Maximum Speed: Misconceptions of Sprinting

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SUMMARY

DESPITE THE RESEARCH AVAILABLE TO COACHES AND PERFORMANCE PROFESSIONALS, TRAINING METHODOLOGY FOR SPRINTING AT MAXIMUM SPEED IS OFTEN MUDDLED BY ANECDOTAL EVIDENCE. THESE APPROACHES DEVIATE FROM SCIENTIFIC SUPPORT RESULTING IN MISDIRECTED ATTEMPTS TO IMPROVE PERFORMANCE. THIS ARTICLE PROVIDES SCIENTIFIC EVIDENCE ON 3 PROMINENT CONSTRUCTS IN THIS AREA: (A) ACHIEVING MAXIMUM SPEED OVER SHORT DISTANCES (≤30 M), (B) ROLE OF THE GASTROCNEMIUS-SOLEUS-ACHILLES COMPLEX IN SPRINT PERFORMANCE, AND (C) THE PHASE OF THE SPRINT CYCLE THAT LIKELY PLAYS A DOMINANT ROLE IN ACHIEVING MAXIMUM SPEED. THE DATA PRESENTED UNDERPINS AN EVIDENCE-BASED APPROACH FOR SPEED TRAINING.

INTRODUCTION

In 1941, Jacob Bronowski, former director of the Salk Institute of Biological Studies said, “It is important that students bring a certain ragnamuffin, barefoot irreverence to their studies; for they are not here to worship what is known, but to question it.” Bronowski’s quote highlights the importance of continually searching for the latest available scientific findings (possibly coming from outside the traditional scope of the strength and conditioning field), which will serve to support current theories or raise questions about constructs that might otherwise have been blindly accepted in the past.

Acknowledging there is an inevitable time lag between conducting research and its availability to the public, practitioners must continually strive to make best efforts to ensure that theories suit the available evidence rather than twisting facts to fit within previous theories, thus allowing anecdotal notions to become adopted as a fact without verification. Although it may be accurate to refer to training principles as a delicate balance between science and art, when published reports provide consistent evidence that conflict with commonly held beliefs or theories, then the dogma requires an upgrade.

Maximal sprint speed is an area important to most sports, yet there is an abundance of evidence in the literature that has seemingly been overlooked and would serve the strength and conditioning community well. The aim of this article is to present evidence that can build upon anecdotal constructs with existing scientific data to enhance athletic development. There are 3 areas addressed below: (a) maximal sprint speed in field sport athletes, (b) joint and muscle dominance providing horizontal propulsion, and (c) the phase of the leg cycle in sprinting (swing or support) that is considered more important for maximum speed.

MISCONCEPTION 1: MAXIMUM SPEED IS NOT IMPORTANT IN FIELD SPORTS

A popular view is that maximal speed development for field sport (e.g., soccer, lacrosse, field hockey) athletes is unimportant. The argument against maximal speed development for these athletes stems from the knowledge that 100-m track and field sprinters do not achieve maximal speed until 50–60 m. Field sport athletes typically sprint 10–30 meters (~2–3 seconds) (17,22,28,29); therefore, the conclusion is that the distance necessary to attain maximal speed is not reached. It would seem logical that maximal speed development is irrelevant if the discussion is stopped here. However, there are 2 vital concepts that have been commonly overlooked: the duration or distance needed to reach top speed for field sport athletes and its relation to the supposed inability to reach top speed over short distances, and static versus flying starts.

First, achieving top speed at 50–60 m can only be applied to 100-m track and field sprinters. There are obvious differences between a track and field sprinter and a soccer or lacrosse player regarding the characteristics of their respective sports that are rarely acknowledged. For instance,

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Maximum Speed: Training With Science

elite track and field athletes train specifically to reach top speed during the later portion of a race. This is not to say that a 100-m sprinter is consciously moving at submaximal speeds during the acceleration phase (i.e., 0–30 m), but by examining when maximal speed occurs during various racing distances, it is clear that highly successful individuals such as World and Olympic Champions, Maurice Greene and Asafa Powell, have completed 50- to 60-m races faster than the 50- to 60-m splits in their respective 100-m world record races (World Open Indoor Track & Field Records, www.usatf.org/statistics/records/view.asp?division=world & location=indoortrack%20%20%20field&age=open&sport=TF). Additionally, athletes reaching top speed sooner, in a 100-m race, are less successful in competition as a result of an inability to maintain those speeds over longer distances. Therefore, it is important for track and field sprinters to build toward maximum sprint speed later in the race (12).

