

Understanding Deceleration in Sport

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SUMMARY

RAPID DECELERATION IS SEEN IN A WIDE VARIETY OF SPORTS WHEN STOPPING OR AS A PRE-CURSOR TO A CHANGE IN DIRECTION. THESE RAPID CHANGES IN VELOCITY OFTEN OCCUR OVER A MINIMAL AMOUNT OF DISTANCE OR TIME AND ARE OFTEN IN RESPONSE TO EXTERNAL STIMULI SUCH AS AN OPPONENT'S MOVEMENT OR BOUNDARY LINES. LITTLE ATTENTION HAS BEEN GIVEN IN THE RESEARCH LITERATURE TO THE KINEMATICS AND KINETICS OF RUNNING DECELERATION. THIS ARTICLE AIMS TO ENHANCE THE UNDERSTANDING OF THE MECHANICAL CHARACTERISTICS ASSOCIATED WITH DECELERATION PERFORMANCE.

INTRODUCTION

There is a great deal of literature that investigates the kinematics and kinetics of human acceleration while running (2,3,12). However, in many sports, the act of rapidly slowing the body (deceleration) is critical to the success of the movement (5). Deceleration is often employed in sports that require an immediate or gradual stop or to decrease the body's velocity before a change in direction (horizontal, lateral, or vertical). The forces applied to the body when decelerating can be exceptionally large in magnitude, especially when the time over which these forces must be absorbed is small. Therefore,

appropriate technique is essential for not only decreasing the risk of injury but also controlling balance and effectively transferring accumulated elastic energy into the subsequent movements (5,13). This article describes some of the critical features (kinematics and kinetics) associated with deceleration to assist strength and conditioning coaches in their understanding of how to condition and "cue" for better change of direction ability. It should be noted that the information presented in this article is a blending of the available empirical information and the qualitative analysis of elite and semi-elite female netball players.

DECELERATION IN SPORT

Deceleration is required after any sprint performance regardless of the relative velocity of the sprint, to slow the body's center of mass (COM). The amount of time/distance allocated to slow the COM is dependent upon a wide variety of factors determined by the individual requirements of the sport. Team sports (e.g., touch rugby, netball, basketball, soccer, etc) have distinct boundary lines that confine numerous players to a specific area. Deceleration in these sports may occur in response to other players' movements (marking, evading, or collision avoidance) or to stay within the playing area. Under these circumstances, players will be required to decelerate from varying velocities over a variety of distances and times.

In contrast, individual sports (e.g., tennis, squash, badminton, etc) require players to accelerate and decelerate

very rapidly over short distances primarily in response to the opposition's shot selection. Irrespective of the sport, it is clear that deceleration plays an important role in both team and individual player performance. This article highlights the differences between acceleration and deceleration in sport, presents qualities of deceleration technique that are important for the safe and effective execution of such rapid changes in velocity, and briefly provides criteria that should assist in exercise selection that enhances the quality of deceleration performances.

BIOMECHANICAL DIFFERENCES BETWEEN ACCELERATION AND DECELERATION IN SPORT

BODY POSITIONING AND JOINT ANGLES

The kinematic characteristics apparent when accelerating and decelerating are similar, with the placement of the limbs in relation to the body's COM being the primary difference between the 2 acts (Tables 1 and 2). The objective of decelerating when moving over ground is to decrease the body's momentum (mass \times velocity) by applying as much force as possible over minimal time to allow a complete stop or movement in a new direction to occur (force \times time = mass \times velocity) (9).

