What are the kinematic factors of performance in sprint starting?

Introduction

Hamill and Knutzen, (1995) sate that:

Kinematics is concerned with motion characteristics, and examines motion from a spatial and temporal perspective without reference to the forces causing motion. A kinematic analysis involves the description of movement to determine how fast an object is moving, how high it goes, or how far it travels. Thus, position, velocity, and acceleration are the components of interest in a kinematic analysis.

The purpose of the sprint start is to give the athlete an advantage by providing an efficient mechanism to assist them in moving in the intended direction . It enables the sprinter to start the race with his/her body sloping as required for accel eration. (McNeill Alexander, 1992 , cited in Harrison and Comyns, 2005.)

The start is an important part of a race however, it is not a separate entity and must be thought of as being an integral part of the overall race.

The overriding principle is that it allows the athlete, if executed properly, to leave the blocks on balance and with maximum velocity.

A crouched start is more effective than a standing start as it places the sprinter in a position to move the centre of gravity rapidly well ahead of the feet and thus the runner must accelerate very quickly or else fall.

(Adrian & Cooper, 1995 , cited in Harrison and Comyns, 2005.)

Starting is an important component of the race, especially in the 100m sprint, since any errors made will affect a significant proportion of the race. (Gordon & Robertson, 2005.)

A great deal of research has been conducted in regards to sprint starting. Hay (1993) has commented that of all the sports techniques that have been subjected to biomechanical analysis, few have been mor e thoroughly examined than the sprint start. Scientific research on sprint starting dates back as far as 1927 when Bresnahan investigated the difference between starting from holes dug in the gr ound and starting from blocks.

The objectives of this study are to compare the kinematic factors that affect the performance in a sprint start of two sprinters of different levels of performance, an elite and novice sprinter. To do this digitised data, using KA2D Video software, was manipulated using Microsoft Exc el in order to produce results that allowed for the comparison between the subjects in terms of linear and angular motion analysis.

The body centre of mass of each athlete was used to obtain information regarding linear motion. Angular motion analysis was done by obtaining angular values for the right hip, knee and ankle joints of each subject.

Results

Linear motion analysis of the sprint start

The total distance covered by the body centre of mass (COM) for the elite sprinter was 1.64m, whereas the total distance covered by the COM for the novice sprinter was only 1.43m.

The average cycle velocity for the body COM for the elite sprinter was 3.12m/s, compared to that of the novice sprinter, which was 2.62m/s.

