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BIOMECHANICAL EFFECT OF JUMPING SPEED ON THE PYRAMIDING BOX HOPS

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The purpose of this study was to compare three different jumping speeds (60 bpm, 75 bpm and 90 bpm) while performing pyramiding box hops in order to investigate the optimal rate for post-injured athletes in the return to sport phase of rehabilitation. Twelve healthy, competitive male athletes with specialty in jump were recruited from track and field team. Kinematical and kinetic data of lower extremities were collected via three-dimensional motion analysis system and two force plateforms. One-way ANOVA (SPSS) was used to determine difference among rates. Less hip adduction, knee valgus and knee valgus/varus moments were found at the rate of 90 bpm. Therefore, performing pyramiding box hops at the rate of 90 bpm may be more pertinent for post-injured athletes with ACL injury.

KEYWORDS: plyometric exercise, ACL, rehabilitation

INTRODUCTION: Anterior cruciate ligament (ACL) injury is a prevalent injury in sport fields especially with non-contact mechanism. Excessive dynamic valgus including hip adduction, knee valgus and ankle eversion was regarded as the predisposing factors for non-contact ACL injuries (Ford, et al., 2005). In the previous studies, various exercises were used as the ACL injury prevention program or post-injured therapeutic exercise including resistance training, plyometric exercise or a combination of two (Lehnhard, 1996; Hewett et al., 1996). Plyometric exercise contains the properties of multiple repetitions, high impacts, high intensities and high loadings that it helps athletes to enhance jumping performance, increase explosive power, increase concentric velocity and improve agility (Toumi, Best, Martin & Poumarat, 2004). However, the demands of this form of exercise could also lead to higher risk of injuries if the athletes didn't meet the criteria before including plyometric exercise into their training programs (Chu, 1998; Hreljac et al., 2000; Potach & Chu, 2000) and let alone for post-injured athletes. Therefore, quantifying plyometric exercise becomes an important issue since there was still no formulated way to determine the intensity as what is in resistance training. Pyramiding box hops was ranked as a more advanced jump among five types of plyometric jumps (Chu, 1998) and the jumping speed is a means to adjust the intensity of plyometric exercise (Houglum, 2001); therefore, three rates (60 bpm, 75 bpm & 90 bpm) were set to represent different jumping speed in order to determine the optimal rate for post-injured athletes in the return to sport phase of rehabilitation via investigating the biomechanical parameters of range of motion (ROM), joint force and joint moment for lower extremities.

METHODS: Twelve healthy, competitive male athletes with specialty in jump were recruited from track and field team (21±2 y/o; 178±8 cm; 70±6 Kg) with no history of serious knee injury or other lower extremity trauma within six months. Written informed consent was provided by the subjects and the study was approved by Research Ethics Committee of the Central Regional Research Ethics Center. VICON motion analysis system and two Kistler force plateforms were used for data collection in the current study. Three pairs of plyometric boxes were set 62.5 cm apart in a line for the following pyramiding box hops, and the box heights were 20 cm, 30 cm and 40 cm respectively with nonslip surfaces attached on the top of the boxes. The marker set attached on the anatomical landmarks of the subjects was modified from Helen Hayes to represent the three-dimensional trajectory of each body segment. The

subjects were first standing with feet shoulder-width apart and then instructed to perform pyramiding box hops with jumping rates of 60 bpm, 75 bpm and 90 bpm respectively. One-way ANOVA was used to compare three different rates relating to the parameters of lower extremity ROM, joint moments and joint forces during the pyramiding box hops.

RESULTS: ROM of hip flexion/extension was found significantly greater in both 60 bpm and 75 bpm than in 90 bpm, while 60 bpm and 75 bpm had no significant difference. In hip internal/external rotation, ROM in 75 bpm was greater than in 90 bpm. While in knee flexion/extension, adduction/abduction and internal/external rotation, ROM in 90 bpm seemed to be the least among all rates. Knee anterior shear force, knee posterior shear force and ankle medial shear force were found the greatest at the rate of 90 bpm. Joint moment appeared to be the greatest at the rate of 90 bpm for knee extensor moment, ankle plantar flexor moment, and ankle internal rotation moment, while the opposite result was found in hip flexor moment. Though the following finding had no statistical significance, these was a trend found at the rate of 90 bpm to hold the lowest value in ROM of hip adduction, knee valgus moment and Knee varus moment as well as knee medial shear force.