Proper joint angles and muscle tension before ground contact are essential to resist the forward momentum. Leg kinematics are crucial to deceleration because of their role as the initial force

KEY WORDS:

deceleration; kinetics; kinematics; agility

Table 1
Kinematic differences between the ground contacts of the acceleration and deceleration phases of sprinting

Kinematic characteristic	Acceleration phase (0–10 m)	Deceleration phase (0–5 m)
COM in relation to point of contact	Anterior	Posterior
Step length	Short	Short
Step width	Wide	Wide
Step frequency	High	High
Braking phase	Minimized/eliminated	Maximized
Propulsive phase	Maximized	Minimized/eliminated
Joint stiffness	Increased	Decreased
Support phase	Lengthened	Lengthened
Landing Distance	Minimized	Maximized
Ground contact time	Long	Long
Predominant muscle action through support phase	Concentric	Eccentric
Flight phase	Minimized	Minimized/eliminated

Information obtained from Andrews et al. (1), Dintiman et al. (5), Weaver (13).

absorption mechanism. Although a rapid deceleration ideally occurs over a limited number of strides, several shortened gait cycles are used to safely decelerate the body by absorbing the high eccentric forces with as little stress to the joints as possible (1). Therefore, greater braking forces and ground contact times are typically observed when rapidly decelerating.

Because force can only be applied or generated while the foot is in contact with the ground, the time in air of the nonstance leg during deceleration is limited to allow for extended time on the ground. In contrast to the acceleration phase (Figure 1a), ground contact of the landing leg during the deceleration phase occurs ahead of the COM (large landing distance—horizontal distance that the lead leg is ahead of the COM when the foot strikes the ground (8)), resisting the forward momentum of the body (Figure 1b). This is accomplished through hip flexion (to an angle similar to that during the maximum velocity phase) while the knee extends and the ankle plantar flexes (1,13).

To maintain ground contact for as long as possible, the foot initially strikes the

ground with the heel (Figure 1b), creating a horizontal braking force, then rapidly rolls to the forefoot, creating a full foot-ground contact (Figure 2b) (1). This is in contrast to the acceleration phase where the forefoot contacts the ground first (Figure 1a), maintaining an elevated heel throughout the support phase (i.e., minimizing braking forces and maximizing propulsive forces) (Figure 2a). The support foot during the acceleration phase remains in contact with the ground until the tibia passes ahead of the ankle's vertical axis (1), allowing for a greater amount of negative work (force \times displacement) to be absorbed by the legs.

Body positioning in the deceleration phase is adjusted to allow for the substantial eccentric forces to be absorbed and dispersed throughout the body (5) (Table 3). To slow the forward moving COM, several body segments are adjusted when compared with the acceleration phase. The forward lean present in the acceleration phase that allows body positioning for greater horizontal propulsive forces is not evident in deceleration, as the body's momentum must be decreased. The torso assumes a more erect posture

(in relation to the lower body) and posterior lean during deceleration, moving the COM posterior to the base of support (1,9), which results in additional horizontal braking forces. On landing, immediate hip and knee flexion and ankle dorsiflexion occur, dissipating the impact forces over as many joints as possible (5,13). This decreases the magnitude of the stress by allowing the muscles to do greater negative work, that is, applying forces over a greater eccentric range of motion.

Although arm action during the acceleration phase is rapid and of large amplitude in the sagittal plane (Figures 1a, 2a) to counteract the powerful driving action of the legs, during the deceleration phase, arm action velocity decreases to coincide with the lengthened support phase (Figures 1b, 2b). A relaxed shoulder position and 90° flexion at the elbows, observed with both the acceleration and maximum velocity phases, are different to the deceleration phase where increased shoulder abduction may be seen (1,5).

PRIMARY MUSCLE GROUPS

The primary muscles used for deceleration are the quadriceps and

Table 2
Body positioning differences during ground support between the acceleration and deceleration phases of sprinting

Joint/body segment	Acceleration phase (0–10 m)	Deceleration phase (0–5 m)
Ground contact		
Foot	Ball of foot	Heel strike
Ankle	Primarily plantarflexion	Dorsiflexion
Tibia	Anterior to vertical axis	Posterior to vertical axis
Knee	Flexed to 30–35°	Extended
Hip/pelvis	Flexed to 20–30°	Posterior tilt, slight hip flexion
Torso	45° anterior lean	Erect or posterior lean
Arms	In line with body, elbows flexed	Abduction, elbow flexion (wide)
Support phase		
Foot	Ball of foot	Full foot contact
Ankle	Plantarflexion	Immediate dorsiflexion until tibia passes the vertical axis
Tibia	Anterior to vertical axis	Moves anterior to vertical axis
Knee	Extended	Immediate increased flexion to 90°
Hip/pelvis	Extended	Immediate increased flexion
Torso	45° anterior lean	Erect or posterior lean
Arms	Aggressive contralateral shoulder flexion and extension	Abduction, elbow extension (wide)