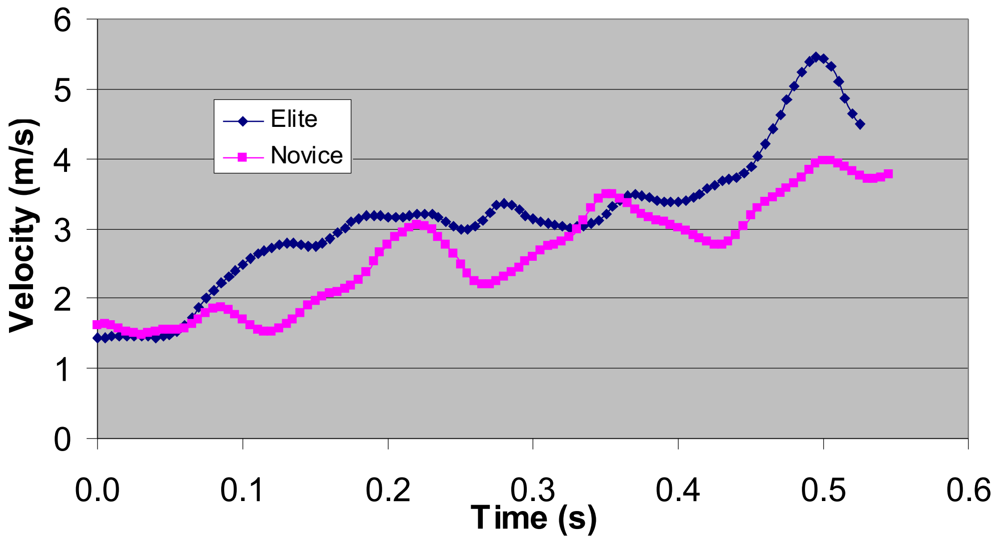

Figure 1 The horizontal velocity of the body centre of mass

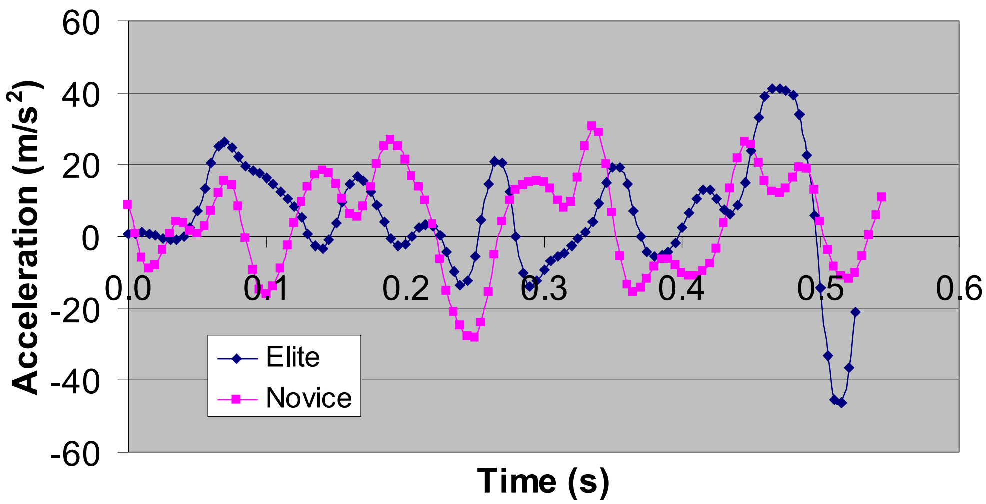

Figure 2 The horizontal acceleration for the body centre of mass

Angular motion analysis of the sprint start

Table 1 The angular range of motion for the hip, knee a nd ankle joints in both the elite and novice sprinter

Angular Range of Motion	Elite	Novice
Hip joint	103.10	108.01
Knee joint	98.42	91.33
Ankle joint	73.17	63.73

Table 2 The angular values for both sprinters at the different ev ents observed in the cycle and the time at which these events occur

Event	RTO1		LTO		RTD		RTO2	
	Elite	Novice	Elite	Novice	Elite	Novice	Elite	Novice
Hip Angle	88.58	76.50	58.67	59.34	106.38	79.49	158.53	157.83
Knee Angle	115.90	118.51	111.45	112.92	107.38	125.14	163.46	170.49
Ankle Angle	107.93	92.60	66.39	65.26	63.05	65.21	123.79	101.52
Actual Event Time	0.170	0.210	0.415	0.455	0.510	0.490	0.695	0.755
Relative Event Time	0.000	0.000	0.245	0.245	0.340	0.280	0.525	0.545

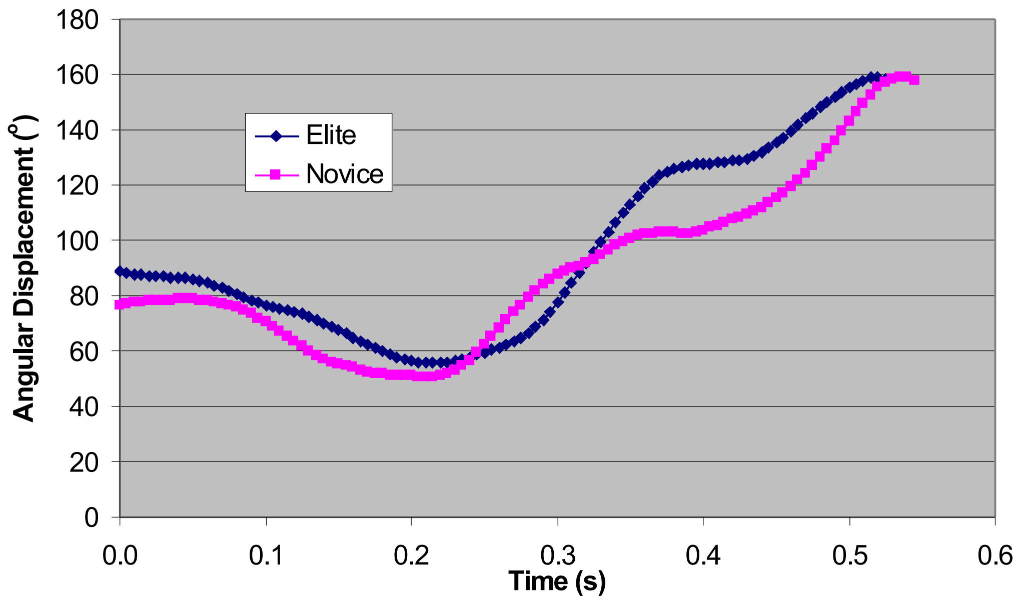

Figure 3 The hip angular displacement for both sprinters during two consecutive right - toe-off events

