Quintic Case Study: Using Quintic Biomechanics v17 to Calculate Centre of Mass, Vertical and Horizontal Velocity during Triple Jump

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Triple jump is one of the three jumping events in track and field. A triple jump consists of an approach run followed by a hop, a step, and a jump. Compared to the long and high jumps which have only one touchdown and takeoff in each, the triple jump has three consecutive touchdowns and takeoffs at high speed and thus is more technically demanding than the long and high jumps.

The goal of in the triple jump is to jump the longest distance combining all three phases. Therefore the single most important AIM is for the athlete to maintain the highest possible horizontal speed, throughout the Hop, the Step and the Jump.

Triple Jump Technical Breakdown

The hop is the first phase of the triple jump, during this phase the athlete runs of the takeoff board with a hop. The objective in the hop is to achieve horizontal vertical velocity (going forward and up) of the take off board, not vertical horizontal velocity (up and forward as in the long jump). The jumper should use his/her strongest leg for the hop phase because the hop leg will be used for two of the three jumps. The horizontal vertical velocity (forward and up) of the take off board is accomplished by keeping the body upright but in a slightly forward position. The heel of the hop leg should rotate high and under the hip and then extended it as far forward as possible with the upper body slightly over the foot on touchdown. This position will make the athlete feels as if he or she is running off the board.

Just before the athlete completes the hop phase, the arms should be pulled back to prepare the athlete for his/her step phase. The step phase is accomplished by bringing the swing leg (opposite of the hop leg) up and forward. The jumper should strive to get the upper leg perpendicular to the body or parallel to the ground about 90 degree. Both arms must come forward to utilize the double- arm action. Whenever the single-arm action is being used during the step phase, the opposite arm goes forward like a continuation of the run.

To execute the proper step phase the jumper should hold his/her leg at 90 degrees for a split second, then the lower leg must extend ahead of the knee just before landing. The requirement for holding this position is to keep the torso extended and slightly forward in order to hole the foot at 90 degree. As the jumper prepares for touchdown and the foot is extended for touchdown, the jumper must extend his/her hand behind the back to prepare for the jump phase. The jumpers arm must be slightly ahead of the free leg to execute the correct jump phase.

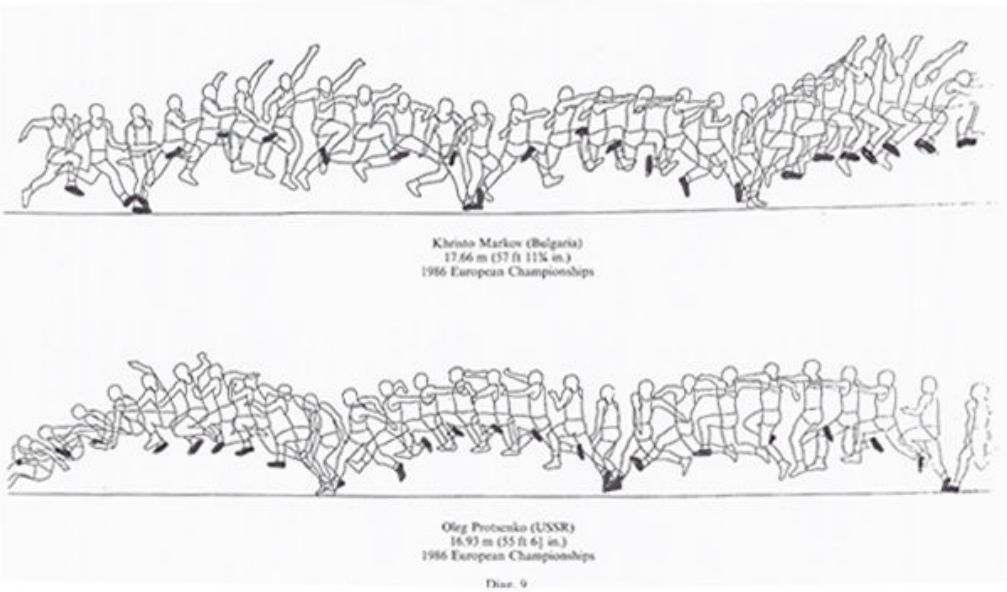
As the jumper prepares to initiate the jump phase, the arms interchange if the single-arm method is used. If the double arm is use, both arm should be back on touchdown and pulled through aggressively with a punching action. The athlete should execute the jump phase with a hang style similar to the action of a long jumper. There is not enough time to execute the hitch-kick. In the air the jumper must delay forward rotation to assure a better landing. The reaching of the arm and the subsequent downward-backward action of the arm will aid in delaying the forward rotation.

