Scientific Responses to Common Coaching Questions

1. What are the mechanical requirements for achieving fast running speeds?

The key to human speed is simple: applying large mass-specific forces to the ground quickly.

From my perspective as a scientist, one of the most appealing aspects of the state of knowledge in this area is how available this essential information is to coaches and athletes. The biological basis of movement and performance is extraordinarily complex when one considers all the events that occur from neural activation to muscular force production to the musculoskeletal transmission of force to the environment. However, as complex as the details of motor control, force production and delivery are during sprinting, a simple, informative and valuable take-home message exists for coaches – speed is all about hitting the ground hard and fast.

2. Is sprint running primarily an acquired skill or innate ability?

Sprint running is a complex skill whose execution depends directly on the musculoskeletal biology of the athlete. The ability of sprinters apply ground forces of 3-5 times the body’s weight in less than one-tenth of a second without losing their balance, while reversing the vertical direction of the center of mass, and with negligible fluctuations horizontal velocity during each stance phase requires both great skill and high-level musculoskeletal function.

In my view, the critical question for coaches and athletes is to what extent both the skill and musculoskeletal function aspects of speed are trainable. Clearly, training can improve speed, but despite the fundamental importance of speed for athletic performance broadly, relatively little published data exists from which the optimal or even most effective training practices can be identified.

My hope is that researchers can begin to document and better understand the extent of the gains in speed that are possible through: 1) regular high-speed running, 2) strength training, and 3) improved motor control.

3. Which muscles or muscle actions should a coach focus on while training away from the track?

The lower limb extensors: ankle, knee and hip; i.e., the muscles that straighten and extend the limb into the running surface and support the body’s weight against gravity during the stance phase.
Techniques that enhance ground force application but do not increase the body’s mass are likely to be most effective.

4. **What is the relative importance of stride frequency vs. stride length for top speed running?**

Speed is often considered as the product of stride length and stride frequency, which, of course is fully accurate, mathematically. However, from the standpoint of the relevant science, both physics and musculoskeletal biology, we have found that conceptualizing speed in terms of forces applied to the ground facilitates greater understanding.

This is true for several reasons. First, applying large, mass-specific forces to the ground quickly is the athletic attribute that determines how fast athletes can run. Nearly all of the difference in speed between different individuals is attributable to what occurs during the contact or ground force application phase. Second, ground force application can be directly related to muscle, tendons and bone function whereas stride lengths and stride frequencies cannot be. Third, as detailed in our 2000 paper on sprint mechanics (5), existing data indicate that both the greater stride lengths and frequencies of faster runners result from the application of greater mass-specific ground forces in shorter periods of time. Fourth, stride lengths and frequencies are not fixed fitness or performance characteristics per se, but rather are co-selected in accordance with the duration of the aerial and contact phases of the stride for different runners and in different gaits (6).

5. **Is dorsiflexion of the ankle joint prior to ground contact beneficial and if so, why?**

Active dorsflexion by the runner using the ankle flexors before foot-ground contact may not be harmful to performance, but in my view, queuing athletes to dorsiflex as a strategy to improve performance makes little sense for the following reasons.

Upon landing, and throughout the earlier portions of the stance phase, the weight of the body weight loads the ankle extensors and Achilles tendon with enormous forces, forcibly dorsiflexing the ankle. The gravitational forces that load the calf muscles and Achilles tendon during the stance phase are at least 10 times greater than the forces the flexor muscles can generate to dorsiflex the ankle prior to foot-ground contact. Accordingly, while actively dorsiflexing the ankle via flexor contraction before landing may not impair performance, any flexion accomplished in this manner is almost certainly functionally and mechanically irrelevant given the extent of gravitational loading that occurs subsequently in the stance phase.

6. **What is the importance of arm swinging in sprinting?**

Once a runner is up to speed, the arms swing largely like passive pendulums, providing balance, minimizing center of mass energy losses and conserving the body’s momentum (3). While arm movements are coordinated with torso and leg movements to achieve the energy transfers that minimize center of mass energy losses, they certainly do not control leg movements and have very little effect on the all-important ground reaction forces.
Arms do seem to play a more important role during the brief acceleration phase at the start of a race than during steady-speed running, but precisely how they might do so is not well understood.

7. Does the action of sprinting involve more of a pushing action or a pulling action against the ground?

In my opinion conceptualizing steady-speed sprint running as either a push or a pull is inaccurate. Furthermore, this conceptualization could easily lead coaches in unproductive and potentially nonsensical directions. This follows from the negligible contribution of the pulling and pushing forces (i.e. horizontal) to the total external force requirement for sprinting. Once a runner is up to speed, nearly all of the ground force required is vertical in orientation while very little is required in the horizontal direction. This somewhat non-intuitive observation is a direct result of how well runners conserve their momentum and forward velocity from step to step once they are past the acceleration phase of a race.

Our precise measurements of the ground reaction forces applied both in the horizontal and vertical directions on our treadmill in the laboratory that agree well with force plate data from over-ground running illustrate this. These measurements show that during sprint running at near-constant velocities, the horizontal (i.e. pushing and pulling forces) ground reaction forces comprise only 2-3% of the total ground reaction force required (6). This percentage is probably slightly greater when speed is more variable, when running into a head wind and in truly elite sprinters who have to push against slightly more air resistance. However, regardless of what the small variations from the 2-3% value might be, the essential conclusion is unchanged – steady-speed sprint running predominantly requires the application of large forces downward and directly into the running surface.

This critical concept has come out of the classic work of Giovanni Cavagna and Dick Taylor (1, 2, 4) published in the 1960s, 70s and 80s that nicely demonstrated that the net requirement for mechanical work and forward propulsion once a runner gets up to speed is negligible. Because runners maintain their forward momentum so effectively, they do not need to either push or pull horizontally while on the ground. They simply need to hit the ground hard enough in relation to their body weight during brief foot-ground contact periods to get back up into the air.
References