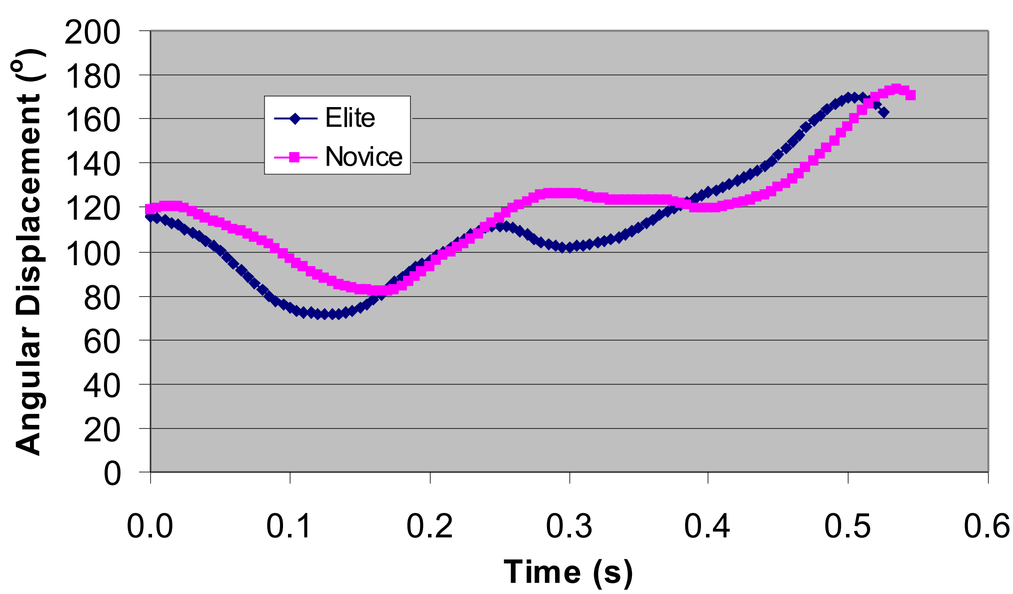

Figure 4 The knee angular displacement for both sprinters during two consecutive right-toe-off events

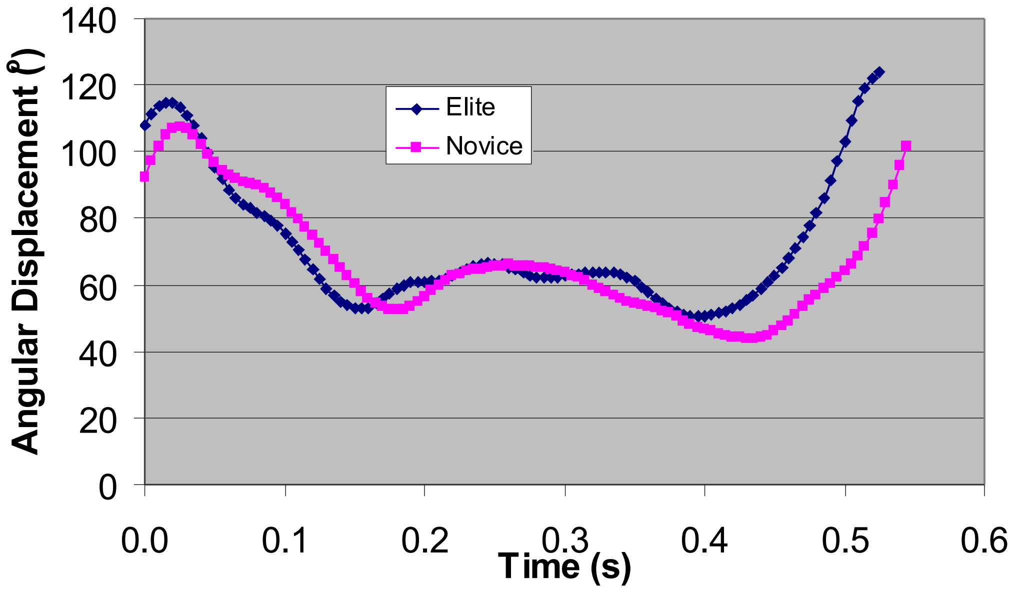

Figure 5 The ankle angular displacement during two consecutive right -toe-off events