DISCUSSION: Less ROM of hip and knee flexion/extension found at the rate of 90 bpm may indicate that subjects performed pyramiding box hops with a stiffer landing which was required for the better athletic performance and would utilize streth-shortening cycle (SSC) more effectively (Hewett et al., 2004). In a knee injury review (Dugan, 2005), adduction and internal rotation of the femur was emphasized to be avoided during landing because those would result in increasing the risk of ACL injury; excessive knee adduction/abduction should also be avoided because of the reason that improper position of the knee joint such as knee valgus during the landing task is the predisposition of ACL injury (Dugan, 2005; Lephart et al., 2005). In this case, our finding may indicate that 90 bpm had better landing position with less undesired knee joint frontal plane deviations compared to 75 bpm and 60 bpm. Knee anterior shear force was found the greatest at the rate of 90 bpm, however, Yu & Garrett (2007) suggested that a combination of knee anterior shear force and knee valgus/varus moment resulted in the greater stress on ACL than anterior shear force alone. Our finding was also correspondent with the notion mentioned above that 90 bpm had the greatest knee anterior shear force among all rates, but it had the lowest value among all in other factors. To sum it up, 90 bpm was found to have less contributing factors for non-contact ACL injury.

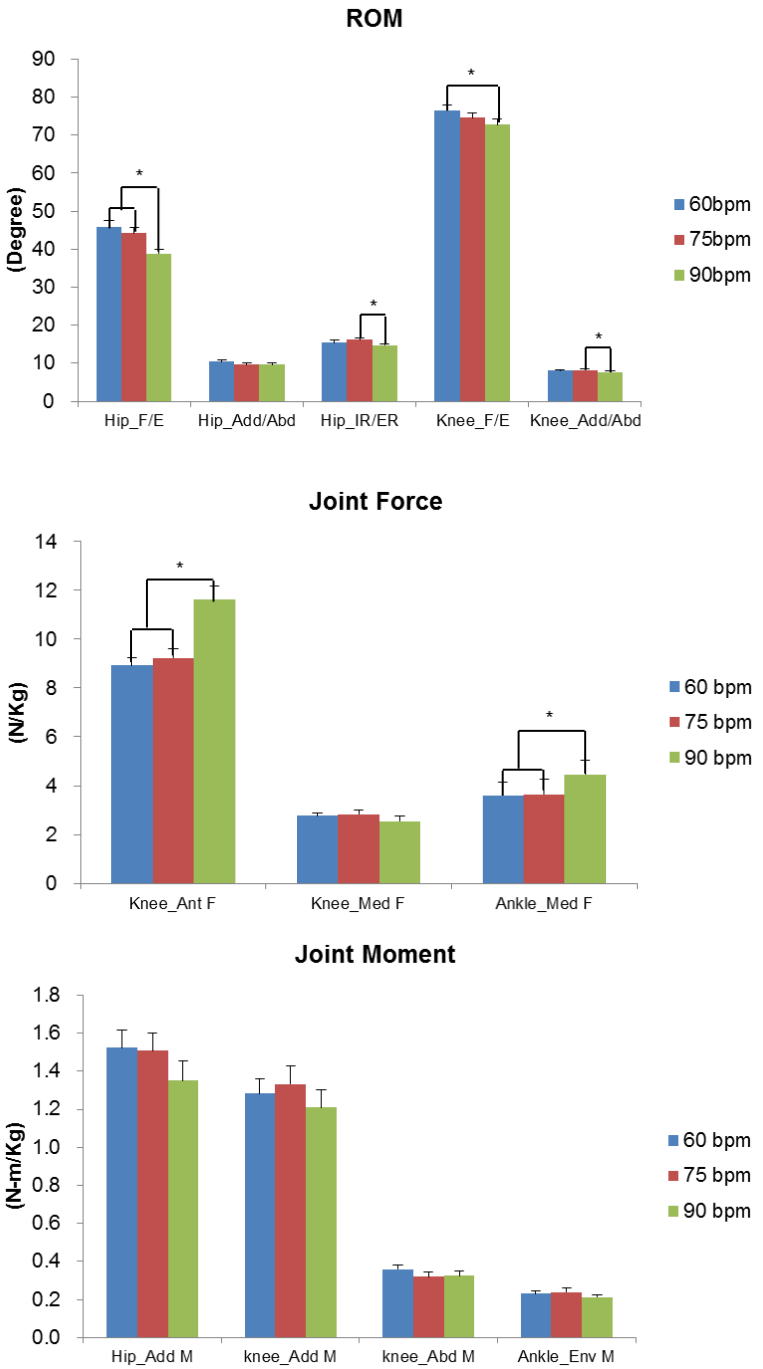

Figure 1. ROM, joint force and joint moments relate to ACL injury contributing factors.

CONCLUSION: According to Chu's notions (1998), all of the jumping speeds set in this study were considered to be the low-intensity task for the beginning and off-season sessions; therefore, they are regarded to be suitable for the beginners or the athletes in the return-to-sports phase of rehabilitation. As a general rule, training at the rate of 90 bpm is more recommended than the other two rates because of the benefit from the effect of stretch-shortening cycle (SSC) and because of the better landing position as well as less undesired moments.

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