement of peak ground reaction force compared with the controls. After fatigue protocol, there was no significant difference in the time from initial contact to the achievement of peak ground reaction force during drop landing between two groups (Figure 2). There was a significant increase in the peak hip range of motion in the fatigued state compared with the unfatigued state in both dancers and controls. Both groups also showed significant increase in peak knee range of motion in the fatigued state during drop landing, while dancers showed significant larger peak knee range of motion compared with the controls in the fatigued state. On initial contact during drop landing, the dancers showed significant smaller knee joint angle compared with the controls in the fatigued state as well as in the unfatigued state. There was a significant decrease in the peak ankle range of motion in the fatigued state for both groups.

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Mean Joint Angle (deg) (SD)		pre	post	pre	post	pre	post
On initial contact during landing	dancers	30.0(5.7)	31.0(5.1)	13.6(2.6)	14.0(3.6)	-34.4(7.5)	-31.8(6.4)
	controls	32.2(8.3)	32.9(9.7)	22.2(3.8)	21.1(4.2)	-28.6(2.6)	-27.6(4.7)
Peak flexion or dorsi flexion	dancers	41.6(5.9)	48.4(10.6)	63.1(7.1)	72.9(6.1)	22.0(6.2)	27.2(6.5)
	controls	42.5(9.7)	45.4(13.8)	65.2(9.2)	70.0(8.6)	21.0(5.2)	23.8(4.3)
delta between the initial contact and the peak angle achieved	dancers	11.7(6.8)	17.4(8.9)	49.5(6.3)	58.8(5.3)	56.5(7.4)	59.0(5.4)
	controls	10.3(4.5)	12.5(6.6)	43.0(6.3)	48.8(5.1)	49.6(6.2)	51.4(4.7)

Table 1 Lower extremity kinematic variables for dancers and controls at pre and post fatigue

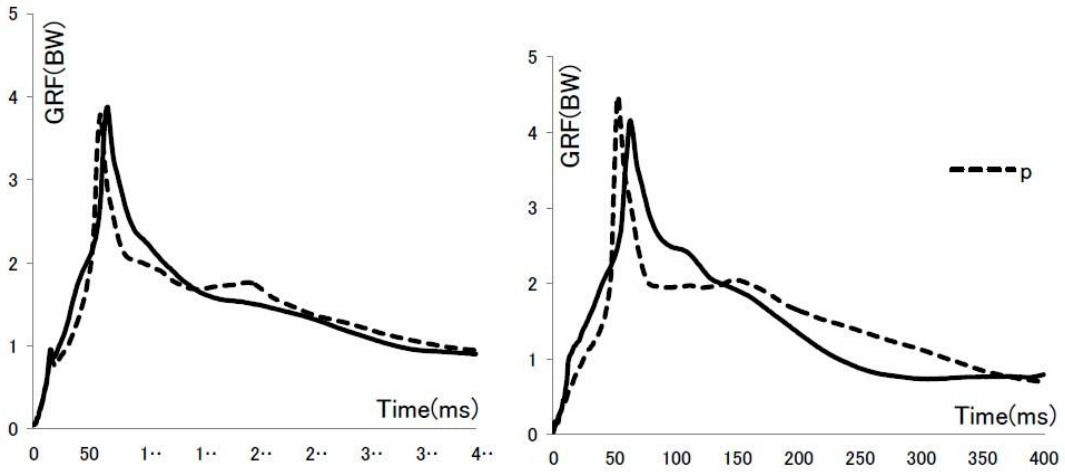

Figure 1: Typical pattern of ground reaction force during landing
(Left figure: Dance group, Right figure: Control group)
(Solid line: before fatigue, dot line: after fatigue)

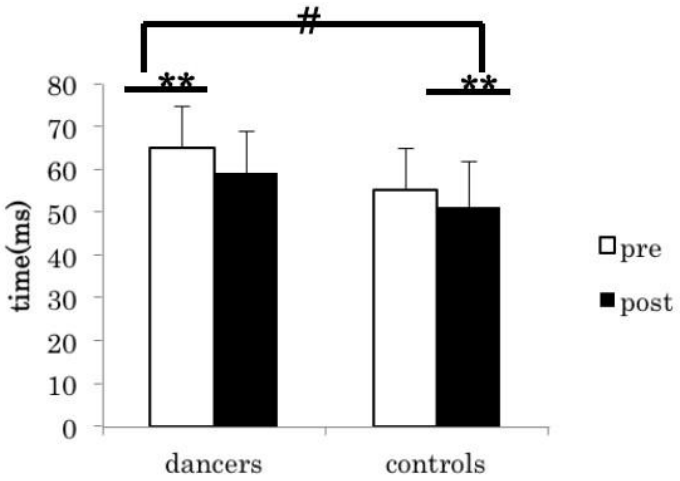

Figure 2: Time between initial contact and the achievement of peak vertical ground reaction force for dancers and controls before and after fatigue protocol

DISCUSSION: Before fatigue protocol, dancers showed unique landing biomechanics such as longer time from initial contact to the achievement of the peak ground reaction force, less hip flexion, less knee flexion, and greater plantar flexion during drop landing. According to the theory proposed by Huston et al. (2001), straight knee landing would lead higher incidence of ACL injury. Despite this theory, in this study, there was no significant difference between dancers and controls in the peak ground reaction force during landing, while dancers` legs more straightened. This theory could not explain dancers` unique landing biomechanics and further research would be needed in this regard. The purpose of this study was to examine the effect of fatigue on landing biomechanics and its relation with long-term dance training. In this study, there was a significant main fatigue effect for peak vertical ground reaction force and lower extremity kinematics such as hip, knee, and ankle joint angle regardless of dance training, although there was no group main effect for those measured variables. So it is indicated that fatigue would change landing biomechanics for either dancers or non-dancers which would increase the possibility of injury during landing.

CONCLUSION: The present study investigated the effect of fatigue on the biomechanical variables of single-leg drop landing for dancers and non-dancers. The findings showed that fatigue elicited a similar response in dancers and non-dancers, resulting in significantly increased peak vertical ground reaction force and peak hip, knee and ankle flexion, while landing biomechanics in the unfatigued state for dancers were partly different from those for controls.

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