Biomechanical Factors in Track and Field Sprint Start

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In athletics sprint events, the block start performance can be fundamental to the outcome of a race. Several biomechanical determinants of sprinters have been identified. In the “Set” position, an anthropometry-driven block setting facilitating the hip extension and a rear leg contribution should be encouraged. At the push-off, a rapid extension of both hips and greater force production seems to be important. After block exiting, shorter flight times and greater propulsive forces are the main features of best sprinters.

track and field sprinters sprint start block start block velocity biomechanics

1. Introduction

The 100 m race is perhaps the highlight of the Olympic Games, as it defines who is the fastest man and woman in the world. In this type of event, the block start performance and the subsequent first two steps can be of critical importance since they have a direct influence on the overall 100 m time [1][2][3][4][5][6][7][8]. Given the importance of the sprint start, a new body of research has emerged in the past two decades that involved advanced technologies, high-precision methods, and sprinters of a higher performance level. For this reason, several technical (kinematic) and dynamic (kinetic) aspects are currently identified as determinant factors for starting block phase and initial sprint acceleration performances [1][4][6][9][10][11][12][13][14][15][16][17][18][19][20][21][22][23][24][25]. However, the concepts, outcomes, and findings between studies are sometimes inconsistent and difficult to interpret and conclude from. These inconsistencies may be accounted for by different research designs, methods, technologies of measure (e.g., external reaction forces under or on the blocks), statistical analyses, or more importantly, the ambiguity between samples of sprinters with different performance levels (e.g., elite, sub-elite, well-trained or trained) and/or between-group analyses based on the overall 100 m performance (i.e., personal best at 100 m—PB100m), and not on block performance.

2. Biomechanical Factors in Track and Field Sprint Start

2.1. The “Set” Position

The “Set” position is the first performance key factor in the block start performance because it depends on block settings and the body posture assumed by sprinters.

2.1.1. Block Settings

The “Set” position depends largely on the anteroposterior block distance, which defines the type of start used. There are three types of block starts based on inter-block spacing: bunched—less than 0.30 m; medium—0.30 to 0.50 m; and elongated—greater than 0.50 m [26][27].

Studies that reported block spacing based on the individual sprinter’s preferences [5][12][13][18][28] reported distances between 23.5 ± 1.9 cm (for female sprinters; PB100: 11.97 ± 2.6 s) [13] and 32 ± 5 cm (for male sprinters; PB100m: 10.79 ± 0.21) [18]. This suggests that most sprinters adopt distances within or very close to the bunched start type, favoring CM positioning closer to the starting line [7][29]. Slawinski, Dumas [8] have demonstrated that elongated start settings increase the block velocity (i.e., horizontal CM velocity at the block clearing [7]), but linked to an increase in the pushing time on the blocks which implies a significantly worse performance at 5 and 10 m compared to the bunched start. The same scholars showed that the medium start offers the best compromise between the pushing time and the force exerted on the blocks, allowing better times at 10 m [8]. Additionally, more recently, Cavedon, Sandri [12] have demonstrated that the anthropometry-driven block setting based on the sprinter’s leg length has an important role in the block start performance leading to a postural adaptation that promotes several kinematic and kinetic advantages [12]. Adjusting inter-block spacing to the relative lengths of the sprinter’s trunk and lower limbs (increasing 25.02% the usually bunched start inter-block spacing), allows greater force and impulse on the rear leg and greater total normalized average horizontal external power (NAHEP) [12], the latter one identified as the best descriptor of starting block performance [2].

Other blocks setting features that should be considered in the “set” position are the feet plate obliquity and the amount of pre-tension exerted on the blocks prior to the gunshot. The block inclination (relative to the track) affects the plantar flexor muscle-tendon units’ (MTU) initial lengths and determines the muscle mechanics and the external force parameters during the block phase [19][25][30]. Faster sprinters presumably produce the peak torque at longer MTU lengths and adopting a more crouched position would allow them to produce a higher force on the block phase [29]. Research data shows that reductions in both footplates’ inclinations (from 65 to 40°), meaning more muscle-tendon pre-stretch, lead to acute increases in block velocity and higher peak joint moments and powers, especially in the ankle [19]. Reductions in front block inclination alone (from 70 to 30°) also acutely increase block velocity without affecting push-off phase duration [30]. In another research [25], however, a greater mean rear block horizontal force was achieved by switching the rear foot to a steeper position (to 65°). This potential conflict between evidence might have arisen from differences in the location of the COP and the length of the footplates’ surface between studies since a better sprint start performance is accomplished with a higher and more to the rear COP on the starting block surface [20][28]. Conversely, a pre-tensioned start does not seem to yield a performance advantage over a conventional start, because the increase in the propulsive force of the lower limbs is reversed by an increase in the back force exerted through the hands during the same period [17].