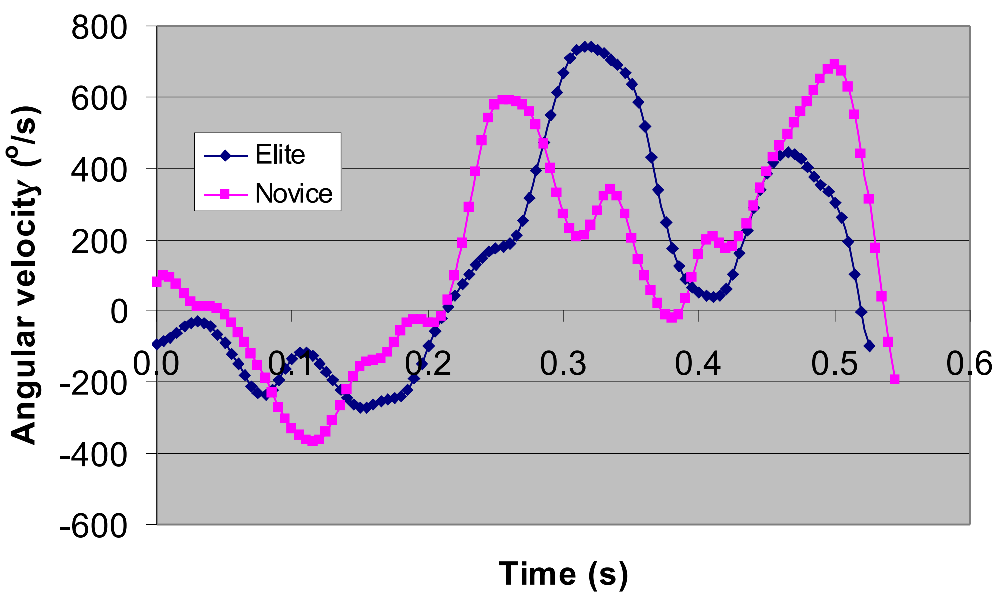

Figure 6 The hip angular velocity of both sprinters during two consecutive right-toe-off events

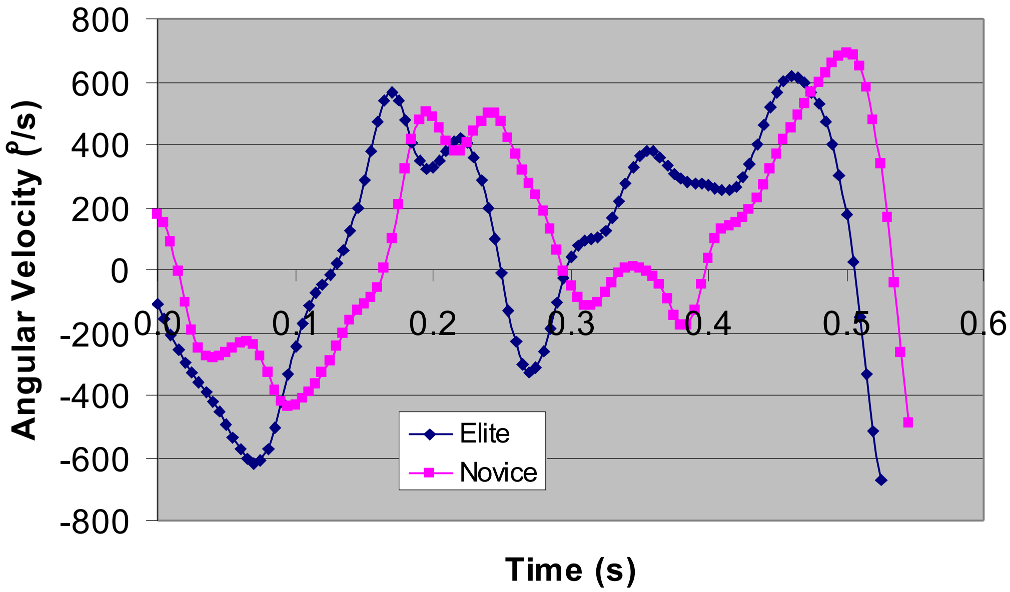

Figure 7 The knee angular velocity of both sprinters during two consecutive right-toe-off events