On the other hand, field sport athletes sprint shorter distances (e.g., 10–30 m) during practice and in competition, so training specificity is drastically different compared with track and field athletes and may alter the ability of reaching higher speeds more quickly. Indeed, it is often stated that field sport athletes must rely more heavily on acceleration compared with top speed. To the authors’ knowledge, no study has examined or compared the ability to accelerate between track and field athletes and field sport athletes. In light of the lack of evidence, caution is warranted with the conclusion that acceleration supersedes maximum speed training for field sport athletes when no data are available to either support or refute this claim.

The second misconception is that participation in a field sport requires performing only short sprints, and therefore, top speed cannot be attained because an athlete needs greater distances (i.e., 50–60 m) to reach maximum speed (24). Vescovi et al. (31) demonstrated that female soccer and lacrosse players do indeed reach top speed somewhere between 20 and 30 m, as evidenced by a lack of change in individual 9.1 m times after 27 m. This is supportive of data that maximal sprint speed occurred at 36 m in a group of college physical education students (11). In addition, Coleman and Dupler (10) illustrated that half of the sprints from home plate to first base over the course of a baseball season (approximately 1,300 sprints/season) were performed at greater than 90% of maximal sprint speed, highlighting the ability to reach near-maximum speed over 27 m. Remarkably, even with this evidence, the authors concluded that baseball players should not apply common principles of speed development because players do not sprint 50–60 m in games, and therefore, top speed is rarely achieved (10).

Another distinction between athletics and field sports is that sprints begin races from a static 4-point stance in the blocks. In contrast, field sport athletes often initiate a sprint from a moving start (e.g., walking or jogging). For instance, nearly 85% of sprints in high school and college-age soccer begin while already moving, and the average distance covered is approximately 18–20 m (2). Delechse et al. (11,12) reported that maximal speed from a static start was reached at 36 m. It would therefore be logical to conclude that if the same individual was evaluated over the same distance, then he/she would cover that distance in a shorter period through the achievement of a higher speed sooner when beginning the sprint with a flying start. Indeed, data from male rugby players and female soccer players illustrate that top speeds are achieved sooner (13) and speeds from consecutive 9.1-m splits over 36.6 m increase by approximately 30% when using a flying start compared with a static start (31).

Taken together, these findings indicate that applying the dynamics of acceleration and achievement of maximal sprint speed from track and field sprinters to develop a training regimen for field sport athletes is at best misguided. Characteristics of linear sprint speed between these sports do indeed differ, and it is these differences that must guide program prescription. This is not to say that fundamental mechanics of sprinting should be ignored, but rather they should be included and can be adapted to other sports as part of proper motor development involving acceleration, maximum speed, and multidirectional movement skills. For example, strength and conditioning coaches working with field sport athletes should include sprints of varying distances ranging between 15 and 35 m that mimic typical distances covered in games and allow for the attainment of near-maximum or maximum speed, thereby providing a sufficient stimulus to improve linear sprint ability.

MISCONCEPTION 2: ANKLE ACTIVITY CAUSES HORIZONTAL PROPULSION IN SPRINTING

Sprinting requires coordination, stability, and muscular power to successfully accomplish the cyclic motion of the legs to achieve maximum horizontal speed. The muscles responsible for hip, knee, and ankle movements play a specific role during the support phase to efficiently propel the body forward. Unfortunately, key concepts have been mistakenly reported to be involved with aiding in horizontal propulsion and thus maximal sprint speed. For example, the gastrocnemius-soleus-achilles complex (GSAC) is considered to be a prime player in horizontal propulsion by storing elastic energy to help project the body forward more quickly while sprinting (25). It has also often been recommended that athletes actively dorsiflex (i.e., “toe up” position) before ground contact and actively plantarflex later in the support phase to help maximize horizontal propulsion (7,8). These statements may lead to erroneous conclusions that the stretch shortening cycle of the ankle joint during the early support phase, in addition to active plantarflexion during the late support phase, contributes considerably to horizontal propulsion during linear sprinting.
Several studies (19–21) provide substantial evidence to the contrary and should help coaches and strength and conditioning professionals understand the contribution of the GSAC during sprinting; which is to help minimize vertical displacement of the center of mass and provide joint stiffness, which assists in power transfer from hip extension into the ground.