2.1.2. Sprinter Body Posture

Apart from block configuration, the choice of the sprinter’s body posture also determines the effectiveness of the “Set” position on the subsequent block push-off phase. The horizontal distance between starting line and the vertical projection of the CM to the ground in the “Set” position (XCM) [7] is a factor that differentiates sprinters with different performance levels. As said before, faster sprinters tend to move their CM closer to the starting line [7][29] and closer to the ground [29]. Elite (PB100: 10.27 ± 0.14 s) and well-trained (PB100: 11.31 ± 0.28 s) male sprinters showed XCM of 22.9 and 27.8 cm, respectively [7]. Likewise, world-class (PB100: 11.10 ± 0.17 s) and elite (PB100: 11.95 ± 0.24 s) female sprinters presented XCM of 16.2 and 24.8 cm, respectively [29]. This more crouched position is only possible due to the high explosive strength of best sprinters, which allows them to produce higher levels of strength in the blocks [29] and reduce the horizontal travel distance of the CM. This body position is complemented by a more advanced shoulder position, putting more tension on the arms, allowing greater blocking speed during the subsequent phase [7].

Related to sprinter joint angles configuration in the “set” position, Milanese and Bertucco [31] have shown that horizontal CM velocity at the block take-off and along the first two steps increases significantly when the rear knee angle is set to 90° instead of 135° or 115°. A 90° rear knee angle allows for a better push-off of the rear leg than larger angles, showing such condition may be a strategy that allows some elite sprinters to maximize their strength capacity [31]. A more flexed front knee may facilitate the optimal joint moment production, but only in sprinters with exceptionally high levels of explosive strength [29].

2.2. The Push-Off Phase

The “block-phase” or “push-off phase” in the starting blocks initiates immediately after the gunshot and is considered a complex motor task that helps to determine sprint start performance [1].

2.2.1. Push-Off Kinematics Analysis

The efficiency of the starting action depends mainly on the compromise between horizontal start velocity (or block velocity) and the block time (referring to the time elapsing from the first movement at the “set” position to the exiting from the block [7]), resulting in the horizontal start acceleration [13]. Despite the horizontal block velocity could be considered the main parameter for an efficient sprint start [13], it cannot be used solely [2] because an increased block velocity could be due to either an increase in the net propulsion force generated or to an increased push-off duration [2][18]. Thus, best sprinters tend to present higher block velocity and greater block acceleration than slower sprinters [1][5][7][13][16][22][32][33], because they are able to produce a greater impulse in a shorter time [2][5][34] and optimize their force production on the blocks [16][19]. In fact, if sprinters increase their anteroposterior force impulse (FI = force × time) from a longer block time, they decrease their block acceleration [2][33] and the performance at 5 and 10 m [8]. Studies comparing data between sprinters of different performance levels mostly show higher block velocities (3.38 ± 0.10 vs. 3.19 ± 0.19 m·s^{-1}; 3.48 ± 0.05 vs. 3.24 ± 0.18 m·s^{-1}; 3.61 ± 0.08 vs. 3.17 ± 0.19 m·s^{-1}; and 3.36 ± 0.15 vs. 3.16 ± 0.18 m·s^{-1}) [5][7][22][35] and greater block accelerations (9.5 vs. 8.8 m·s^{-2}; 8.2 vs. 7.9 m·s^{-2}; 9.72 vs. 8.4 m·s^{-2}; and 7.47 vs. 7.35 m·s^{-2}) [1][5][7][33] for faster sprinters. Furthermore, higher performance levels also appear to be slightly related to lower block vertical velocities [29] and more horizontal CM projection angles (i.e., resultant direction from the CM horizontal and vertical block exit velocities) [35][32].

