A THEORETICAL MODEL FOR THE ENHANCEMENT OF AMPUTEE SPRINT PERFORMANCE

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INTRODUCTION: Speed is a quality desired by most coaches and athletes, and gives an unparalleled advantage in sport. In essence, speed kills. The fastest sprinters in the world display these pronounced talents on the biggest of stages. On this same stage, amputee sprinters achieve similar performance levels. Recent dissention regarding the eligibility of amputee sprinters in International competition has become a pressing issue due to these performance similarities. Adapted athletes has a seen a surge in interest since the initiation of this issue. Coincidently an evidence-based model with which to train athletes has not been adopted, even with the progressing interest.

Developing such a model will offer a conceptual platform to strategically plan and implement training to enhance performance. Therefore, the primary purpose of this paper is to outline an evidence-based theoretical model to train amputee sprint-athletes. Additionally, the secondary focus of this paper is to use the foundation on which this model is built to further investigate the differing demands of training and competition for amputee sprinters versus able-bodied sprinters.

Underlying mechanisms of sprint performance: Amputee vs. Able-bodied athletes

Regarding elite sprint performance, there are a few key points which are foundational to understanding. Sprinting is traditionally defined as the product of stride length and stride frequency. However, the relationship between these two variables is not as simple as it is often perceived, as they are interrelated rather than separate entities as shown by Weyand, Sternlight, Bellizzi, & Wright (2000). In this investigation the authors demonstrated faster runners achieved greater velocities by applying higher ground reaction forces (GRF) rather than repositioning their legs at a faster rate between strides when equated to slower runners. In other words, better sprinters do not achieve greater speeds by repositioning their limbs at a faster rate. Rather, they produce higher forces during their stance phase when compared to their sub-elite counterparts. Another critical finding explained sprinters not only produce higher GRF, but they do so in the first half of their stance or support phase (Clark, Ryan, & Weyand, 2014). Dr. Ralph Mann (2013) adds to the discussion by noting that no significant difference in airtime exists even between high school sprinters and elite sprinters. Mann (2013) also adds that performances of elite sprinters are enhanced by decreasing ground contact times, thus producing increases in stride rate.

Amputee Sprinting

Now that there is a clear understanding of what separates elite and sub-elite sprinters, the focus shifts to understanding the mechanisms of amputee sprinting performance. While explorations on this subject are scarce, valuable insights can be drawn from the existing body of evidence. One study found while the physiological demands imposed upon amputee sprinters may be similar to their able-bodied competitors, the mechanical parameters governing this task are very different for both parties (Weyand et al. 2009). This finding indicated the bilateral amputee subjects produced 22% less vertical ground reaction forces compared to able-bodied sprinters with similar performances, and spent roughly 14.0% more time applying force to the ground. These findings can be further investigated in Table 1 or visualized in Figure 1. Other explorations from Southern Methodist University (2009) also illustrates a 15.7% increase in repositioning times for bilateral amputee sprinters, although Grabowski et al. (2010) found conflicting evidence. Another research study confirms sprinters using running-specific prosthesis (RSP) produce significantly lower vertical ground reaction forces (McGown et al. 2012).

Amputee sprinters experience certain advantages and disadvantages by sprinting with RSP devices. For instance, one such study presents the theoretical hardships evident within amputee sprinting events (Taboga, Grabowski, Prampero, & Kram, 2014). This paper outlines the inherent nature of the "spring-like" RSP device, utilizing the first half of the contact phase to store energy and the second half to release energy stored to propel the sprinter forward. This directly contradicts the findings on able-bodied sprinters mentioned above (Clark et al, 2014). Along with this finding, coaches inevitably know how difficult it is for amputee sprinters to start out of the blocks, which is supported by research (Tabogoa et al., 2014). Amputee sprinters also lack the ability to 'modulate' stiffness within the race and especially within the actual stance phase, like their able-bodied equals (McGown et al. 2012). This is likely the culprit for amputee sprinters limited ability to apply vertical ground reaction forces.