Information obtained from Andrews et al. (1), Dintiman et al. (5), Kreichbaum and Barthels (9).

gastrocnemius (1). However, unlike the concentric contraction of the acceleration phase, these muscle groups work through an eccentric contraction as the impact force is absorbed and dispersed.

The relatively extended leg at impact combined with the purely anterior–posterior forces acting on the body place the leg in a potentially compromising position (1,13). However, the

preactivation of these 2 muscle groups before ground contact contributes to the absorption of the substantial eccentric forces (negative work = eccentric force × downward displacement of the COM) that occur during ground contact. The kinetic energy ($KE = \frac{1}{2} \times mv^2$) of the body decreases during this phase as the downward (negative) velocity decreases to zero before the propulsive concentric phase. The KE is not lost but rather transferred to elastic energy (5), which is immediately available for a subsequent movement (e.g., change of direction or jump) or dissipated as heat (10) and sound in the case of a complete stop.

STANCE PHASE

As shown in Table 1, the length of the support and flight phases are similar between acceleration and deceleration; however, the purpose for each differs markedly between the 2 movement



Figure 1. Body positions at ground contact of the acceleration (a) and deceleration (b) phases when sprinting.



Figure 2. Body positions during the support phase of the acceleration (a) and deceleration (b) phases when sprinting.

strategies. When accelerating, the support phase is maximized to generate greater propulsive forces at push-off (4). However, when decelerating, contact time is maximized, thereby allowing the COM to remain posterior to the base of support longer (i.e., greater and longer landing distances) and to increase the amount and time that energy is absorbed through the legs (1,5). The more time that the body is in contact with the ground, the greater the ability of the leg muscles to decrease the momentum and KE of the body by producing greater negative impulse and work (1,5,13).

FLIGHT PHASE

In both acceleration and deceleration, a small flight phase is desired; however, the reasoning behind this abbreviated flight differs again between movement strategies. During the acceleration phase, the greater amount of time spent in the air decreases velocity, as force can only be produced when in contact with the ground. Therefore, the flight phase is kept short as velocity is rapidly increased (3,11). In contrast, when decelerating, the absorption of previously accumulated energy and momentum can only take place when in contact with the ground (5,13).

Additionally, the heel to toe contact observable in the deceleration phase often results in the subsequent foot strike occurring before takeoff, thereby completely eliminating the flight phase.

GROUND REACTION FORCES

Similar to the kinematics of deceleration, there has been a lack of research that has investigated the kinetics of deceleration; therefore, the information presented in the following section is primarily anecdotal. The 4 properties that determine the nature of motion in response to a force (magnitude of force, angle of force application, location of force application, and line of action) remain crucial to the deceleration of a body (Table 3).

When accelerating, the large force produced from the ground at takeoff, combined with the posterior force application and decreased angle of application (i.e., the absolute angle created by the horizontal (ground) and the hip at ground contact) (Figure 3), create a large horizontal force component (propulsive ground reaction force), resulting in an increasing forward velocity (9). For deceleration, the anterior foot strike to the COM resulting in large forces applied to the ground at greater angles, that is, increased horizontal force into the ground (braking ground reaction force) (Figure 1b) (9). The ground reaction force created as a result of the braking force is dissipated through the immediate dorsiflexion of the ankle and flexion of the knee and hip joints, thereby decreasing the magnitude of stress. The combination of these features will result in decreased forward momentum and if repeated, will ultimately result in a full cessation of momentum in that direction.