Lower limbs joints pattern during the pushing phase (i.e., from movement onset until block exit) is mostly associated with extension movements, especially on the hips and knees [3][4][6][25][34]. The front leg joints typically extend through a considerable ROM in a proximal-to-distal extension pattern [3], reaching their maximum at the beginning of the flight phase (e.g., hip: 183.2 ± 6.8°, knee: 177.4 ± 5.2°, and ankle: 133.1 ± 6.7°) [6]. Contrarily, the rear leg does not exhibit the same proximal-to-distal extension strategy, with the knee reaching its peak angular velocity before the hip and the ankle [3][34]. This happens perhaps due to considerably less ROM of the rear knee compared to the front knee [3], as it starts from a more extended angle in the "set" position (e.g., rear knee: 120.7 ± 9.7°; front knee: 91.0 ± 9.8°). The movement of the ankles is more complex because it involves first a dorsiflexion and after an extension resulting in a stretch-shortening cycle of the triceps surae muscle [3][6][25][34]. The duration of the ankle's flexion is greater for the rear ankle (50% of the block phase) than for the front ankle (20% of the block phase) [34]. Experimental manipulations on footplates' inclinations [19][30] have shown an inverse association between block angles and muscle-tendon lengths of the gastrocnemius and soleus, highlighting that block angles steeper than 65° could have disadvantageous effects on plantar flexor function [19]. Peak angular velocities at both hips are reached by a combination of flexion–extension, abduction–adduction, and internal–external rotation [23][34], reinforcing the importance of a 3D analysis of the sprint start [34]. Whilst there is a consistent trend among sprinters in the joint angular velocity sequence during the block phase, the lack of comparative data between sprinters of different performance levels does not allow to highlight the technical aspects critical to success. However, a rapid hip extension should be one of the first aspects to consider on a sprinter's technique during the start, as peak angular velocities at both hips and rear hip range of extension are positively associated with block power (r = 0.49) [3].

Although upper body kinematics in the push-off phase has been the focus of a small number of studies, some important findings are noteworthy. The action of the upper limbs is more variable between sprinters than that observed for the lower limbs [34]. Despite this, it is possible to recognize a 3D movement pattern for shoulders and trunk with a combination of flexion–extension, abduction–adduction, and internal–external rotation movements, while the elbows exhibit an extension and pronation movement [34]. The velocity of the rear shoulder tends to be slightly greater than that of the other joints, but the peak resultant angular velocities at the upper limb joints are comparable to those at lower limbs during the push-off phase, particularly that of both knees and front ankle [34]. However, there is no evidence linking different upper limb kinematic patterns with any block phase performance predictor, and further research is needed to compile relevant recommendations for athletes and coaches.

2.2.2. Push-Off Kinetic Analysis

According to Newton's second law of motion, horizontal CM acceleration requires net propulsive forces to be applied to the athlete's body in the sprinting direction. Therefore, as said before, the horizontal force impulse, made up by the mean horizontal force and push-off time, is the determining factor of the horizontal velocity at block exit [2][5][34][33]. The relationship between these factors (i.e., horizontal force and push-off time) shows that the application of a greater amount of horizontal force is a key performance factor [33], as an increase in the time action (block time) conflicts with the criterion for 100 m performance: 'shortest time possible'. Thus, best sprinters generate greater average forces [10][22], higher rates of force development [7][25], and larger net [7] and horizontal [5] block impulses than their slower counterparts. Likewise, Graham-Smith, Colyer [32] comparing senior to junior athletes also showed that sprinters with faster PB100m (senior athletes) exhibit higher relative horizontal force during the initial block phase and higher forces during the transition from bilateral to unilateral pushing [32]. The evident importance of the force generated against the blocks for proficient execution of the starting block phase has encouraged researchers to gain a deeper understanding of the kinetic determinants of such a crucial phase of sprinting. Bezodis, Salo [2] tried to find the push-off performance measure that was more adequate, objective, and possible to quantify in the field. From their analysis, the NAHEP was identified as the most appropriate measure of performance because it objectively reflects, in a single measure, how much sprinters are able to increase their velocities and the associated length of time taken to achieve this, whilst accounting for variations in morphologies between sprinters [2]. Later, the identification of the magnitude of the force applied to both blocks and their optimal orientation as major determinants of performance encouraged researchers to gain a deeper understanding of the push-off forces applied against each block separately. Consequently, some studies support the importance of the force generated by the front leg for forwards propulsion [6][33] and show that faster sprinters are able to produce higher force impulses in the front block than slower sprinters [5][35] (for example: 221.3 ± 15.8 N·s vs. 178.3 ± 13.1 N·s for faster and slower sprinters, respectively [5]). Colyer, Graham-Smith [35] reinforce this feature highlighting that higher front block force production during the transition (when the rear foot leaves the block, 54% of the block push) and a more horizontally orientated front block force vector in the block phase (81–92%) are important performance-differentiating factors. However, other evidence ensures that the rear block force magnitudes are the most predictive external kinetic features of block power [10][35] and sprint performance [5][7][12][16].

