THE JOINT KINETICS OF THE LOWER EXTREMITY ASSOCIATED WITH DROP JUMP HEIGHT INCREMENTS

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The purpose of this study was to identify the joint kinetics of the lower extremity associated with drop jump height increments. Sixteen subjects performed the drop jumps from the 20, 30, 40, 50 and 60-cm heights. Eleven Eagle cameras (200 Hz) and two AMTI force platforms (2000 Hz) were synchronized to collect the data. The study showed the impact was relatively larger in the higher height of drop jump. The greater joint absorption in drop jump from 40, 50 and 60-cm heights was found in the study. Moreover, subjects had greater knee and ankle absorption in drop jump during the eccentric movement. Drop jumps from 20 and 30-cm heights were advisable.

KEY WORDS: plyometric, biomechanics, power, work.

INTRODUCTION: Many athletes practice the drop jump as a kind of plyometric exercise for training their lower extremities. Plyometric training is widely used to enhance the neuromuscular ability since the stretch-shortening supplies the elastic energy and elicit the stretch reflex for greater force output (Bosco, Viitasalo, Komi, & Luhtanen, 1982). Athletes who need explosive jumping performances are often trained with drop jumps from different heights of platforms. Commonly, athletes perform the drop jumps at increased heights for a greater training stimulus. However, the intensity of drop jump is based on anecdotal evidence rather than scientific evidence. In these circumstances, they may be exposed to a higher incidence of joint injuries. Previous research has quantified various plyometric exercises (Jensen & Ebben, 2007). Few studies examined the incremental height of drop jump. The purpose of this study was to investigate the joint kinetics of the lower extremity associated with drop jump height increments.

METHODS: Data Collection: Sixteen college students of the department of physical education – eleven males (age: 21.8 ± 1.8 years; height: 172.8 ± 8.1 cm; mass: 73.6 ± 15.5 kg) and five females (age: 21.2 ± 1.1 years; height: 162.4 ± 3.8 cm; mass: 57.2 ± 7.2 kg) voluntarily participated in this study. All volunteers had no prior knee pain or any history of trauma on other joints of the lower extremities. Subjects changed into specific footwear (Model s.y.m. B9025, Lurng Furng, Inc., Taipei, Taiwan) to control for the different shoe-sole absorption properties before testing. A standardized dynamic warm-up of five-minute cycling on a stationary bicycle at a self-selected pace was performed prior to the testing protocol. Following the warm-up, subjects rested for five minutes. Each subject performed three bounce drop jumps from each of the 20, 30, 40, 50 and 60-cm heights (DJ20, DJ30, DJ40, DJ50 and DJ60). The testing sequence was randomly determined. They were asked to immediately and maximally jump off the ground after landing (Bobbert, Huijing, & van Ingen Schenau, 1987a, b). Their hands were put on their waist during the drop jumps. A sixty-second rest was practiced between jumps.

The movement data were collected with eleven Eagle cameras (Motion Analysis Corporation, Santa Rosa, CA, USA) at 200 Hz sampling rate which were positioned around the performance area. Cameras were synchronized to two force platforms (AMTI Inc., Watertown, MA, USA) which sampling rate was 2000 Hz. One platform collected the right leg data, and another collected the left leg data. Both kinematic and kinetic data were recorded in EVaRT software (Version 4.6, Motion Analysis Corporation, Santa Rosa, CA, USA).

Data Analysis: The data were analyzed in Orthotrak software (Version 6.2, Motion Analysis Corporation, Santa Rosa, CA, USA). The dominant leg, determined in relation to the foot normally used to kick a ball, was analyzed for all subjects. The landing and jumping off during the impact phase was determined where the vertical ground reaction force (vGRF) exceeded a 10 N threshold. The impact phase was then divided into the eccentric and concentric phases where the eccentric phase was from the landing to maximal knee flexion, and the concentric phase was from the maximal knee flexion to jumping off the ground.
The power of joints were calculated from the inverse dynamics. The work of joints was calculated from the integration of power-time curve. The average power of joints was the work divided by the impact time. These variables were normalized by each subject's body weight (BW). The impulse was calculated from the integration of force-time curve. The vertical ground reaction force was also normalized to subjects' body weight.
One-way repeated measures ANOVAs were used to compare the differences between drop jump heights in peak vGRF, time to peak vGRF, peak knee flexion angle, impulse, and duration variables during the phases of the jump. Two-way (3 joints × 5 heights) repeated measures ANOVAs were used to compare the differences between joints and drop jump heights during eccentric and concentric phases in power and work. The significance level was set at α=0.05. The *post-hoc* analysis was performed with the Bonferroni test.

