CHANGES IN LOWER LIMB JOINT RANGE OF MOTION ON COUNTERMOVEMENT VERTICAL JUMPING

Adam Clansey[1] and Adrian Lees[2]

[1]Sport and Exercise Sciences Research Institute, University of Ulster, Jordanstown, Northern Ireland
[2]Research Institute for Sport & Exercise Sciences, L.J.M.U, Liverpool, UK

KEYWORDS: coordination, countermovement, range of motion, relationship.

INTRODUCTION: Humans naturally perform a countermovement (CM) action in order to attain a certain height or distance in jumping. This CM action initiates many movement coordination principles such as increasing lower limb joint range of motion (ROM) to allow the performer to be in a more effective position for jumping. In a study where the knee joint ROM was experimentally controlled Moran and Wallace (2007) reported a 17% increase in jump height with a 20° increase in knee joint flexion. Although Moran and Wallace (2007) experimentally controlled two knee flexion ranges, their results revealed a natural increase in hip joint ROM with subsequent increased knee flexion. No study, to the author's knowledge, has managed to identify the possible relationship between knee and hip joint ROM during a CM jump. The aim of this study is to examine the relationship between hip and knee joint ROM during CM vertical jumping and to determine if there are optimum joint flexion ranges at the hip and knee for jump height.

METHOD: Six healthy male participants (23 ± 6 years, 1.80 ± 0.10 m and 68.82 ± 8.1 kg) were asked to perform a series of 8 (non-arm) maximum effort CM vertical jumps with a wide array of peak knee flexion ranges. Verbal feedback and demonstrations on the required knee flexion range were given to each participant before commencement of each trial. Motion capture data collected at 240 Hz recorded a 6 degrees of freedom (DoF) lower limb retro reflective marker set from a standing position to the apex of the jump. Joint kinematics (sagittal plane) of the hip, knee and ankle were processed and analysed. Jump height was defined by the vertical displacement of the sacrum marker from standing to the apex of the jump. The coefficient of determination (R^2) was calculated to assess the relationship between kinematic variables during the CM action.

RESULTS: A strong positive curvilinear relationship was observed between peak hip and knee joint flexion ranges ($R^2 = 0.827$). Figure 1 illustrates that as peak knee flexion increased from approximately 60° to 110°, peak hip flexion was shown to increase linearly from 50° to 105° and as knee flexion further increased from approximately 110° and 150°, hip flexion subsquently plateaued between 110° to 120°. A moderate positive correlation ($R^2 = 0.3462$) was seen between peak hip flexion and jump height. Participants were shown to jump highest between peak hip flexion ranges of 100° to 130°.

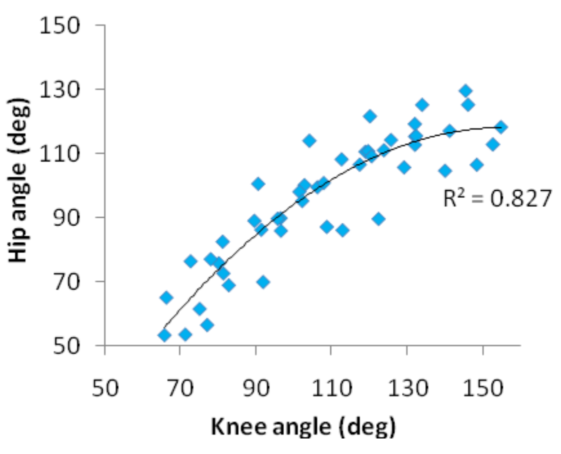
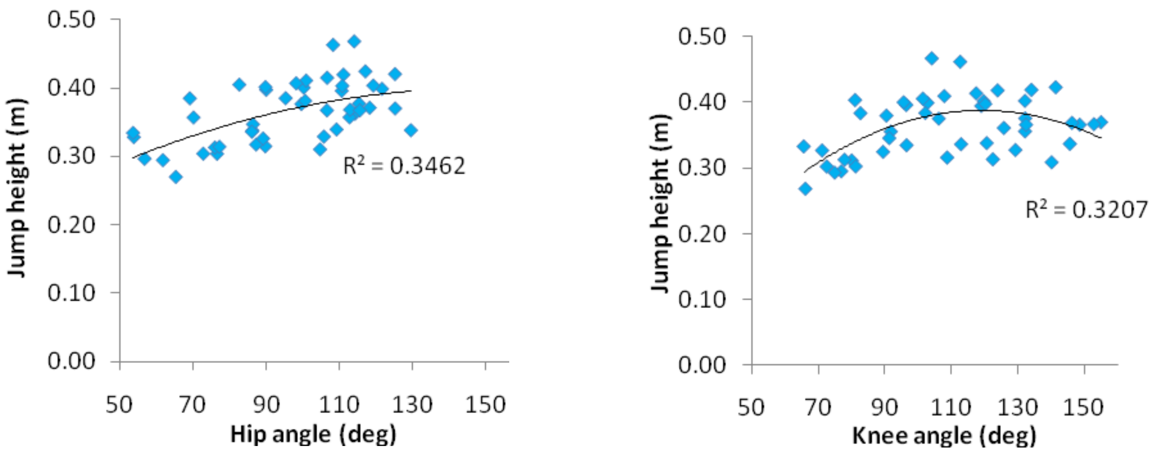


Figure 1. Peak flexion ranges of the hip and knee joints. Standing position was defined as 0°. A 2nd order polynomial trendline was used.



(a) (b)

Figure 2. Relationship between jump height and peak hip (a) and knee (b) flexion angles. Standing position was defined as 0°. A 2nd order polynomial trendline was used.

A moderate positive correlation (R^2= 0.3207) was also seen in peak knee flexion angle with jump height. The peak knee flexion ranges for optimal jump heights were shown to be between 100° to 130°, then after 130° jump height decreased.

DISCUSSION: A strong positive relationship between hip and knee joint ROM was clearly shown in CM vertical jumping. This movement coordination could be related to the muscle system (bi-articular muscles crossing both hip and knee joints) producing a constant force-length relationship (Voigt et al. 1995), thus as a result contributing to an effective power transfer for centre of mass (COM) vertical translation (Jacobs et al. 1996). Additionally, observations in this study suggest that during the deep CM (high peak knee flexion) the natural increase in peak hip flexion was used to keep the COM balanced and the resultant ground reaction force vector in front of COM in order to allow the lower limbs to optimally rotate forward during propulsion phase. A decrease in jump height when peak knee flexion was shown to be greater than 130° could be related to participants lack of practice and coordination on performing very deep CM as Domire and Challis, (2007) study suggested that in deep squat positions sub-optimal muscle coordination conditions arose from participants lack of practice.

CONCLUSION: The strong relationship between knee and hip joint ROM may be related to natural interlimb co-ordination of the human system to allow for optimal muscle contractile conditions. This finding suggests jumpers naturally engage both knee and hips joints in order to achieve an effective vertical jump height performance. The moderate relationships seen in hip and knee joint flexion ranges with vertical jump height may be accounted for individual jumping strategies and participants varying jumping ability.

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