The landing should be similar to long jump; The jumper leg should be bent to bring them through to prepare to land. They must, however, reach extension again on the way down to landing. It is one flowing motion to throw the arms forward and down, extending the legs bending forward resulting in the hand being close to ones knee. Every effort must be made to hold this position until the first contact with the sand.

At contact the jumper knee should bend to help absorb the shock associated with landing. In order to maintain forward momentum the arm should be in a position where they are extended, moving backward.

From this position at landing, one can continue the backward motion of the arms and propel the body forward. This will eliminate the problem of falling back and losing distance.

Two methods could be use to exit the landing after completing a jump; the techniques are the straight ahead and side out exit. In the side out exit the knees are not as deeply flexed when using this method. In the straight ahead method, the athlete must have great timing to successfully use the arms. If done properly it can be safer and the result in lost of distance due to falling back.

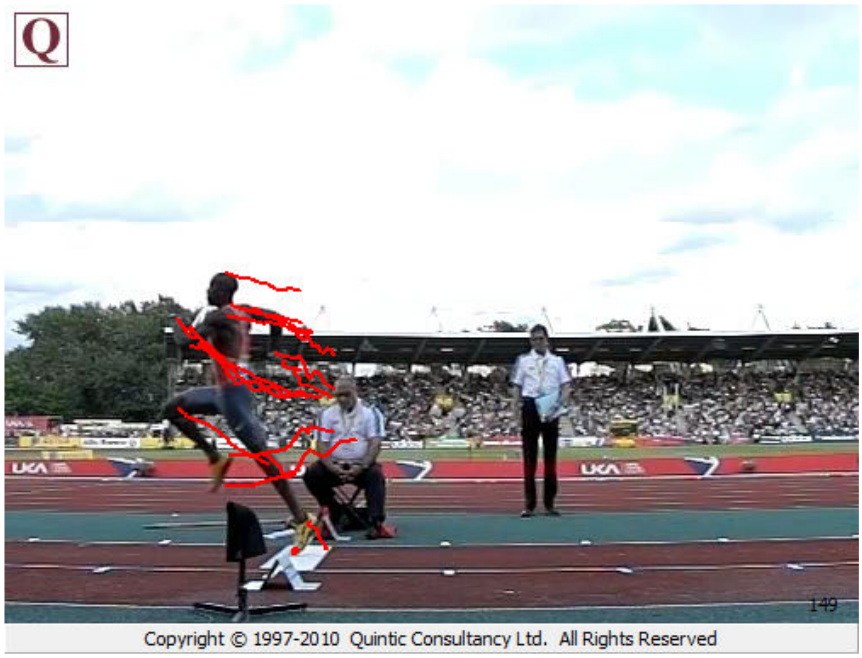


Data Collection

Data for the analysis of Centre of Mass (COM) was collected during a UKA Grand Prix event at Crystal Palace in 2009. 3 cameras where used set up parallel to the take off points of each triple jump stage, (Hop, Step & Jump). To capture to the jump footage all 3 cameras were set to record at a frame rate of 300fps and a shutter speed of 1/6000th sec. Before the video footage was taken the triple jump runway was marked at 1 metre intervals for calibration purposes. A panning camera filming at 25fps and a shutter speed of 1/2000th sec was also used to capture the full triple jump technique.

Data Interpretation

Following the data collection the panning video (25fps) was opened in Quintic Biomechanics 9.03v17 video analysis software and deinterlaced using the Quintic editor. The 300fps MOV Casio Exilim F1 videos could be opened directly Biomechanics v17 software and were firstly calibrated by setting the frame rate and measuring a known length on the video (in same plane athlete is moving) calibrating the video allows accurate measurements of velocities, distances and accelerations to be calculated. Using the manual digitisation procedure (automatic digitisation couldn't be uses as footage was taken within competition and body markers could not be applied) an 18 point model is implemented, all 18 points were tracked from 2 metres before takeoff until after takeoff of the jump phase. Once digitised, the inbuilt butterworth filters set optimal smoothing values for the X and Y co-ordinate of every digitised marker to smooth the raw data. Distances, acceleration and velocities of the tracked anatomical landmarks can now be viewed and analysed within the linear analysis window. Joint angles can also be views and analysed by selecting the angular analysis tool. All of the co-ordinate data is then exported directly into a Centre of Mass (COM) excel spreadsheet. These steps are repeated for all 3 phases of the triple jump, (Hop, step and Jump)



