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Biomechanical Analysis of Sprinting Technique in 100-m Female Academy Athletes

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Abstract

The 100-m sprint is a highly technical athletic event in which performance is determined by the effective interaction of force production, acceleration, running velocity, and movement technique. This review examines the major biomechanical characteristics of sprinting technique in female athletes, with particular relevance to academy-level sprinters. The analysis focuses on the block start, acceleration, maximum velocity, and speed-maintenance phases, together with key variables such as step length, step frequency, ground contact time, flight time, joint kinematics, and ground reaction forces. Evidence from research on female sprinters indicates that distinct biomechanical factors contribute to performance across successive phases of sprinting. During early acceleration, effective propulsive force and progressive development of step length are important, whereas at higher running velocities, increased step frequency and shorter support times become particularly relevant. Efficient application of horizontal force also contributes substantially to acceleration and overall sprint performance. Female-specific research further suggests that biomechanical characteristics are influenced not only by sex but also by the athlete's performance level. Understanding these mechanical and technical factors can help coaches identify limitations in sprint technique and develop appropriate training strategies for academy-level female athletes.

Keywords: Sprint biomechanics, 100-m sprint, female athletes, sprint technique, acceleration, step frequency, ground reaction force.

1. Introduction

The 100-m sprint is one of the most technically demanding events in athletics, requiring an athlete to generate high levels of force and progressively increase running velocity within a very short period. Although sprint performance is commonly represented by finishing time, the final result is influenced by a complex interaction of biomechanical factors, including starting technique, acceleration, step length, step frequency, ground contact time, body position, and force application [1], [2].

A 100-m race can be broadly divided into the phases of the block start, acceleration, maximum velocity, and speed maintenance or deceleration. Each phase presents different mechanical requirements. During the start and early acceleration, the athlete must generate substantial horizontal propulsion to increase forward velocity. As running speed increases, changes occur in step length, step frequency, contact time, flight time, and body orientation. At maximum velocity, maintaining effective force application during increasingly short ground-contact periods becomes particularly important [2], [3].

Biomechanical analysis provides an objective method for examining these technical characteristics. Rather than evaluating sprinting technique only through visual observation, variables such as joint motion, step characteristics, ground reaction forces, and running velocity can be used to identify mechanical factors associated with better performance. Such information is valuable for coaches when correcting technique and designing sprint-specific training.

Research involving female sprinters has demonstrated that biomechanical determinants can change throughout a sprint. During early acceleration, increasing step length and effective propulsive force appear important, whereas higher step frequency and shorter support times become increasingly relevant as running velocity rises [4]. Research also suggests that differences in sprint mechanics should not be automatically attributed to sex, as performance level accounts for a substantial proportion of the variation in sprint-start characteristics [5].

For academy-level female athletes, understanding these biomechanical principles may be particularly valuable, as their sprint technique is still developing alongside their strength, coordination, and training experience. Therefore, the present review examines the major biomechanical characteristics of the 100-m sprinting technique in female athletes and discusses their practical relevance to the technical development of academy-level sprinters.

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3. Biomechanics Across the Phases of 100-m Sprinting

3.1 Block Start

The block start establishes the initial conditions for acceleration and can influence overall 100-m performance. In the set position, the athlete must adopt a configuration that permits rapid extension of the lower limbs and effective force production against the starting blocks. Following the starting signal, coordinated extension of the hip, knee, and ankle joints contributes to forward propulsion [1], [6].

Effective block clearance is characterized by the rapid development of horizontal velocity rather than excessive upward movement. Better-performing sprinters generally demonstrate greater block velocity, effective force production, and appropriate projection of the centre of mass. The contribution of both legs, particularly the rear leg's action, is also important during block clearance.

3.2 Acceleration Phase

After leaving the blocks, the primary objective is to progressively increase horizontal running velocity. During early acceleration, the athlete maintains a forward body orientation and applies substantial propulsive force against the ground. As velocity increases, the trunk gradually becomes more upright, and step length progressively increases.

Female-specific biomechanical evidence indicates that increasing step length is particularly important during the initial steps of acceleration. Greater propulsive and anteroposterior forces have also been associated with superior acceleration in female sprinters [4]. Therefore, acceleration depends not simply on taking faster steps but on effectively coordinating step characteristics with the application of force.

3.3 Maximum-Velocity Phase

As acceleration decreases, the athlete approaches maximum running velocity. Sprint mechanics at this stage differ from those observed during early acceleration. The body assumes a more upright position, ground contact becomes shorter, and maintaining high step frequency becomes increasingly important.

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At maximum or near-maximum velocity, the athlete must generate sufficient force within a very short ground-contact period while minimizing unnecessary braking. Research on female sprinters indicates that a higher step frequency, combined with a shorter support time, is associated with higher running speed during the later steps of a sprint [4].

