THE EFFECT OF ALTERING STRENGTH AND APPROACH VELOCITY ON TRIPLE JUMP PERFORMANCE

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The triple jump is an athletic event comprising three phases in which the optimal proportion of each phase to the total distance jumped, termed the phase ratio, is unknown. This study used a whole body torque-driven computer simulation model of all three phases of the triple jump to investigate the effect of strength and approach velocity on optimal technique. The strength and approach velocity of the simulation model was increased by up to 30% in 10% increments from baseline data collected from a national standard triple jumper. Increasing strength always resulted in an improved performance, increasing velocity also typically resulted in an improved performance but there was a point past which increasing velocity without increasing strength did not lead to an increase in performance. Increasing both strength and velocity by 10%, 20%, and 30% led to roughly equivalent increases in triple jump distance. The phase ratio employed by the simulation model typically became more balanced when the strength of the model was increased by more than its velocity.

KEY WORDS: triple jump, computer simulation, optimisation, phase ratio, technique.

INTRODUCTION: The triple jump is an athletic event involving three consecutive phases during which athletes must distribute their 'effort' in order to maximise the total distance. The 'phase ratio' is the distances of each phase expressed as three percentages of the total distance. Triple jump techniques with respect to phase ratio have been defined as being: (a) hop-dominated – where the hop percentage is at least 2% greater than the next largest phase percentage; (b) jump-dominated – where the jump percentage is at least 2% greater than the next largest phase percentage; and (c) balanced – where the largest phase percentage is less than 2% greater than the next largest phase percentage (Hay, 1992).

Hay (1993) stated that the peak ground reaction forces (GRFs) recorded during the support phase of the step in triple jumping are, 'much greater than a human limb is exposed to in any other voluntary activity for which data could be found'. Given the magnitude of these peak ground reaction forces it is reasonable to suggest that strength is of great importance to triple jump performance. However the isolated effects of changes in strength on performance are hard to gauge.

It has been proposed that athletes may approach more slowly when triple jumping compared to long jumping, indicating that approach velocity in triple jumping is submaximal (Hay, 1993). The fastest athletes in the men's triple jump final during the IAAF World Championships in 2009 achieved approach velocities of ~10.5 $m.s^{-1}$ (equivalent to the maximum velocity in this study); this was roughly equivalent to the majority of athletes in the long jump final at the same championships. However the average velocity in the triple jump final was lower than in the long jump final, with some athletes approaching below 10 $m.s^{-1}$ (German Athletics Federation, 2009).

The aim of this study was to determine the effects of increasing the approach velocity and strength of an athlete on total jump distance and technique using a whole body forward dynamics computer simulation model of all three phases of the triple jump.

METHODS: Kinematic and force data were gathered at the Loughborough University indoor High Performance Athletics Centre (HiPAC) from a male triple jumper of national standard (age: 22 years; mass: 72.6 kg; height: 1.82 m; best performance: 14.35 m). The study was carried out in accordance with the Loughborough University Ethics Committee guidelines.

Forty-five 25 mm retroreflective markers were placed in positions on the body of the jumper in order that locations of joint centres could be determined. Eighteen Vicon MX cameras captured data at 240 Hz during a single triple jump performance. Orientation, defined as the angle of the trunk in a global reference frame, and configuration angles were calculated by considering the joint centre coordinates in the sagittal plane.

A 13-segment planar torque-driven computer simulation model was used to investigate triple jumping technique (Allen et al., 2010). Subject-specific torque and inertia parameters were calculated from measurements taken from the triple jumper. Both the strength and approach velocity of the model were increased by: 0%; 10%; 20%; and 30% from the measured values and all combinations of these two parameters were investigated, leading to 16 conditions in total.

A Genetic Algorithm was used to maximise total jump distance by varying 243 parameters: 231 torque generator parameters (77 in each phase); and four initial angles in each phase: the orientation angle, and the hip, knee, and ankle angles of the stance leg, giving 12 in total. The total distance of each optimised simulation was calculated along with the distance of each constituent phase.

Technique is reported as per Hay's (1992) definition as either: hop-dominated; balanced; or jump-dominated.

RESULTS: The optimisation of technique with measured strength and approach velocity resulted in a total distance of 14.05 m and employed a hop-dominated technique. Increases in strength resulted in an increase in jump distance in every condition, whereas increases in velocity led to an increase in jump distance in all cases except one (Table 1).

Table 1
Triple jump distances as a function of increases in strength and velocity

strength / velocity	**100%**	**110%**	**120%**	**130%**
100%	14.05 m	14.67 m	15.12 m	15.12 m
110%	14.87 m	15.54 m	16.03 m	16.53 m
120%	15.48 m	16.34 m	17.10 m	17.58 m
130%	16.20 m	17.06 m	17.94 m	18.49 m

The phase ratios employed by the model were sensitive to both strength and velocity (Table 2). All techniques were either balanced or hop-dominated. There was a trend in step phase percentage; this was shortest when the approach velocity of the model was high and its strength was low, and longest when approach velocity was low and strength was high. Technique tended to be hop-dominated when approach velocity increases matched strength increases, and balanced when an increase in either of these parameters was not matched by an increase in the other.

Table 2
Triple jump phase ratios as a function of increases in strength and velocity

strength / velocity	100%	110%	120%	130%
100%	35.6%:30.8%:33.6%	36.0%:30.4%:33.6%	36.6%:28.6%:34.7%	35.5%:28.9%:35.5%
110%	34.5%:32.7%:32.8%	36.7%:30.1%:33.2%	34.6%:31.3%:34.2%	36.6%:28.6%:34.7%
120%	34.3%:32.6%:33.1%	36.7%:30.5%:32.7%	36.2%:30.3%:33.6%	36.5%:29.5%:34.0%
130%	34.7%:33.0%:32.3%	33.3%:33.3%:33.4%	36.4%:31.0%:32.6%	35.3%:31.2%:33.5%

DISCUSSION: The results of the optimisations indicated that triple jump distance was sensitive to both approach velocity and strength levels. Approaching as quickly as possible may be optimal for athletes with high strength levels, assuming the athlete can coordinate the movement at these higher velocities. It is clear that triple jumpers do approach more slowly than long jumpers on average and, if this is due to submaximal effort, the findings of this study would indicate that the disparity in approach velocity is likely to be a coordination issue, since increasing approach velocity should always be beneficial to a relatively strong athlete, assuming optimal technique.

Phase ratios could largely be predicted by the step phase percentage; when this was approximately 30-31% the phase ratio was typically hop-dominated, if this deviated in either direction it became balanced. No jump-dominated techniques were found to be optimal, in fact, in no optimal solution was the jump phase the longest phase. This could have been in part due to the fact that the landing configuration of the model was invariant; it is possible that a jump-dominated technique may allow the landing distance to increase. However even if this were the case then it is unlikely that any of the optimal techniques found in this study would become jump-dominated. It has been proposed that a jump-dominated technique allows athletes to approach faster than they would otherwise be capable of (Hay, 1995). However these results indicate that, even at the highest velocity and the lowest strength level, the optimal phase ratio was balanced. It is possible that athletes who use a jump-dominated technique do so because it is easier to coordinate than other techniques.

CONCLUSION: A wide range of outcomes were observed in optimisations of triple jump distance when the approach velocity and strength were manipulated. Although other subject-specific parameters remained the same, such as anthropometry, segmental inertias, and the shape of the torque/ angle/ angular velocity relationships, the fact that altering approach velocity and strength led to such a wide range of triple jump distances indicates that these factors are likely to be the overriding determinants of triple jump performance.

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