Screen shot of 'hop take-off' illustrating the 18 point model used.
Video footage captured at 300fps using a Casio Exilim F1 Camera

Data Analysis

Once the data has been exported into a custom spreadsheet a biomechanical report is constructed illustrating the full breakdown of each phase. The results shown below are just for the 'hop phase'
Graph 1 illustrates the angles of the left leg during the 'hop' take off phase, the green line indicates the instant that the take off foot makes contact with the board, the orange line indicates Maximum knee flexion (marks the end of the compression phase and beginning of the extension phase) and the white line indicates the Instant the take-off foot leaves the board (marks the beginning of the flight phase). The graph shows that post maximum knee flexion (orange line) the athletes hip, knee and ankle angles all increase, allowing the athlete to explosively extend off the board and increase vertical velocity.

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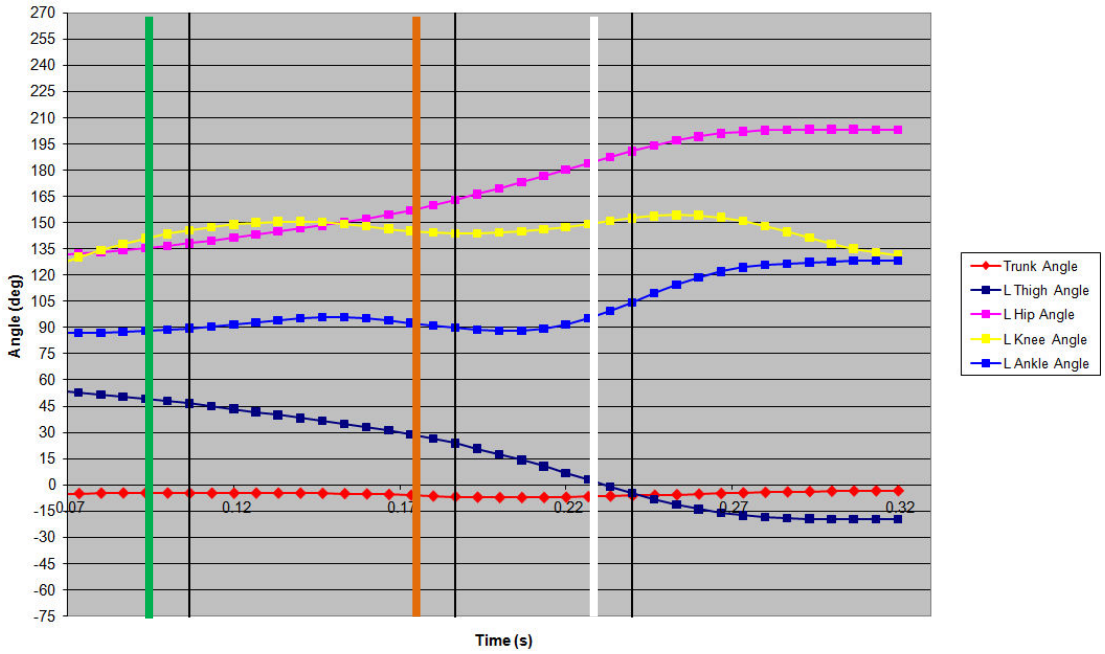

Graph 1: Right Leg joint angles during the 'Hop take-off'

Graph 2 illustrates the vertical displacement of the athletes COM during the 'Hop' take off phase, again the green line indicates the instant that the take off foot makes contact with the board, the orange line indicates Maximum knee flexion - marks the end of the compression phase and beginning of the extension phase and the white line indicates the Instant the take-off foot leaves the board - marks the beginning of the flight phase. The graph shows that the athletes COM vertical displacement decreases slightly before maximal knee flexion. The COM's vertical displacement then increases throughout the take off from the board and into the flight phase. The increase in COM height is due to the increase in ankle, knee and hip angles illustrated in graph 1 causing the athlete to extend off the board and begin the flight phase.