Mann and Sprague (19) examined the muscle actions of the hip, knee, and ankle joints of highly skilled sprinters. They observed that posterior muscle dominance of the ankle joint was highlighted by eccentric action early and fading concentric action late during the support phase. Corroboration for these findings has been provided by several other groups of researchers who reported that as the support phase progresses, the muscle activity of the gastrocnemius begins to subside and may even cease before toe-off (9,17). It has also been revealed that hip extensor (gluteus and hamstrings) dominance continues through initial ground contact and into the mid support phase to minimize braking but acts primarily to pull the body forward—findings that were subsequently supported (35).

Ensuing work by Mann et al. (21) compared muscle activation patterns among jogging, running, and sprinting. Again, there was a rapid eccentric action of the posterior muscles of the ankle followed by plantarflexion during the support phase; however, the amount of plantarflexion that occurred during the time of gastrocnemius activity was only 6° out of 33° of motion. Considering that the push-off during ground support lasts only 0.06 seconds (4,18), there is little time for such a small amount of muscle activity over such a small range of motion to contribute substantially to horizontal propulsion during linear sprinting. On the other hand, the hamstrings are well suited, because of the favorable lever arm with regard to the hip joint, to generate high levels of force during this phase of the sprint cycle (5).

These findings indicate several important characteristics of the GSAC during the support phase of sprinting. First, the large eccentric action during the early support phase is primarily responsible for preventing negative vertical displacement of the center of mass. A sprinter with greater negative vertical displacement will remain on the ground longer and require more effort to reverse the position, thus resulting in a decrement in performance. Second, and more importantly, concentric activity of the GSAC is balanced, negligible, or nonexistent during the later portion of the support phase (9,18,19), and if GSAC activity was increased, it would be safe to conclude that greater vertical displacement, not horizontal propulsion, would be elicited. Greater vertical displacement would in turn negatively alter the sinusoidal path of the body or potentially initiate a longer flight phase. The additional elapsed time would appear to be disadvantageous for maximal sprinting speed (35). Therefore, Mann (21) has repeatedly concluded that horizontal propulsion from the GSAC does not truly exist and has been overstated in the literature (20).

It is important to keep in mind that the fundamental objective of sprint training is to achieve reflexive ground contact, with a period of brief force application early during the ground support while limiting the range of motion at the ankle. There does not seem to be conflicting views in the scientific data regarding the contribution of the GSAC to sprinting, but the available evidence often contrasts with what has become popularized in some speed development programs, such as the emphasis on active plantarflexion as the hips pass over the foot to push the body forward (8). Instead, strength and conditioning coaches teaching sprint technique should not overemphasize the ankle activity for horizontal propulsion but direct the focus on the ability of the ankle to quickly absorb vertical forces. This can be accomplished by including vertical jumping exercises that require rapid ground contact (e.g., skipping rope).

**MISCONCEPTION 3: RECOVERY OF THE LEG DURING THE FLIGHT PHASE IS CRUCIAL FOR SPEED**

The stride cycle can be divided into 2 segments: the flight phase and the support phase. The support phase is when the foot is in contact with the ground, whereas the flight phase occurs from toe off to the beginning of the following support phase of the contralateral leg. It is important to generate substantial horizontal power during the support phase and recover the leg quickly during the flight phase; thus, both phases are important for maximal linear sprint speed. It is beyond the scope of this article to provide a detailed discussion of sprint mechanics and the influence on sprint speed. Instead the intent of this section is to focus on describing the evidence surrounding what makes one individual sprint faster than another when specifically concerned with the contribution of the 2 cycle phases.