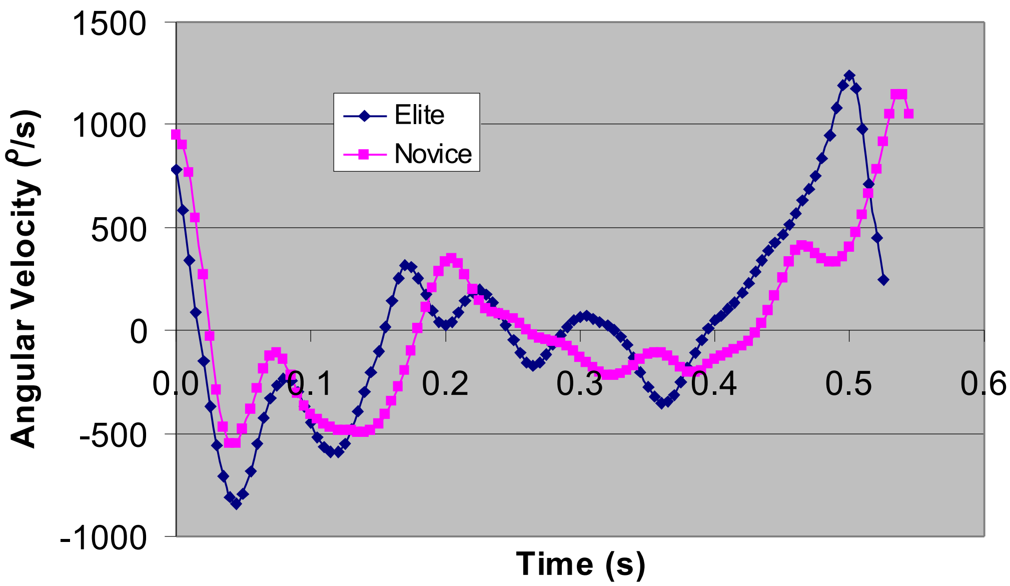

Figure 8 The ankle angular velocity of both sprinters during two consecutive right-toe-off events

Discussion

Use the linear parameters calculated to address the difference of performance level between the two subjects.

From the velocity-time curves for both subjects (Figure 1) it can be seen that during the complete cycle between two right-toe-off (RTO) events, that the elite sprinter produces a higher overall velocity compared to the novice, (average velocity 3.12m/s compared to 2.62m/s respectively.) This demonstrates the elite sprinter's ability to achieve higher velocities in comparison to the novice at the start of a sprint. The acceleration-time curves for both sprinters (Figure 2) show that the elite sprinter has a smoother acceleration during a complete cycle, compared to the greater, more frequent fluctuations in the acceleration of the novice sprinter. This smoother acceleration may be a contributing factor the higher overall velocity gained by the elite sprinter.

Detail where in the cycle both sprinters are losing speed. Explain why?

The novice sprinter loses speed between the initial RTO event and the LTO event. This may be due to less power being generated from the initial push off the blocks in the crouch position compared to that produced by the trained elite sprinter. The novice also loses speed again after the LTO event. This is just prior to the RTD event and an explanation for this may be due again to the lack of power produced initially from the push out of the blocks. The fact that the RTD event for the novice sprinter occurs that much earlier than for the elite sprinter signifies an unsustainable drive forward. The elite sprinter on the other hand is able to sustain the velocity developed during the initial push off from the blocks to allow them to have a later RTD event and thus almost no fluctuation in speed. Both sprinters experience a loss in speed immediately prior to the second RTO event. This may possibly be due to the momentum of the start wearing off and the next RTO event providing the next boost of power to drive the athlete forward again.

Describe where in the cycle, the horizontal velocity pattern differed between the two sprinters.

Between the first right-toe-off (RTO) event and the left-toe-off (LTO) event the elite sprinter's velocity increased more quickly than the novice's (the acceleration at 0.07s was 26.49m/s^2 and 15.44m/s^2 respectively.) However, by the left-toe-off (LTO) event (0.25s into the cycle) the velocity for the elite sprinter was 3.03 m/s and for the novice sprinter was not far behind at 2.64 m/s. Immediately after the LTO event the novice sprinter's velocity decreased to 2.21m/s at 0.27s, while the elite sprinter' s velocity increased to 3.13m/s for the same time. The right-toe-down (RTD) events for both sprinters occurred at different times in the cycle. For the novice the RTD event occurred at 0.28s into the cycle (velocity 2.31m/s) and for the elite sprinter this event did not occur until 0.34s into the cycle (velocity 3.13m/s.) After the RTD event for both sprinters their velocities increased, for the elite sprinter the velocity increased again at a higher rate, (acceleration 41.06m/s ^{2} at 0.47s into the cycle compared to just 12.22m/s^2 for the novice at the same time.) The final velocity for the elite sprinter at the second RTO event (0.53s) was 4.50m/s, whereas the final velocity for the novice sprinter at their second RTO event (0.55s) was 3.76 m/s.