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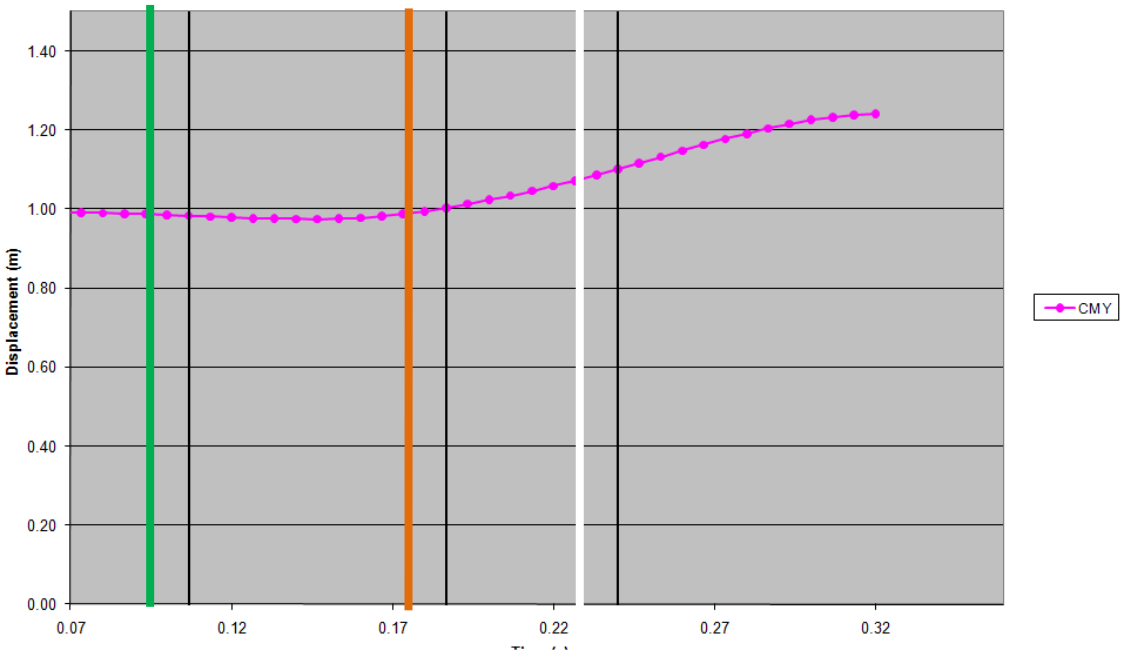

Graph 2: Athletes projected COM during the 'Hop take-off'

Graph 3 illustrates the athletes vertical and horizontal velocities during the 'Hop' take off phase, again the green line indicates the instant that the take off foot makes contact with the board, the orange line indicates Maximum knee flexion - marks the end of the compression phase and beginning of the extension phase and the white line indicates the Instant the take-off foot leaves the board - marks the beginning of the flight phase.
The graph shows that as the athlete reaches the take off board peak horizontal velocity has been reached. Horizontal velocity then begins to decrease as vertical velocity increases (preparation for takeoff). Vertical velocity continues to increase until take off (indicated by the white line). The Athlete main objective now is to maintain their horizontal velocity so that it can be used in the next stage of the sequence.