Forces under the hands have been reported in relatively few studies [10][35][33], showing somewhat contradictory results. While some point to a primary support role [33], others point out that the best athletes produced less negative horizontal impulse under hands compared with their slower counterparts [35]. Therefore, the importance of the hands' kinetics during the push-off phase remains unclear and should be the subject of future research.

In addition to external kinetic analyses, which provide valuable insight into starting block performance, the analysis of internal kinetics (i.e., joint kinetics) helps to increase the understanding of the segment motions that are responsible for CM acceleration. In the rear block, the magnitude of the horizontal force produced is determined by the rear hip extensor moment and the rear hip extensor power coupled with large ankle joint plantarflexion moment [4][36][37], without any significant knee joint contribution [4][36]. At the front block, a proximal–distal pattern of peak joint power is evident [4], highlighting a strategy often adopted in power demanding tasks, with the main periods of positive extensor power at the front ankle and knee occurring after the rear foot has left the block [4].

2.3. The First Two Steps

The primary goal of the first steps is to generate a high horizontal velocity [38]. However, the transition between block start and the first steps represents a specific biomechanical paradigm: integrate temporal and spatial acyclic movements into a cyclic action [5]. The efficiency of this transition depends on the biomechanical demands of the first stances after block clearance, which are very different from the other stances during acceleration [14]. The sprinter aims to generate maximal forward acceleration during the transition from start block into sprint running [2][14][22][33] while generating sufficient upward acceleration to erect itself from a flexed position in the start blocks to a more extended position [6][14]. Specific technical (kinematic) and dynamic (kinetic) skills are therefore needed to successfully achieve this transition.

2.3.1. First Two Steps Kinematic Analysis

The primary goal of the initial steps of a sprint running is to generate a high horizontal sprint velocity, which results from the product of the length and frequency of the sprinter's steps [22][38]. Spatiotemporal parameters have shown that the sprinter's step length increases regularly during the acceleration phase, while step frequency is almost instantaneously leveled to the maximum possible [22]. Typically, the step frequency reaches the maximal values very quickly (80% at the first step and about 90% after the third step) [22], achieving around 4 Hz immediately after block exit [39][38]. The length of the first steps is more variable between sprinters, ranging from 0.82 to 1.068 m (senior females) [1][29] or 0.85 to 1.371 m (senior males) [1][7] on the first step, and from 1.06 to 1.30 m (senior females) [1][13] or 1.053 to 2.10 m (senior males) [7][27] on the second step. Despite this variability, step length tends to be longer in faster sprinters, particularly in the first step (e.g., 1.371 ± 0.090 vs. 1.208 ± 0.087 m [7]; 1.30 ± 0.51 vs. 1.06 ± 0.60 m [5]; 1.135 ± 0.025 vs. 0.968 ± 0.162 m [29]), exhibiting an increase of about 14 cm for every 1 s less in PB100m [29]. This may be a consequence of the lower vertical velocity of the CM at the block clearing shown by faster sprinters, allowing them to travel a longer distance despite shorter flight times [29]. Indeed, the kinematics of faster sprinters is also characterized by a tendency to assume long ground contact times in the first two steps (e.g., mean first contact duration for Diamond League sprinters is 0.210 s for males and 0.225 s for females, which is greater than those of lower-level Italian junior sprinters: 0.176 and 0.166 s, respectively), associated to short flight times (0.045 and 0.064 s, for the first flight of world-class and elite male sprinters, respectively) [29]. This strategy allows the high-level sprinters to optimize the time during which propulsive force can be generated, minimizing the time spent in flight where force cannot be generated. Combined with this, best sprinters have their CM projected further forward [7] at the first touchdown, putting the foot behind the vertical projection of the CM [3], and minimizing the braking phase. At the takeoff of the first and second steps, the CM horizontal position is also greater in elite than well-trained sprinters [7]. This means that the CM resultant and horizontal velocity in the first two steps are generally greater in high-level sprinters [7][15].

