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EFFECT OF APPROACH RUN VELOCITY ON THE OPTIMAL PERFORMANCE OF THE TRIPLE JUMP

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The purpose of this study was to determine the effect of approach run velocity on the optimal phase ratio and actual distance of the triple jump. Three-dimensional kinematic data of 13 elite male triple jumpers were obtained. Computer simulations were performed using a biomechanical model of the triple jump to optimize the phase ratio for the longest actual distance with different approach run velocity vectors. As horizontal velocity increased, the actual distance and jump percentage increased while the hop percentage decreased. As the vertical landing velocity increased, the actual distance, hop percentage, and jump percentage decreased. As the velocity conversion coefficient increased, the effect of vertical landing velocity of approach run on the optimal performance increased.

KEY WORDS: computer simulation, biomechanics, kinematics.

INTRODUCTION: Triple jump is one of the four jumping events in track and field. A triple jump consists of three consecutive takeoffs and landings following the landing of approach run. The three consecutive takeoffs and landings formed three phases named: hop, step, and jump. The actual distance a triple jump jumped is the sum of the three stances. The ratio of the three phase distances as the percentage of actual distance is referred to as phase ratio. Previous studies on triple jump techniques have demonstrated that an optimum phase ratio exists for a given triple jumper that yields the longest actual distance (Yu and Hay, 1996; Yu, 1999). The optimum phase ratio for a given triple jump is determined by a parameter named as coefficient velocity conversion (Hay and Yu, 1996; Yu, 1999). A recent study demonstrates that phase ratio significantly affects the actual distance (Liu and Yu, 2012).
Biomechanically, approach run velocity is another factor that affects the performance of the triple jump. Understanding how approach run velocity and velocity conversion coefficient interactively affect the optimal phase ratio would provide further information for athletes and coaches to understand triple jump techniques and select optimal ratio for longest actual distance. As a continuation of previous studies, the purpose of this study was to determine the effects of approach run velocity vector at the landing of approach run before the takeoff of the hop on the optimal phase ratio and longest actual distance of the triple jump. We hypothesized that the horizontal velocity of the center of mass of a triple jumper at the landing of approach run before the hop takeoff significantly affects the optimal phase ratio and longest actual distance with a given velocity conversion coefficient. We further hypothesized that the vertical velocity of the center of mass of a triple jumper at the landing of approach run before the hop takeoff also significantly affects the optimal phase ratio and longest actual distance with a given velocity conversion coefficient.

METHODS: The subjects of this study were 13 finalists of the men’s triple jump competition at the 1992 US Track and Field Olympic Team Trials. Each subject had at least one legal trial in which the subject completed the full sequence of the triple jump and was entirely videotaped for quantitative data reduction.
Two S-VHS video camcorders were used to collect three-dimensional (3-D) coordinates of 21 body landmarks (Hay, 1993) at a frame rate of 60 frames per second with a setup for A Direct Linear Transformation (DLT) procedure with two panning cameras (Yu et al, 1993). The real life 3-D coordinates of the 21 body landmarks during the last two steps of approach run, hop, step, and jump were obtained for each trial of each subject using the DLT procedure with

panning cameras (Yu et al, 1993). The raw 3-D coordinates were filtered through a second-order recursive Butterworth digital filter with an estimated optimum cutoff frequency of 7.14 Hz (Winter et al, 1974; Yu, 1989). The 3-D coordinates of the whole center of mass (COM) of each subject in each video frame were estimated using the segmental procedure (Hay, 1993; Hinrichs, 1990). The horizontal and vertical velocities of the COM at the takeoff and landing of the last step of the approach run, hop, step, and jump, and the losses in horizontal velocity of the COM and gains in vertical velocity of the COM during the stances of the hop, step, and jump were calculated for each trial of each subject (Yu and Hay, 1996; Yu, 1999). The takeoff and landing heights and distances of the hop, step, and jump were also estimated for each trial.
Computer simulations were performed using an optimization model of the triple jump validated in previous studies (Yu and Hay, 1996; Liu and Yu, 2012) to determine the effects of horizontal and vertical velocities at the landing of the last step of approach run on the optimal phase ratio and longest actual distance with a given velocity conversion coefficient. The horizontal and vertical approach run velocities were varied from 8 to 11 m/s with an increment of 0.5 m, and from -0.5 to -1.1 m/s with an increment of 0.2 m/s, respectively, while the velocity conversion coefficient varied from 0.3 to 1.3 with an increment of 0.05. These variations of the input variables were all within the corresponding observed ranges as described in the previous study (Yu, 1999; Liu and Yu, 2012). With each combination of the horizontal and vertical approach run velocities and coefficient of velocity conversion, gains in the vertical velocity during the stances of the hop, step, and jump were optimized for the longest actual distance a given subject could achieve. The phase ratio corresponding to the longest actual distance was considered as the optimal phase ratio for the given combination of horizontal and vertical approach run velocities and velocity conversion coefficient. The takeoff and landing heights and distances of the hop, step, and jump phases were considered as constants for each subject and presented as the observed means of the corresponding parameters of the subject. The longest actual distances and the optimal phase ratios were recorded for analysis. The mean and relative errors in predicted actual distance were 0.15 ± 0.09 m and 0.01 ± 0.005 m (Liu and Yu, 2012)