TRAINING CONSIDERATIONS

The amount of force applied and the time that the foot is in contact with the ground will directly affect the change in momentum, and therefore, velocity is increased or decreased (6,9). When accelerating, the impulse developed must be greater than the body's

Table 3
Force properties that determine acceleration and deceleration (9)

Property	Acceleration (0–10 m)	Deceleration (0–5 m)
Magnitude of the force	Large propulsive	Large braking
Angle when the force is applied	Approximately 45°	Approximately 135°
Location to the COM when the force is applied	Posterior	Anterior
Line of action (GRF) dominant component	Horizontal	Horizontal
Resultant effect on forward momentum	Increased	Decreased

GRF, ground retraction force.

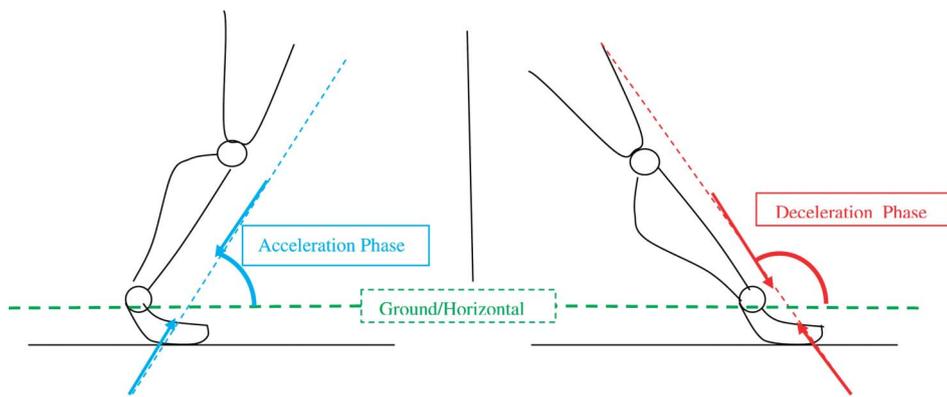


Figure 3. Comparison of the acceleration and deceleration force properties that determine the nature of motion.

stationary and mobile inertia (resistance to change) in order for an increase in velocity/momentum to occur (6–9). The opposite is true when decelerating. In order for a body to decrease its velocity/momentum, the impulse must be greater than the momentum. Therefore, increasing the body’s ability to produce greater braking forces is desirable. This can be achieved by (1) increasing the eccentric force capability of muscle via strength training using exercises that accentuate eccentric loading and control (e.g., drop jumps, resisting towing, vest decelerations, etc) and (2) extending the time over which the braking force is applied on landing (i.e., technical cues), resulting in a greater impulse to reduce the velocity/momentum of the athlete (5). Additionally, it is important that training stimuli remain as representative of the sporting context as possible. Similar distances (sprinting and deceleration distances or body segment range of motions when strength training), velocities (sprinting velocities or rate of force development when strength training), and directional components should also be incorporated into the eccentric strength training program.

SUMMARY AND CONCLUSIONS

Deceleration in sport is commonly performed throughout the entirety of the event, commonly preceding a rapid change of direction. Unfortunately, there has been a paucity of research

investigating the kinematics and kinetics of such critical movements. Although many of the individual step length and step frequency characteristics of acceleration are similar to that of deceleration, it is important to differentiate these 2 phases of sprinting in both research and coaching as the force, contraction type, and technique demands are dissimilar.

The braking forces incurred during each ground contact when decelerating must be rapidly absorbed throughout the lower limbs. When completing these rapid changes in velocity, athletes need to be given appropriate “cueing” (i.e., “contact ground with heel, mid foot, foot,” “increased knee flexion on landing,” “plant stance leg ahead of body—increase landing distance,” etc) from their coaches to avoid injury and optimize performance.

Increasing the time that the foot is in contact with the ground allows for the force to be absorbed over a greater amount of time, which should result in decreased stress to the musculoskeletal structure of the lower limbs. However, in many sports, the time taken to decelerate may be the critical determinant of success—so longer deceleration times or decelerating too much before a change of direction is often disadvantageous. High levels of eccentric strength are required in tandem with appropriate training of deceleration technique specific to sporting

performance, while the demands of the sport situation determine the critical distance, direction, and time that the deceleration must occur.



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