Speed play: Guiding skill through a seamlessly sequenced sprint curriculum.

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KIRBY LEE IMAGE OF SPORT

Within track & field, various models exist regarding the macro-management of speed enhancement. For instance, coaches may subscribe to a short-to-long, long-to-short, or concurrent system to inform global progressions within the allocated preparation time. Though these themes speak to how a plan conceptually attempts to advance the skill of sprinting along with specific fitness, these overarching modes of training are superficial and limited in their scope as it relates to the micro-level management of planning. Specifically, these broad models fail to provide insightful perspective that allows the coach to carefully deliver nuanced programming, and more importantly, instruct a speed development session with precision. In other words, having greater clarity on both the intended goals and actual outcomes of a given sprint tactic or drill may improve a coach's ability to deliver targeted cues or verbal instruction. As a result, the motor-learning effects of properly designed sprint-skill development sessions are augmented through informed and artful coaching. While the development and practice of coaching should be grounded in evidence, they are often separated — causing a detrimental dissociation between the aspects of curriculum delivery, skill analysis, and movement modification. Therefore, the purpose of this article is to arm coaches with a logical progression of tactics that develops sprint skill while considering the temporal aspects of high-velocity running.

ADVANCES IN SPRINT MODELING

The current understanding of maximum effort locomotion demonstrates that sprinting is indeed a skill. While elegant in design, Bushnell and Hunter's (2007) investigation on the relationship between movement quality and running speed demonstrated that while endurance athletes and sprinters shared similar biomechanical and spatiotemporal qualities at low cadences, the distance runners within their study failed to adjust technique as speed increased. In short, this supports the notion that sprinting proficiency is improved through coaching intervention and quality-repetition.

As a skill, sprinting may be further enhanced through training tactics that mature the musculoskeletal system's ability to efficiently produce, tolerate, and transfer high forces into the track (Colyer et al., 2018). Moreover, those forces should be distributed in an appropriate magnitude and direction so as to maintain elastic qualities while minimizing braking (Nagahara et al., 2019). Lastly, the properly-oriented forces must be transmitted within an abbreviated amount of time, typically ~90-100ms at top speed, which reinforces explosive strength as the primary criterion for sprint success.

This explosivity is underpinned by a collection of neuromuscular factors including, but not limited to motor-unit typing, intra- and inter-muscular coordination, rate-coding, and neural drive, which collectively work to actualize sprint-movement characteristics. Because of their role in rate and magnitude of force development, these neuromuscular factors serve as prerequisites for proper mechanical actions within critical time frames. For example, sprinters who initiate GC with as stance phase that is more proximal to the center of mass at top-speed are more likely to conserve energy and prioritize elastic behavior through the SSC, a rapid and forceful lengthening of a muscle-tendon complex followed by an immediate shortening or contraction (Komi, 2008). Practically speaking, Manzer, Mattes, and Hollander (2016) described this phenomenon with the following observation of top-speed sprinting: "a high lifted knee stretches the hamstrings and gluteal muscles for the forthcoming hip extension at downswing during the pre-support-phase. This leads, furthermore, to a sudden stop of the upper leg at maximum knee lift to the momentum transfer on the entire body and supports the takeoff extension because the time of maximum knee lift coincides with the takeoff of the opposite side."

Conceptually, the SSC is important for sprinting as it underpins the spring-mass model (SMM). The SMM depicts sprinting as the result of a body mass bouncing along two springs (Blickhan, 1989, Dalleau et al., 1998, Dutton & Smith, 2002, Farley & Gonzalez, 1996). During a complete running cycle, one spring compresses and propels the sprinter's body forward. Simultaneously, the other spring swings forward in preparation for ground contact. Within an upright sprint, compression of the spring begins at foot strike, which results in horizontal braking forces. This sudden deceleration assists in propelling the swing leg forward in preparation for the following step. As the center of mass moves ahead of the stance foot, the sprinter enters the "mid-stance" phase. Within the SMM, the spring is compressed to the lowest point, which coincides with a lowered center of mass at mid-stance. The most proficient sprinters are able to minimize this downward COM displacement – once again pointing to the importance of magnitude and rate of force production in sprinting (Mann & Murphy 2015). Finally, the push-off (toe-off) segment of the stance phase describes the return of energy through the extension of the coiled spring. This return of force projects the sprinter forward into the next step (DeWeese, 2015).

Though useful in rudimentary conceptualization, the SMM is limited in its appreciation of integral aspects of running mechanics such as the unique force-time characteristics of elite sprint foot-strikes. Specifically, Clark & Weyand (2014) demonstrated that fast sprinters produce a significant amount of their ground force within the first third to half of a stance phase. Furthermore, this same research group helped decode this asymmetrical force profile through a Two-Mass Model (TMM) system (Clark et al., 2017). Still mathematically elegant, the TMM only requires the mass of a sprinter's shank and remaining body, alongside variables collected during a sprint cycle: contact time, aerial time, and shank acceleration.

This revised TMM system considers two consistent and consecutive running actions that are independent of movement speed. In short, ground contact results in a nearly-immediate halt of the shank while the remaining body accelerates up and ahead of the shank throughout stance phase. We can represent these events mathematically as two overlapping impulses: Impulse 1 (I1) captures the ground reaction forces and temporal characteristics of shank stabilization, while Impulse 2 (I2) describes the forces required to accelerate the rest of the body through a given stance phase (Clark et al., 2017).