Although sprint performance is underpinned by differing mechanisms between the able-body sprinter and the amputee sprinter, goals of training will remain identical. Increasing the athlete's ability to create force quickly, or rate of force development (RFD) will function to increase ground reaction forces (GRF). The rise in GRF will increase the horizontal displacement of the athlete with each step. Contact times will also decrease with increases in GRF allowing the athlete to spend less time on the ground and more time in the air moving down the track. In this manner sprinting can be thought of as flying. With additional force applied down into the track, flight path/time will increase, allowing the athlete to travel further down the track. With the current understanding, training approaches for both sprint performances are very similar in nature, apply more force and fly further.

The Model

As conceptualized above, flying further with each step sounds simple enough. However, the focus now shifts to application. The information above points towards a training model emphasizing the velocity an athlete can attain. In order to approach training for maximal velocity, an athlete must first grasp the ability to accelerate. This accelerative ability is the underlying mechanism leading to enriched maximal sprinting velocities. While these capabilities are being trained, the athlete is simultaneously being trained to increase work capacity, strength, and rate of force development. This model is conceptualized in Figure 2 below.

This model is based around the short-to-long (S2L) model initially proposed by Francis (1992) and further expounded upon by DeWeese, Sams, Williams, and Bellon (2015). The approach proposed by DeWeese and colleagues (2015) synchronizes all forms of training to enhance specific abilities in a planned manner, which then function to enhance the succeeding training phase. The authors further justify the importance of force production and the rate of force production illuminated by Stone and colleagues (2003). The model provides a novel tactic in which speed and strength training are complementary. The harmonizing attributes within each phase of training can be viewed within Figure 2, so the coach may further understand the rationale used to enhance performance.

With the obvious start difficulties of amputee sprinters, this model above proposes a prolonged acceleration phase of training for amputee sprinters. This phase will serve to enhance the athlete's skill at directing force in a desirable direction, providing a greater ability to attain higher velocities in later stages of the race. This phase is also paired with strength endurance work to effectively bolster the athlete's ability to tolerate greater training loads in succeeding phases. Notice, the model above includes "Equivalent" and "Adapted" for strength movements. Coaches should modify exercises according to their specific situation. The ensuing phase of training will focus on attaining higher velocities of movement by progressively moving to lower grade inclines, depressed start positions, and flat ground sprinting. This will ease the athlete into greater sprinting velocities whist preserving accelerative abilities and mechanics allowing for a seamless transition to over-ground sprinting. At this point the emphasis in the weight room will have changed to strength-oriented work and introduced work aimed at increasing RFD.

Succeeding phases of training will move toward a maximal sprinting velocity emphasis, with periods of re-visitation of accelerative work interlaced. This maximal velocity work will be combined with weight room work moving toward emphasizing RFD. This is due to the critical nature of a high RFD in sprint performance (Clark et al, 2014).

The model proposed will provide a unifying approach to speed development along with weight room work for Amputee athletes (DeWeese et al, 2015; Plisk and Stone, 2003). The merits of the short to long approach are obvious, and even more so for Amputee athletes because of their difficulties particularity in the starting portion of the race. This approach harmonizes the disadvantages of the athletes in question and the strengths of the approach being used. When the enhancement of speed is the objective, Able-body athletes and Amputee athletes require the same skillset: generate more force in a smaller amount of time. The mechanisms used to attain speed may be different, however, physics governs the world of speed. Therefore, we must take our cues from physics and allow our athletes to pursue greater velocities with a sound approach, with focus on force production.

CONCLUSION: Future research groups should look to optical systems to collect data and help aid in our understanding of amputee sprinting, especially in regard to the sprint start. This data in accordance with the proposed model will direct future training practices of coaches and athletes, and will also add to the body of research on the differences between able-bodied and amputee sprinters. Strength training will be helpful for Amputee athletes, however, there is a paucity of information on Amputee strength work specifically with sprint athletes.