RESULTS: Mean peak vGRF, time to peak vGRF, peak knee flexion angle, impulse, and duration variables are shown in Table 1. The peak vGRF in DJ50 and DJ60 was significantly greater than that in DJ20, DJ30 and DJ40 (*P*=.000). The impulse in DJ40, DJ50 and DJ60 during eccentric phase was significantly greater than that in DJ20 and DJ30 during eccentric phase (*P*=.000). No difference was found in impulse during the concentric phase. The time to peak vGRF in DJ40, DJ50 and DJ60 was significantly smaller than that in DJ20 (*P*=.000). No difference was found in the duration of both eccentric and concentric phases and in the peak knee flexion angle.

Table 1 Peak vGRF, time to peak vGRF, peak knee flexion angle, impulse, and duration variables; MEAN (SD). (N=16)

Variables	DJ20	DJ30	DJ40	DJ50	DJ60
Peak vGRF (BW)	2.00 (0.22)	2.27 (0.47) [d]	2.47 (0.50) [d]	3.07 (0.75) [b]	3.78 (0.85) [a]
Eccentric Impulse (BW · s)	0.185 (0.035)	0.197 (0.039)	0.221 (0.028) [c]	0.232 (0.025) [c]	0.265 (0.037) [a]
Concentric Impulse(BW · s)	0.189 (0.021)	0.191 (0.026)	0.189 (0.026)	0.198 (0.032)	0.194 (0.027)
Total Impulse (BW · s)	3.682 (0.486)	3.878 (0.552)	4.075 (0.488) [d]	4.271 (0.494) [c]	4.552 (0.543) [a]
Eccentric Time (ms)	143 (42)	142 (42)	146 (36)	148 (37)	156 (41)
Concentric Time (ms)	165 (30)	168 (37)	168 (35)	178 (46)	184 (46)
Contact Time (ms)	309 (68)	309 (77)	315 (70)	325 (81)	340 (86)
Time to peak vGRF (ms)	119 (51)	84 (44)	70 (28) [f]	60 (24) [f]	49 (8) [e]
Peak knee flexion (degree)	79.0 (12.0)	77.1 (13.6)	78.3 (13.0)	80.9 (16.9)	83.4 (16.7)

[a] Significantly greater than 20, 30, 40, 50 cm; [b] Significantly greater than 20, 30, 40 cm; [c] Significantly greater than 20, 30 cm; [d] Significantly greater than 20 cm; [e] Significantly smaller than 20, 30, 40 cm; [f] Significantly smaller than 20 cm. (*P*<.05)

The results of comparing the differences between joints and drop jump heights during eccentric and concentric phases are shown in Figure 1. Negative power and work during eccentric phase are expressed in absolute value in the figure. The negative power indicates absorption power while the positive power indicates generation power (Winter, 1990). The peak absorption power and average absorption power of the hip, knee and ankle joint in DJ50 and DJ60 during eccentric phase were significantly greater than those in DJ20 and DJ30 (*P*=.000). A significant interaction was found in work between joints and heights (*P*=.025), then the simple main effect was tested in joints and heights, respectively. The work at the ankle joint in DJ40 and DJ60 during eccentric phase was significantly greater than that in DJ20 and DJ30. The work at the knee joint in DJ40, DJ50 and DJ60 during eccentric phase was significantly greater than that in DJ20 and DJ30. The work at the hip joint in DJ60 during eccentric phase was significantly greater than that in DJ20 and DJ30. The peak