Lower limb joints pattern during the first two steps is associated with a proximal-to-distal sequence of the hip, knee, and ankle of the stance leg [4][9][40]. During both first and second steps, the ankle joint undergoes dorsiflexion during the first half of stance (e.g., 17 ± 3° and 18 ± 3° for the first and second steps, respectively [40]) and subsequently a plantarflexion movement (e.g., 45 ± 6° and 44 ± 5° for the first and second steps, respectively [40]).

The hip performs extension for the entire stances, the knee extends until the final 5% of stances, and the ankle is dorsi-flexed during the first half of stances before the plantar flexing action [6]. After leaving the rear block, there is a small increase in ankle joint dorsiflexion during the swing phase, preceding the plantarflexion that occurs just before touchdown [6]. Although the ankle plantar-flexes slightly at the end of the flight, the ankle is in a dorsi-flexed position at initial contact (e.g., first stance: 70.6 ± 5.8° and second stance: 72.4 ± 7.1° [6]). During both first and second steps, the ankle joint dorsi-flexes during the first half of stance (e.g., 17 ± 3° and 18 ± 3° for the first and second steps, respectively [40]) and subsequently performs a plantarflexion movement (e.g., 45 ± 6° and 44 ± 5° for the first and second stance, respectively [40]). Note that a reduction in the range of dorsiflexion during early stance, requiring high plantar flexor moments, has already been associated with increases in first stance power [41]. Maximal plantarflexion occurs immediately following takeoff reaching, for example, 111.3° at the first stance and 107.1° at the second stance [6]. The extension of both knees occurs just after the block exit and reaches its maximum at the beginning of the flight phase, with larger extension in the front compared with the rear leg (e.g., rear: 134.9 ± 11.2°; front: 177.4 ± 5.2°) [6]. From a flexed position at initial contact, the knee extensors generate power to induce extension throughout stance and to attain maximal extension at takeoff, achieving peak extension angles of around 160–170° (not full extension; e.g., first stance: 165.2 ± 20.6°; second stance: 163.6 ± 17.7° [6]). This extension action of the knee during stances on its own may play a role in the rise of the CM during early acceleration [39]. The hip joints extend during block clearance to reach maximal extension during the beginning of the flight phase. During stance, the hips are in a flexed position at initial contact and continue to extend throughout stance, achieving maximal extension immediately following takeoff (e.g., first stance: 180.6 ± 20.9°; second stance: 181.1 ± 20.0° [6]). There is also a considerable ROM in hip and pelvis rotation during stance as well as abduction. Although there are detailed descriptions of the lower limb angular kinematics during the first two stances and flight phases [3][6], there seems to be no clear evidence about the joint kinematic features that differentiate faster from slower sprinters. Furthermore, there is also a lack of experimental data on arm actions during early acceleration and its relationship to performance descriptors, making necessary future research in this area to help identify the most important performance features.

2.3.2. First Two Steps Kinetic Analysis

As said before, fast acceleration is a crucial determinant of performance in sprint running, where a high horizontal force impulse in a short time [13] is essential to reach high horizontal velocity [40]. Thus, as the highest CM acceleration during a sprint occurs during the first stances [7][9][14] (e.g., first stance: 0.36 ± 0.05 m·s^{-2}; second stance: 0.23 ± 0.04 m·s^{-2} [14]), the ability to generate during this phase greater absolute impulse [7][18], maximal external power [32][33], and a forward-leaning force oriented in the sagittal plane [21][22][24][33] is linked to an overall higher sprint performance. Larger propulsive horizontal forces are particularly important during early acceleration, being a discriminating factor for superior levels of performance [42]. Experienced male sprinters (PB100m: 10.79 ± 0.21 s) can produce propulsive horizontal forces of around 1.1 bodyweight during the first stance [18]. However, a negative horizontal force has also been reported during the first contact after the block exit, even if the foot is properly placed behind the vertical projection of the CM [18]. During the first stance, for example, the braking phase represents about 13% of the total stance phase and the magnitude of the braking forces can reach up to 40% of the respective propulsive forces [18].