RESULTS: Simulation results showed that actual distance increased as the horizontal velocity at the landing of the last step of approach run increased, but decreased as the downward vertical velocity at the landing of the last step of approach run increased (Figures 1 and 2). Simulation results also showed that optimal hop percentage decreased as the horizontal and downward vertical velocities at the landing of the last step of approach run increased (Figures 1 and 2). Simulation results further showed that optimal jump percentage increased as the horizontal velocity at the landing of the last step approach run increased, but decreased as the downward vertical velocity at the landing of the last step of approach run increased (Figures 1 and 2). The downward vertical velocity at the landing of the last step of approach run had more effect on the optimal hop percentage than on the optimal jump percentage (Figures 1 and 2). The effect of downward vertical velocity at the landing of the last step of approach run on actual distance, hop percentage, and jump percentage decreased as the velocity conversion coefficient decreased (Figures 1 and 2). The downward vertical velocity at the landing of the last step of approach run had little effect on actual distance, hop percentage, and jump percentage when the velocity conversion coefficient was 0.3 (Figure 2).

DISCUSSION: The results of this study support our first hypothesis that the horizontal velocity at the landing of the last step of approach run affects actual distance and optimal phase ratio. Triple jump jumpers need to increase their horizontal velocities of approach run to increase their actual distances. Phase ratio needs to be adjusted for optimum when horizontal velocity at the landing of the last step of approach run is increased. The optimal hop percentage should be decreased and jump percentage should be increased as the horizontal velocity at the landing of the last step of approach run is increased.

The results of this study also support our second hypothesis that the downward vertical velocity at the landing of the last step of approach run affects actual distance and optimal phase ratio. Triple jumpers should minimize their downward vertical velocities at the landing of the last step of approach run before the takeoff of the hop to increase their actual distances. To minimize the downward vertical velocity at the landing of the last step of approach run, triple jumpers should minimize their vertical velocity at the takeoff of the last step of approach run, or control the height COM at the landing of the last step of approach run. This means that triple jumpers should drive as horizontally as possible at the takeoff of the last step of approach run and avoid further lowering COM at the landing of the last step of approach run. These are more important for those athletes with high velocity conversion coefficients and using jump dominant techniques.

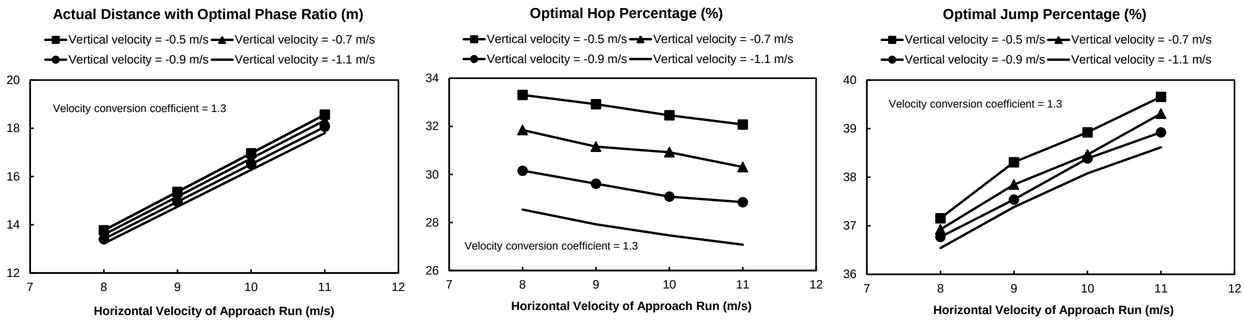

Figure 1. Effects of horizontal and vertical velocity at the landing of the last step of approach run on actual distance with optimal phase ratio and optimal hop and jump percentages with velocity conversion coefficient of 1.3.

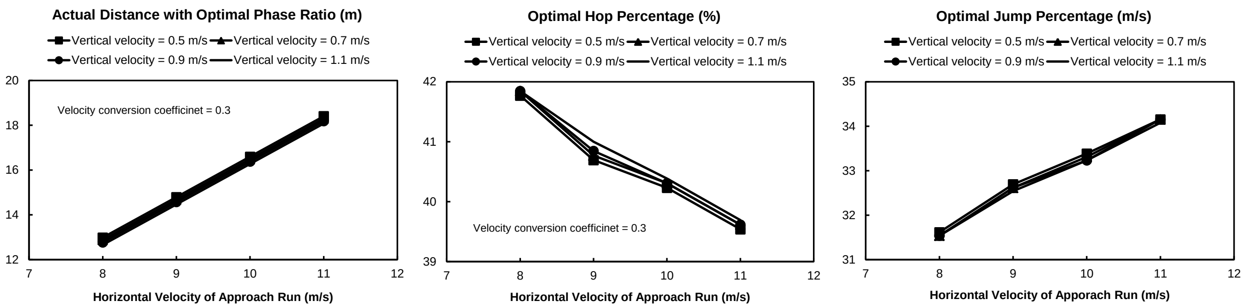

Figure 2. Effects of horizontal and vertical velocity at the landing of the last step of approach run on actual distance with optimal phase ratio and optimal hop and jump percentages with velocity conversion coefficient of 0.3.

CONCLUSION: Increasing the horizontal velocity and decreasing the downward vertical velocity of COM at the landing of the last step of approach run increase the actual distance of the triple jump with optimal phase ratio. As horizontal and vertical velocities varied the optimal phase ratio also varied, especially for those triple jumpers with high magnitude of velocity conversion coefficient and using jump dominant techniques.

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