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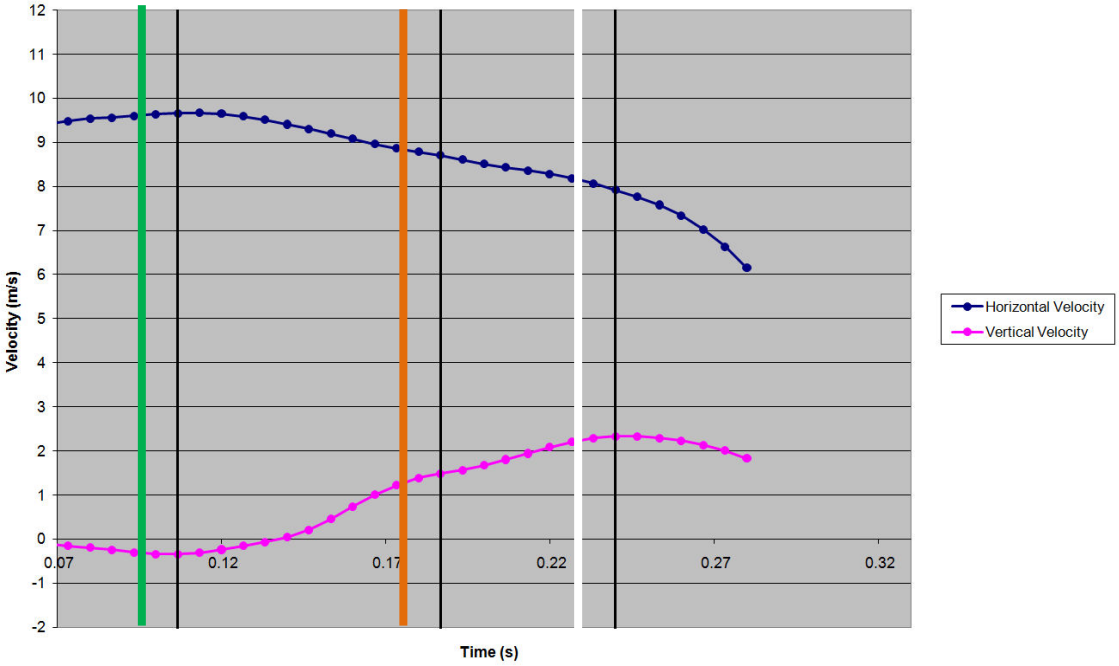
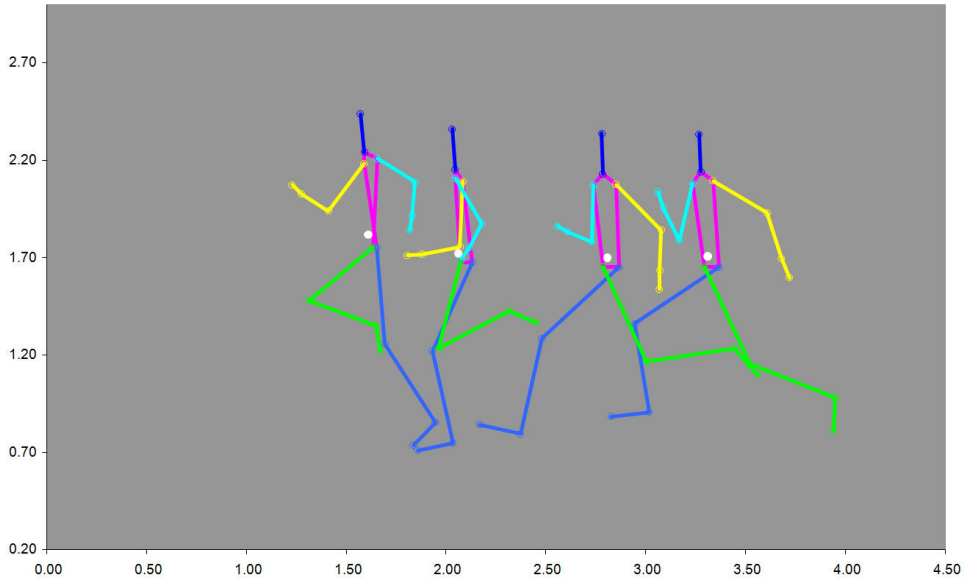


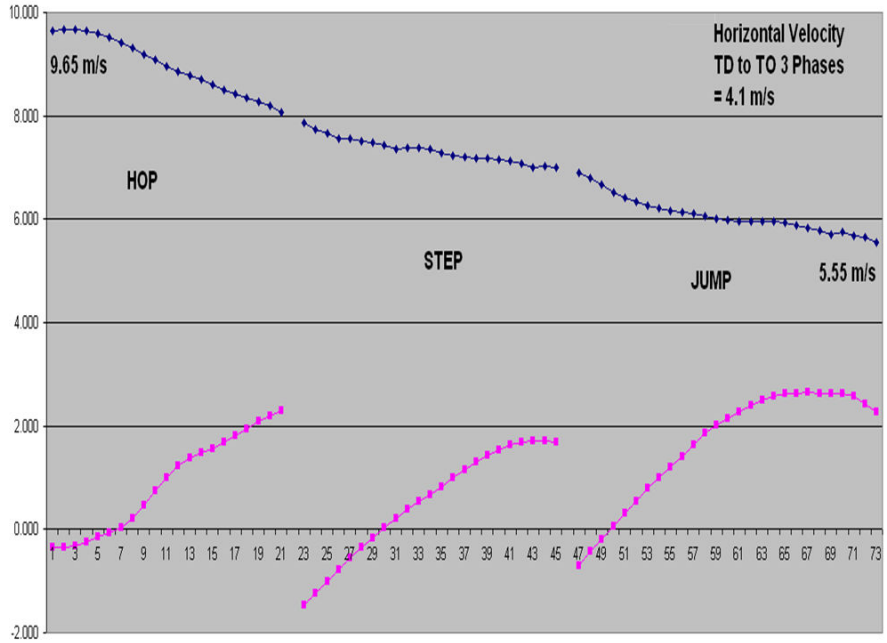
Graph 3: Athletes Vertical and Horizontal COM during the 'Hop take-off phase'