At joint level, the hip, knee, and ankle joints generate energy during stance leg extension [6], although it appears that the ankle joint is the main contributor to CM acceleration [14]. However, experimental and simulation studies highlight that the knee plays an important role during the first stance, being decisive for forward and upward CM acceleration [4][6][14][15]. The importance of power generation at the knee seems to be specific for the first stance when the knee is in a more flexed position and the sprinter is leaning forward. From the second stance onwards, the knee becomes less and the ankle more dominant since the plantar flexors are in a better position to contribute to forward progression [6]. As the knee is in a flexed position during the first step, the sprinter favors the immediate power generation of the knee extensors rather than preserving a stretch-shortening cycle [6]. In contrast, a stretch-shortening mechanism can be confirmed at the hip and ankle [4][6][14][15]. Hip extensors maximal power generation occurs near touchdown [4][6] where the hip extensors actively pull the body over the touchdown point [6]. The hip can effectively generate large joint moments and power [14], but only contributes minimally to propulsion and body lift during the first two stances [14]. Ankle plantar flexors act throughout both the first and second stances under a stretch-shortening cycle. There is therefore an initial phase of power absorption preceding the forceful power generation at take-off [4][14]. As a major contributor to CM acceleration, the ankle joint can generate up to four times more power than it absorbs during the first two stances [40]. Nevertheless, the importance of ankle stiffness during the first two stances remains unclear. While Charalambous, Irwin [43], in a case report, found a correlation between greater ankle stiffness and greater horizontal CM velocity at take-off ($r = 0.74$), Aeles, Jonkers [9] did not, still highlighting the lack of differences between faster (senior) and slower (junior) sprinters. Future work is therefore needed to further clarify this issue. Furthermore, it remains unclear whether ankle stiffness is influenced by foot structure and function (e.g., planus, rectus cavus, clubfoot) as well as other important performance variables such as greater maximal power, a forward-leaning force oriented in the sagittal plane, or COP location during push-off.

Concerning kinetic factors differentiating senior and junior athletes, Graham-Smith, Colyer [32] reported that, contrarily to the block phase where there are marked differences between groups, the force and power waveforms relating to the first two steps did not differ considerably across groups. Still, senior sprinters are able to produce greater horizontal power during the initial part (10–19% of the stance phase) of the first and second ground contact (first step: 25.1 ± 3.6 W·kg^{-1} vs. 23.1 ± 6 W·kg^{-1} and second step: 26.7 ± 3.6 W·kg^{-1} vs. 24.9 ± 4.5 W·kg^{-1}, for senior and junior sprinters, respectively), and also exhibit a higher proportion of forces immediately after braking forces are reversed (from 9% to 15% and 25% to 29% of stance phase) [32]. Furthermore, Debaere, Vanwanseele [15] also highlight that adult sprinters are able to generate more joint power at the knee during the first step compared to young sprinters, inducing longer step length and therefore higher velocity [15]. Younger sprinters tend to prioritize a different technique: the hip contributes more to total power generation, while the knee contributes far less [15]. This indicates that younger sprinters lack the specific technical skills observed in adult sprinters, likely due to less musculature than adults [1][9][15]. However, there is no evidence of differences in ankle joint stiffness, range of dorsiflexion, or plantar flexor moment between young and adult sprinters [9]. This indicates that the technical performance-related parameters of the first stances are not likely to explain the better 100 m sprint times in adult compared to young sprinters [9].

3. Conclusions

(i) the choice of an anteroposterior block distance relative to the sprinter’s leg length may be beneficial for some individuals, promoting greater block start performance (greater normalized average horizontal external power); (ii) the use of footplate inclinations that individually facilitate initial dorsiflexion should be encouraged—footplate angles around the 40° are recommended and block angles steeper than 65° should be avoided; (iii) pushing the calcaneus onto the block (posterior location) may be beneficial for some individuals, improving the 10 m time and/or horizontal external power; (iv) short block exit flight times and optimized first stance contact times should be encouraged, as they maximize the time during which propulsive force can be generated; (v) focus attention on the magnitude of force applied on the rear block, as it is considered to be a primary determinant of block clearance; (vi) rapid hip extension during the push-off phase should be a priority in sprinter focus and coach feedback; (vii) the large role played by the hips on the push-off phase and by both the knee and ankle at the early stance must be acknowledged within physical and technical training to ensure strength and power are developed effectively for the nature of the sprint start.

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