Efficient lower-limb positioning and coordinated hip, knee, and ankle movements are also important for maintaining high velocity. Excessive reaching of the foot ahead of the body may increase braking forces and reduce movement efficiency.

3.4 Speed-Maintenance and Deceleration Phase

After reaching maximum velocity, the athlete attempts to maintain it for as long as possible. However, running velocity generally decreases toward the end of the 100-m race because maximum sprint speed cannot be sustained indefinitely.

During this phase, fatigue may influence step frequency, step length, force production, and overall movement coordination. An effective sprinter attempts to minimize these changes and maintain technically efficient movement rather than consciously increasing effort through excessive muscular tension.

The ability to limit the decline in velocity is therefore an important component of overall 100-m performance. For academy-level female athletes, technical development should address all sprint phases, as weaknesses in the start, acceleration, maximum-velocity mechanics, or speed maintenance can independently affect overall performance.

4. Key Biomechanical Variables Affecting Sprint Performance

4.1 Step Length and Step Frequency

Running velocity is determined by the interaction between step length and step frequency. Step length is the distance covered per step, whereas step frequency is the number of steps taken per unit time. An effective sprinter develops an appropriate combination of both variables rather than maximizing either one independently [7], [8].

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During early acceleration, progressive increases in step length substantially increase running velocity. As the athlete approaches higher speeds, step frequency becomes increasingly important. Research involving female sprinters has shown that a higher step frequency in the later stages of sprinting is associated with greater running speed [4].

4.2 Ground Contact and Flight Time

Ground contact time represents the period during which the foot remains in contact with the ground, while flight time is the interval when neither foot is in contact with the surface. These temporal variables change as sprint velocity increases.

At higher running speeds, athletes generally demonstrate shorter ground contact periods. Research on female sprinters has reported that shorter support time is associated with greater running velocity during later sprint steps [4]. However, simply minimizing contact time is not sufficient; the athlete must also produce and orient adequate force during the available contact period.

4.3 Running Velocity and Acceleration

Acceleration describes the rate at which running velocity increases. It is particularly important during the first part of the 100-m sprint, when the athlete progresses from a stationary position toward maximum velocity.

Greater acceleration depends on effective propulsive force, appropriate body orientation, and coordinated changes in step mechanics. The ability to continue applying force effectively as velocity increases is therefore an important mechanical characteristic of successful sprinting [3], [6].

4.4 Joint and Lower-Limb Kinematics

The movement of the hip, knee, and ankle joints contributes to efficient sprinting technique. During acceleration, coordinated extension of the lower extremities helps produce forward propulsion. As the athlete becomes more upright, rapid limb repositioning becomes increasingly important.

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Appropriate lower-limb mechanics also influence foot placement at ground contact. Excessive forward placement of the foot relative to the body may increase braking action, whereas effective positioning helps the athlete maintain forward momentum. The sprint technique should therefore emphasize coordinated movement rather than isolated changes at a single joint.

4.5 Ground Reaction Force and Force Application

Ground reaction force is produced when the athlete applies force against the running surface. Both the magnitude and direction of this force influence sprint acceleration and velocity.

Evidence indicates that effective horizontal force application is particularly important during acceleration. The ability to orient the resultant ground reaction force backward against the ground contributes to forward acceleration and has been associated with better 100-m performance [3].

For developing female sprinters, these biomechanical variables should be considered collectively. Step characteristics, contact time, joint movement, and force application interact continuously, and improvement in sprint performance is therefore more likely to result from coordinated technical development than from modification of a single variable.

5. Biomechanical Characteristics of Female Sprinters

Biomechanical characteristics of sprinting in female athletes are influenced by several factors, including performance level, training experience, strength, anthropometric characteristics, and technical proficiency. Therefore, female sprint mechanics should be evaluated based on the athlete's individual performance characteristics rather than on generalized assumptions based on sex alone [5], [9].

Research examining female sprinters has identified important relationships between sprint performance and step frequency, support time, step length, and force production. Gleadhill and Nagahara [4] reported that during early acceleration, greater increases in step length and effective propulsive force were associated with better acceleration. During later stages of sprinting, higher step frequency and shorter support time were associated with greater running speed.

Performance level also influences the biomechanical profile of female sprinters. Nagahara [9] examined female athletes at different sprint performance levels and found differences in step

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frequency, support time, ground reaction force impulses, and mean forces. These findings suggest that improvements in sprint performance are accompanied by changes in both spatiotemporal and kinetic characteristics.

The sprint start also demonstrates performance-related differences. Research involving elite male and female sprinters has shown that many characteristics previously interpreted as sex-related differences are strongly influenced by absolute sprint performance. Faster athletes tend to demonstrate more effective body positioning, horizontal velocity development, and mechanics during the first steps [5].