Graph 4 shows a stick figure interpretation of the athlete's body during the 'Hop' take off stage this is produced using the co-ordinates that were calculated during the digitisation. The athletes COM has also been overlaid and is represented by the white dot.



Graph 4: Stick Figure representation of athlete and COM

Graph 5 illustrates the complete breakdown of all 3 stages of the triple jump. The graph shows the rate of decrease in horizontal velocity throughout the 3 stages, with an overall loss of 4.1m/s. The graph also illustrates the vertical velocity throughout all 3 stages; we can see that peak vertical velocity is created during takeoff of the final stage.



Graph 5: Vertical(pink) and Horizontal (Blue) velocities throughout the 3 triple jump phases.

Athlete Comparison

Using Quintic video Analysis software to digitise the athletes in competition and training allows for comparison between events and between athletes. Graph 6 shows the horizontal velocities of 2 athletes over the 3 phases of a triple jump technique.

Athlete A starts with a horizontal velocity of 10.9m/s and finishes with a horizontal velocity of 7.16 m/s resulting in a 3.74m/s loss in horizontal velocity over the 3 phases. Athlete B starts with a horizontal velocity of 9.64m/s and finishes with a horizontal velocity of 6.13m/s resulting in a 3.33m/s loss in horizontal velocity over the 3 phases.

Although athlete A has a greater horizontal velocity at the beginning and end of the 3 phases we can argue that athlete B is a more efficient triple jumper as they have lost less horizontal velocity throughout the 3 stages.

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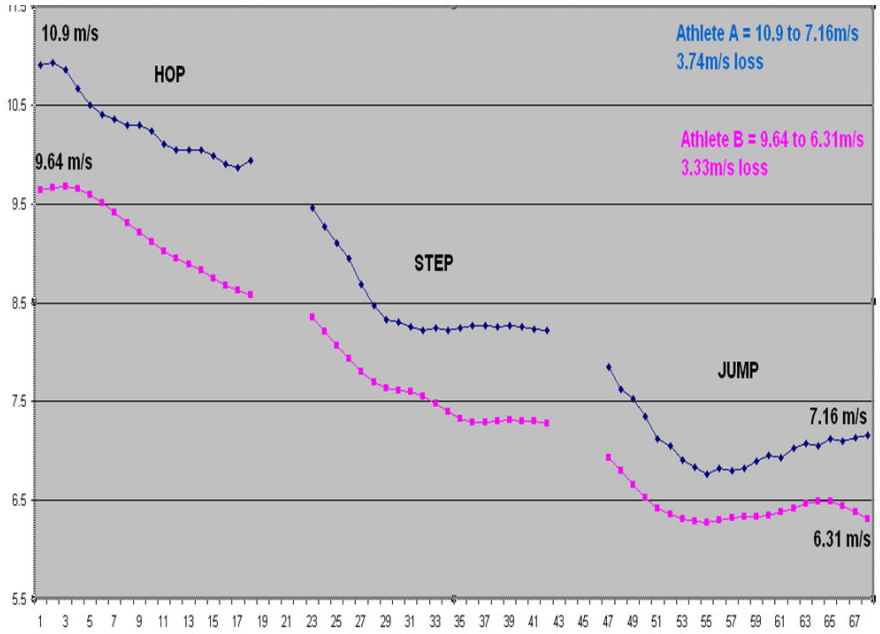

Quintic Biomechanics 9.03 v17 software is vital for me to keep track on what athletes are doing in competition and training, the field knowledge of Quintic's consultants allows them to develop software which supplies me and the coaches I work with the information we need quickly and efficiently.

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