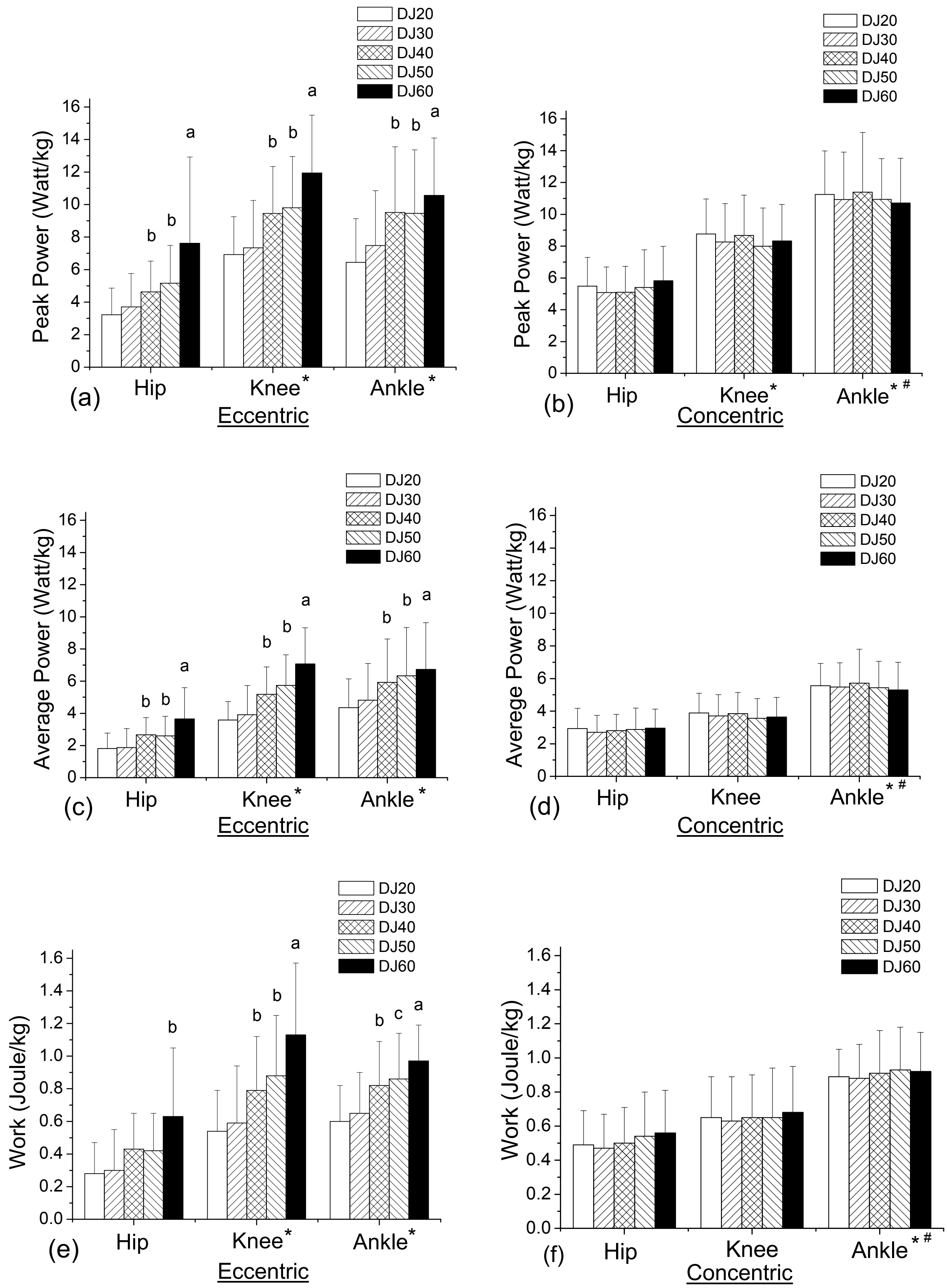

Figure 1: Peak power of joints in different heights during (a) eccentric and (b) concentric phase; Average power of joints in different heights during (c) eccentric and (d) concentric phase; Work of joints in different heights during (e) eccentric and (f) concentric phase. [a] Significantly greater than 20, 30, 40 cm; [b] Significantly greater than 20, 30 cm; [c] Significantly greater than 20 cm; * Significantly greater than Hip; # Significantly greater than Knee. (*P*<.05)