Conclude on the differences between the two sprinters.

The elite sprinter has a greater acceleration during the cycle than does the novice sprinter. This may be due to training effects such as increased muscle power and increased reflexes. It can be seen from both the velocity-time curves and the acceleration-time curves for both subjects that the elite sprinter displays less fluctuation in both their velocity and acceleration during a complete cycle, compared to the novice sprinter. This may again be explained through training. The elite sprinter may have more control over their muscles, and therefore the force they produce, than the novice sprinter. This may enable them to provide a more sustained and controlled acceleration and velocity.

Briefly explain what may be gained by undertaking a joint angular kinematic analysis of the lower limb?

Undertaking a joint angular kinematic analysis of the lower limb provides one with a breakdown of the angular displacements for each of the hip, knee and ankle angles, and from this the angular velocities of the same joints. This allows for comparisons to be made between the two sprinters in terms of the specific position the leg is in at the different events during a cycle. Further comparisons can be made in relating this information back to the linear parameters to analyse performance and the effect of different positions of the leg.

Describe the main differences in the joint angular displacements between the two sprinters (discussion points may involve data of range of motion, angular data at specific events in the cycle and observation of the pattern of motion.)

From Table 1 it can be seen that there are differences in the angular range of motion of the particular joints between the two sprinters. The novice has a greater range of motion in the hip joint in comparison to the elite sprinter, (108.0 ° and 103.1° respectively.) However, in both the knee and ankle joints it is the elite sprinter who has the greater range of motion, 98.4 ° and 73.2° compared to 91.3° and 63.7° (knee and ankle.)

There are also differences in the two sprinters' joint angular displacements at the different events during the cycle. At the initial RTO event the elite sprinter's hip, knee and ankle angles were 88.6°, 115.9°, and 107.9° respectively, compared to those of the novice sprinter who's hip, knee and ankle angles were 76.5°, 118.5° and 92.6°. From these figures it can be seen that the novice has lesser hip and ankle angles, but a greater knee angle than that of the elite sprinter.

At the next event, the LTO, the elite's hip, knee and ankle angles were 58.7 °, 111.5° and 66.4°. Those of the novice were 59.3°, 112.9° and 65.3°. The angular displacements for both sprinters at this stage are relatively similar.

The elite sprinter's joint angles at the RTD event were 106.4°, 107.4° and 63.1° for the hip, knee and ankle angles. For the novice sprinter these angles were 79.5 °, 125.1° and 65.2°. From this one can see that the novice's hip angular displacement is considerably less than that for the elite sprinter. The knee angle however, is greater for the novice than for the elite, so too is the ankle angle. At the second RTO event the hip, knee and ankle angles for the elite sprinter were 158.5 °, 163.5° and 123.8° respectively. Those of the novice sprinter were 157.8°, 170.5° and 101.5° respectively. There was not much difference between the two sprinters' hip angles at this stage, although there were significant differences in the both the knee and ankle angles. The novice sprinter had a greater knee angle and a lesser ankle angle.

Relate these points to the conclusion for the linear data.

At the initial RTO event the novice sprinter has a higher initial velocity, (1.61m/s compared to 1.45m/s). From the joint angular kinematic analysis it can be seen that the novice sprinter at this event has smaller hip and ankle angles in comparison to those of the elite sprinter. This suggests that maybe the novice sprinter produces a greater elastic initial power that produces this higher velocity. By the LTO event however, the elite sprinter has a higher velocity, (3.03 m/s compared to 2.64 m/s), and it can be seen that here the hip and knee angles are smaller than those of the novice sprinter, and that the ankle angle is larger. At the RTD event the elite sprinter's velocity is again higher than that of the novice, (3.13 m/s compared to 2.31m/s) and the knee and ankle angles are smaller than those of the novice sprinter, whereas the hip angle is larger. At the final RTO event the elite sprinter's velocity is significantly higher, (4.50m/s compared to 3.76m/s) and at this stage the hip and ankle angles are greater than those of the novice sprinter, but the knee angle is smaller.

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