For academy-level female athletes, these findings have practical importance. Developing athletes may differ considerably in maturation, strength, coordination, and technical experience. Consequently, coaches should avoid applying a single ideal sprinting model to every athlete. Biomechanical assessment should instead identify individual limitations in acceleration, step mechanics, ground contact, force application, and body positioning.

Thus, the biomechanical development of female sprinters should emphasize individualized technical improvement while considering the athlete's performance level and stage of development.

6. Evidence from Previous Studies

Biomechanical research on sprinting has identified several kinematic and kinetic variables associated with sprint performance. Although a considerable proportion of earlier research involved male or mixed samples, an increasing number of studies have specifically examined female sprinters.

Gleadhill and Nagahara [4] investigated the kinetic and kinematic determinants of sprint performance in female athletes. Fifteen female sprinters completed 60-m sprints while spatiotemporal and ground reaction force variables were recorded. During early acceleration, increases in step length and greater propulsive force were associated with better acceleration. During later steps, greater running speed was associated with higher step frequency and shorter support time.

Nagahara et al. [9] subsequently provided normative spatiotemporal and ground reaction force data from 44 female sprinters across different performance levels. Significant differences were observed in step frequency, support time, impulses, and mean forces. The findings indicated that improved sprint performance is accompanied by changes in both temporal characteristics and force production.

Research on world-class 100-m athletes has also demonstrated the importance of mechanical characteristics throughout the entire race. Slawinski et al. [10] analyzed 100 distance–time curves from international 100-m finals, including 50 female sprinters. Maximum sprint velocity and mean power output were strongly associated with 100-m performance. The study also emphasized the importance of maintaining effective horizontal force application as running velocity increases.

Sprint-start research provides additional evidence concerning the importance of the initial phase. Systematic analysis of sprint-start biomechanics indicates that rapid hip extension, effective force production during block push-off, horizontal velocity at block clearance, and propulsive forces during the initial steps contribute to better starting performance [1].

Table 1. Selected Biomechanical Evidence Relevant to Female Sprint Performance

Study	**Participants/Data**	**Variables Examined**	**Major Findings**
Gleadhill and Nagahara [4]	15 female sprinters	Step length, step frequency, support time, flight time, GRF	Step length and propulsive force were important during acceleration; step frequency and shorter support time were associated with higher later-stage speed
Nagahara et al. [9]	44 female sprinters	Spatiotemporal variables, impulses and GRF	Sprint performance levels differed in step frequency, support time, impulses and force characteristics

Slawinski et al. [10]	100 world-class 100-m performances, including 50 women	Velocity, acceleration, force and power	Maximum velocity and mean power were strongly associated with 100-m performance
Sprint-start systematic review [1]	36 studies	Block start, kinematics and kinetics	Effective push-off, horizontal velocity and propulsive force were important characteristics of superior sprint starts

Overall, previous research demonstrates that successful sprinting cannot be attributed to a single biomechanical variable. Sprint performance results from the interaction of step mechanics, ground contact characteristics, force production, body positioning, and the athlete's ability to adapt these variables across different phases of the race. For female academy athletes, these findings provide an evidence-based foundation for evaluating sprint technique and identifying areas requiring technical development.

7. Discussion

The reviewed evidence demonstrates that 100-m sprint performance is determined by the interaction of several biomechanical factors rather than by a single technical characteristic. The mechanical requirements of sprinting change continuously from block clearance through acceleration to maximum velocity and the final stages of the race. Consequently, effective sprint technique requires athletes to modify body position, force application, and step characteristics according to the demands of each phase.

During the start and early acceleration, the ability to generate and direct force effectively is particularly important. Rapid extension of the lower limbs during block clearance and effective horizontal propulsion contribute to the initial development of velocity. During the following steps, progressive increases in step length and appropriate propulsive force support continued acceleration [1], [4].

As running velocity increases, the relative importance of biomechanical variables changes. Female-specific evidence indicates that step frequency and support time become increasingly important during later stages of sprinting. Faster female sprinters tend to exhibit higher step frequencies and shorter support times, along with differences in propulsive and ground reaction force characteristics [4], [9]. Therefore, the technique required for effective early acceleration should not be assumed to be identical to that required at higher running velocities.

An important implication is that neither step length nor step frequency should be considered independently. Excessive attempts to lengthen the stride may disrupt natural sprint mechanics and increase braking, while focusing solely on rapid stepping may limit effective force application. Efficient sprinting requires an individualized interaction between step length, step frequency, ground contact, and force production.