absorption power, average absorption power and work of the knee and ankle joint during eccentric phase were significantly greater than those of the hip joint. The peak generation power, average generation power and work at the ankle joint were significantly greater than those at the knee and hip joint during the concentric phase. The peak generation power at the knee joint was significantly greater than that at the hip joint during concentric phase.

DISCUSSION: The study showed the impact was relatively greater in the drop jump of higher heights. If a subject stands on a higher platform, theoretically his body will have higher potential energy. The potential energy transfers to the kinetic energy which is proportional to the square of velocity during the fall (Hall, 2002). After landing, the downward velocity of his body has to be reduced to zero before push-off can start (Bobbert, Huijing, & van Ingen Schenau, 1987b). The eccentric impulse could reflect the profile that as a subject tried to decelerate while the concentric impulse would be the effort of push-off. Subjects had greater impact peak force and eccentric impulse when jumping from 40, 50 and 60-cm heights. The higher the drop jump height is; the greater joint muscle effort may be needed to decelerate during the landing.

Subjects utilized hip, knee and ankle joint muscles to absorb the impact during the eccentric movement. A higher rate of joint power absorption was performed with the raised platform to reduce the direct impact to the body. Greater joint power absorption in drop jumps from 40, 50 and 60-cm heights were found in the study which maybe with regard to high injury risk. Moreover, the knee and ankle had greater power absorption in drop jumps during the eccentric movement which was in agreement with studies by Bobbert, et. al. (1987b) and Walsh, Arampatzis, Schade, & Bruggemann (2004).

Following the absorption, the joint muscles generated power to push off. In this study, subjects could not generate more power during the push-off due to the contact time limitation. The joint power generation which mainly contributed to the jump performance during the concentric movement showed less variation with respect to drop height increments. Bobbert, et. al. (1987b) indicated that there was no advantage of performing drop jumps from a height of 60 cm. The contact time of drop jump was the factor for joint power generation rather than the height (Bobbert, et. al., 1987a, b). In addition, the greater ankle joint power generation output was found to contribute to the push-off.

CONCLUSION: Athletes should be cautious when practicing drop jumps from 40, 50 and 60-cm heights because of the greater impact at the knee and ankle. In terms of injury prevention, drop jumps from 20 and 30-cm heights were advisable in this study. The further study could look into the muscles activation.

REFERENCES:

Bobbert, M. F., Huijing, P., & van Ingen Schenau, G. (1987a). Drop jump I. The influence of dropping technique on the biomechanics of jumping. *Med. Sci. Sports Exerc, 19*, 332-338.

Bobbert, M. F., Huijing, P., & van Ingen Schenau, G. (1987b). Drop jump I. The influence of dropping height on the biomechanics of jumping. *Med. Sci. Sports Exerc, 19*, 339-346.

Bosco,C. Viitasalo, J.T., Komi, P.V., & Luhtanen, P. (1982). Combines effect of elastic energy and myoelectrical potentiation during stretch-shortening cycle exercise. *Acta. Physiol Scand, 114*, 557-565.

Jensen, R. L., & Ebben, W. P. (2007). Quantifying plyometric intensity via rate of force development, knee joint, and ground reaction forces. *Journal of Strength and Conditioning Research, 21*(3), 763-767.

Walsh, M., Arampatzis, A., Schade, F., & Bruggemann, G. P. (2004). The effect of drop jump starting height and contact time on power, work performed, and moment of force. *Journal of Strength and Conditioning Research, 18*(3), 561-566.

Hall, S. J. (2002). *Basic biomechanics (4th edition)*. Columbus: McGraw-Hill.

Winter, D. A. (1990). *Biomechanics and motor control of human Movement (2nd edition)*. New York: John Wiley & Sons.

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