One side of the debate favors leg recovery as the essential element to faster sprinting ability. This concept is believed to allow an individual to position himself/herself more quickly for the next stride. In other words, by increasing the speed of the leg movement during the flight phase, the rate of overall horizontal displacement is improved because the next ground contact can occur sooner. Although this hypothesis has been developed over many years by accumulating anecdotal coaching experience with elite sprinters, studies providing supportive evidence that an increase in stride frequency results in greater sprinting ability have been limited to animal models (14–16). It has also been shown that the duration of the flight phase in humans remains consistent across a wide range of speeds (20,33,36) and is reliant upon the duration of vertical displacement of the center of mass. Indeed, repositioning the limbs more quickly results in the reduction of the impulse during the support phase, which is required to maximize sprint speeds, ultimately having an adverse effect on the overall performance (32).
Hence, the authors are not aware of any evidence supporting the notion that a quick swing phase will result in faster sprint time or that the swing phase can be improved with training.

Another concept thought to aid in faster leg recovery is the triple flexion mechanism. This mechanism is a spinal reflex consisting of flexion at the hip, knee, and ankle in response to a painful stimulation of the sole of the foot (i.e., an individual stepping on a nail) and is a necessary component for gait reeducation in patients who experience severe neurological damage such as spinal trauma or cerebral palsy (3,23,30,34). Thus, its role in sprinting appears questionable. In fact, in a search of the literature, the authors found no published research that links the triple flexion mechanism to maximal linear sprinting, nor that it plays any role in athletics, suggesting that extreme skepticism is warranted about its applicability to sport. In addition, the considerable latency (tens of a second) in conjunction with the habituation of the reflex, if repeated more than once every 10 seconds (26,27), indicates the unlikelihood of this reflex being able to enhance sprinting ability, nevertheless function as a trainable phenomenon.

Several studies have illustrated that faster individuals take considerably longer strides compared with slower individuals (1,6). Similarly, the same individual running at increasingly faster speeds will show increasingly greater stride lengths (36), yet in both circumstances, the duration of the support phase is drastically reduced (~45–50%) (20). Therefore, propelling the body over a greater distance while spending less time on the ground would suggest that greater horizontal force/power is generated during the 120–200 milliseconds of the support phase. In contrast, stride rate is increased only slightly when running between 4 and 8 m/s with no change in the duration of the flight phase. This suggests that the alteration in stride rate is mostly attributable to the change in support phase duration.

In a study by Weyand et al. (33), the swing time (duration of time between toe-off and touch-down of the same foot) and ground reaction forces were measured while sprinting at maximal speed on a level treadmill. Maximal sprint speed for the participants ranged between 6.2 to 11.1 m/s. It was reported that the faster individuals were able to apply greater forces during a shorter support phase, whereas the slower individuals applied smaller ground forces with a longer support phase (33). Interestingly, the slowest subject in that study (top speed of 6.2 m/s) was able to reposition her leg as rapidly as the fastest 100-m male sprinter in the world, although sprinting at only half the speed. So although faster sprinters should possess a greater ability to reposition their limbs more quickly compared with an average sprinter, this notion is currently not supported in the scientific literature and should be viewed with caution.

Because of the constraints of swing duration and support duration, Weyand et al. (33) concluded that sprint speed is principally governed by the ability to create greater muscular force to the ground and to minimize ground contact time, better using the stretch shortening cycle during the transference of power down and back up the kinetic chain. Therefore, to improve speed, athletes should focus on training the ability to produce a high power output during a short ground contact phase rather than emphasizing a fast leg recovery during the flight phase. Strength and conditioning coaches could include depth jumps (during appropriate periods of the training cycle) and use a contact mat to ensure that ground time is minimized (e.g., 0.1–0.2 seconds) while directing athletes to maximize jump height.

**CONCLUSION**

Training athletes at any level is a delicate balance between science and art. Coaches and training professionals alike continually seek best practices to help them improve the performance of their athletes. Over time, sufficient proof allows for prevailing dogma to be revisited and revised, reflecting what is scientifically proven rather than anecdotally presented as absolute truth. Current concepts regarding maximum speed and subsequent methods for training now require an altered view of prevailing practices and should strive to reflect available evidence that demonstrate that (a) field sport athletes can achieve maximum sprint speed between 20 and 30 m, (b) the GSAC provides a way to minimize the vertical displacement rather than contribute substantially to horizontal propulsion, and (c) increased forces generated during the support phase, not quicker swing phase, is the underlying mechanism for faster sprint ability. We encourage others to continue searching the literature for additional knowledge on this topic because the views expressed here might also need to be revised one day.

**REFERENCES**


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