The evidence also suggests that biomechanical characteristics among female sprinters are influenced by performance level and training status. Therefore, differences observed between athletes should not automatically be attributed to sex. This is particularly relevant for academy-level female sprinters, whose technique, strength, coordination, and sprint experience may still be developing.

Overall, biomechanical analysis can provide valuable information for identifying technical limitations in female sprinters. However, technical modifications should be individualized and tailored to the specific phase at which performance limitations occur, rather than attempting to impose a single ideal sprinting technique on all athletes.

8. Practical Implications for Academy-Level Female Athletes

Biomechanical analysis can assist coaches in identifying specific technical limitations and designing appropriate training programmes for developing female sprinters. Rather than evaluating sprint performance solely by 100-m completion time, coaches should consider the mechanical characteristics of the sprint's different phases.

8.1 Start and Acceleration Training

During the start and early acceleration, emphasis should be placed on effective block positioning, forward projection, and horizontal force application. Athletes should develop the ability to produce propulsive force while gradually increasing step length. Technical drills should therefore focus on effective block clearance and controlled progression through the initial acceleration steps.

8.2 Maximum-Velocity Technique

At higher running velocities, athletes should focus on maintaining efficient step frequency, appropriate ground contact, and coordinated lower-limb movement. Excessive attempts to increase stride length should be avoided because sprint velocity depends on an effective interaction between step length and step frequency, rather than on either variable in isolation.

8.3 Individualized Technical Correction

Female sprinters may demonstrate different combinations of step length, step frequency, contact time, and force production. Therefore, coaches should avoid applying identical technical corrections to all athletes. Video analysis, split times, step characteristics, and, where available, force measurements can help identify individual limitations.

8.4 Consideration of Growth and Maturation

For younger academy athletes, biological maturation should be taken into account when evaluating sprint mechanics. Growth-related changes can influence body dimensions, relative force production, step length, and propulsive impulse. Consequently, temporary changes in sprint technique or performance during adolescence should not automatically be interpreted as technical deficiencies.

Training programs should therefore progress according to the athlete's developmental and performance level. Combining biomechanical assessment with sprint-specific strength, coordination, acceleration, and technical training can provide a more appropriate approach to improving 100-m performance in academy-level female athletes.

9. Research Gap and Future Directions

Although sprint biomechanics has been extensively investigated, comparatively fewer studies have focused specifically on female sprinters, particularly developing athletes at the academy level. Much of the established knowledge regarding sprint mechanics has traditionally been derived from male or mixed-athlete populations, which may not completely represent the biomechanical characteristics of developing female sprinters [11], [12].

Another limitation is that many studies examine isolated sections of sprinting, such as the block start, initial acceleration, or maximum-velocity phase. Fewer studies have evaluated biomechanical changes throughout the entire 100-m performance in female athletes. Consequently, the interaction between start mechanics, acceleration, maximum velocity, and speed maintenance requires further female-specific investigation.

For academy-level athletes, growth and biological maturation are additional considerations in research. Changes in body dimensions, muscular capacity, ground reaction force, and step mechanics during adolescence may influence sprint technique independently of training [13]. Therefore, comparisons based solely on chronological age may not adequately account for differences in sprint biomechanics among young female athletes.

Future studies should include larger samples of female sprinters across different performance and maturation levels. Longitudinal research combining video or motion analysis with step characteristics, split times, joint kinematics, and ground reaction force measurements would provide a more complete understanding of technical development. Such evidence could also help establish age- and performance-appropriate biomechanical reference values for female academy sprinters.

Greater emphasis on female-specific and development-sensitive research may ultimately improve sprint assessment, technical coaching, talent development, and individualized training programs.

10. Conclusion

The present review demonstrates that 100-m sprint performance is influenced by the coordinated interaction of several biomechanical factors across different phases of the race. The block start, acceleration, maximum velocity, and speed maintenance phases each impose distinct mechanical demands on the athlete.

During the start and early acceleration, effective application of horizontal force, body orientation, and progressive development of step length are important for increasing running velocity. As sprint speed increases, step frequency and shorter support times become increasingly relevant. At the same time, efficient application of ground reaction forces and coordinated lower-limb mechanics are necessary to maintain high running velocity.

Evidence from female sprinters indicates that biomechanical characteristics vary with performance level. Faster female athletes demonstrate differences in step frequency, support time, propulsive force, and other kinetic variables compared with lower-performing athletes. Therefore, sprint technique should not be evaluated using a single biomechanical characteristic or an identical technical model for every athlete.

For academy-level female sprinters, biomechanical assessment can provide useful information for identifying limitations in starting technique, acceleration, step mechanics, and force application. Coaches should consider individual performance level, training experience, and biological development when providing technical corrections. Overall, an individualized and phase-specific approach to sprint training may provide the most appropriate foundation for improving 100-m performance in developing female athletes.

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