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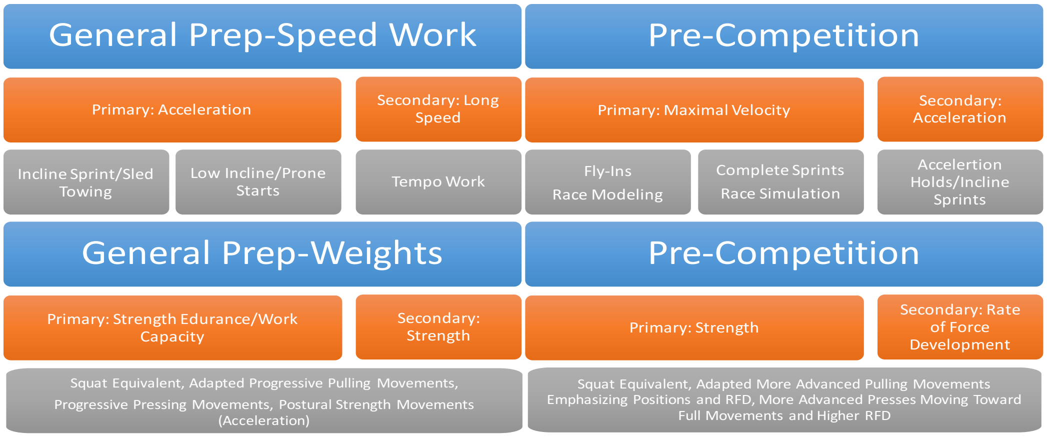
Table 1.

Parameter	Amputee Sprinter	Able Bodied sprinter	Percent Difference
Ground Contact time (s)	0.113 +/- (0.004)	0.099 +/- (0.004)	14.10%
Aerial time (s)	0.092 +/- (0.011)	0.0140 +/- (0.011)	34.30%
Swing times (s)	0.293 +/- (0.023)	0.371 +/- (0.023)	21.00%
Stance Avg. Vertical Forces (Wb)	1.79 +/- (0.10)	2.32 +/- (0.10)	22.80%
Adapted from Weyand et. al, 2009.			



General Prep-Speed Work

Pre-Competition

Primary: Acceleration

Secondary: Long Speed

Primary: Maximal Velocity

Secondary: Acceleration

Incline Sprint/Sled Towing

Low Incline/Prone Starts

Tempo Work

Fly-Ins
Race Modeling

Complete Sprints
Race Simulation

Accelertion Holds/Incline Sprints

General Prep-Weights

Pre-Competition

Primary: Strength Edurance/Work Capacity

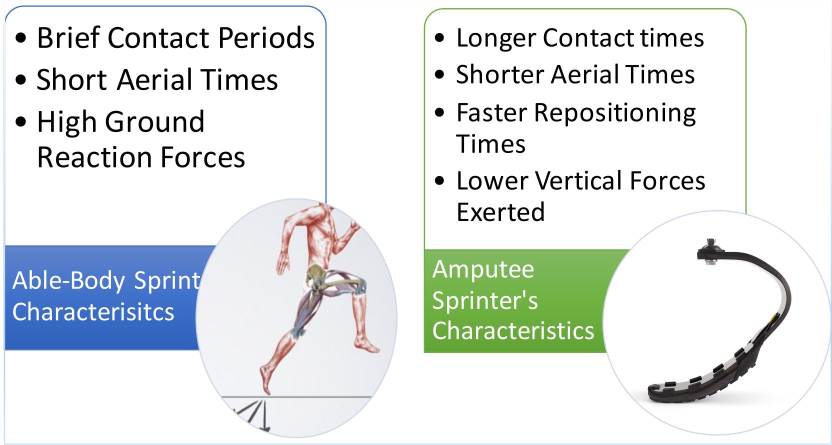
Secondary: Strength

Primary: Strength

Secondary: Rate of Force Development

Squat Equivalent, Adapted Progressive Pulling Movements, Progressive Pressing Movements, Postural Strength Movements (Acceleration)

Squat Equivalent, Adapted More Advanced Pulling Movements Emphasizing Positions and RFD, More Advanced Presses Moving Toward Full Movements and Higher RFD



- Brief Contact Periods
- Short Aerial Times
- High Ground Reaction Forces

Able-Body Sprint Characterisitcs

- Longer Contact times
- Shorter Aerial Times
- Faster Repositioning Times
- Lower Vertical Forces Exerted

Amputee Sprinter's Characteristics