Acknowledging the depth of value that a TMM adds to the assessment of individualized sprinter profiling and programming, the authors developed and validated a method to capture ground reaction force data using inertial measurement units (IMU) within a traditional training environment. As compared to recent investigations that capture kinetic data during open sprints on an instrumented track (force plates), this is the first time that sprint waveforms have been collected and analyzed in a manner that is unrestrained from the laboratory setting.

WHAT IS IMPULSE AND WHY IS IT IMPORTANT?

Force transmission to the track does not occur instantaneously. Instead, a sprinter imparts force to the track across the entire stance duration, which ranges from 100-130ms during acceleration to 85-90ms during maximum velocity sprinting (Aagaard et al., 2002). Impulse is the product of these ground reaction forces and the stance duration for each step. While large ground reaction forces are integral to successful sprint performance, the time-dependent nature of sprinting prevents athletes from fully expressing their maximum force capabilities (Cormie et al., 2010; Seitz et al., 2014). Therefore, rate of force development (RFD) is integral in allowing athletes to develop high percentages of their maximum force capabilities during each step permitting large impulses to be produced under the time constraints of sprinting.

Because it is the product of force and

FIGURE 1: THE STAGING AND EXIT OF A CROUCH START.

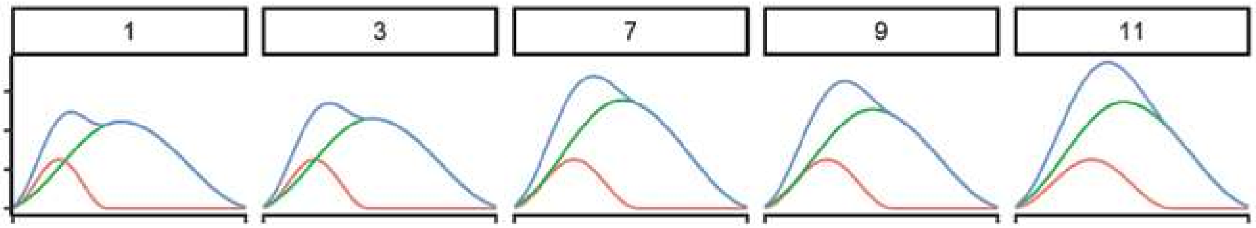

FIGURE 2: FORCE-WAVEFORM REPRESENTATIONS OF THE TWO-MASS MODEL FOR STEPS 1,3,7,9,11 FOR THE CROUCH START.

time, impulse describes the area under the force-time curve. In theory, practitioners can describe the shape and magnitude of an athlete's sprint force-time profile similarly to phase analyses performed on the countermovement jump (Mizuguchi et al., 2015; Sole et al., 2018). The recent development of the TMM (Clark et al., 2017) provides a platform from which to examine the qualitative and quantitative characteristics of an athlete's running form at ground contact. Specifically, a coach can tie the movement quality observed on the track to the impulse profile of each stance phase. Further, supplemental information regarding common impulse shapes for various sprint tactics can aid coaches in properly sequencing these drills in a logical, timely manner.

SPEED PLAY

Using force-time waveform models collected over the training season of two high-level male sprint athletes (a 2018 Olympic sprint-sport athlete who is also a former Division 1 All-American sprinter and an International sprinter with personal bests of 10.11 and 20.23 in the 100m and 200m, respectively) as a guide, we hope to provide the coaching community with greater clarity on several sprint drills common to track & field. While not an exhaustive list, the sprint drills presented within this paper were strategically chosen for their ability to emphasize certain aspects of a sprint run, while collectively exposing the athlete to a wide array of movement velocities and force characteristics.

This data and the accompanying interpretation may help with the organizational process of training tactics within a competitive year. As Coyler and associates (2018) remind us, an athlete's response to training is highly specific to the conditional stimuli (e.g., velocity and load) prescribed. These conditions should be programmed in an emphasis/de-emphasis manner throughout the training year as improvements during one phase may be accompanied by reductions in performance across another (Coyler et al., 2018). Due to the acknowledgement of these interconnected force signatures, it may be possible to better represent the phasic nature of sprinting and provide targeted constraints by which motor learning can be maximized. More specifically, the consideration of both the absolute and relative magnitudes of the 'two-masses' make it more reasonable to infer potentially distinct characteristics. This may then lead to more precise methods that can be applied in the development of sprint skill. While limited by population, the data gleaned from this ecologically-valid investigation demonstrates, for the first time, what occurs when traditional sprinting is altered to enhance or address isolated aspects of a run.

ACCELERATION TACTICS

Within a periodized program, coaches may elect to enhance race performance through concentrated (not isolated) efforts of shorter-distance sprints prior to higher workloads at top-speed. This training decision is supported by Naito et al. (2013) and Schiffer (2009) who concur that maximum velocity results from the acceleration established within earlier zones of a sprint race. Therefore, if this premise is to be accepted, then it is logical to equip the coach with a diverse array of tactics by which to systematically mature the foundational component of skillful sprinting. Further, if we acknowledge that sprinting is a skill that depends on neuromuscular readiness, coaches should emphasize programming strategies that improve movement proficiency through organized training tactics that consider both technical aspects and biomechanical characteristics.

STANDING STARTS

Crouch Start: The track and field block start is considered to be a high-skill, high-out-

FIGURE 3: STARTING POSITION AND EXIT STEPS OF THE PRONE START.

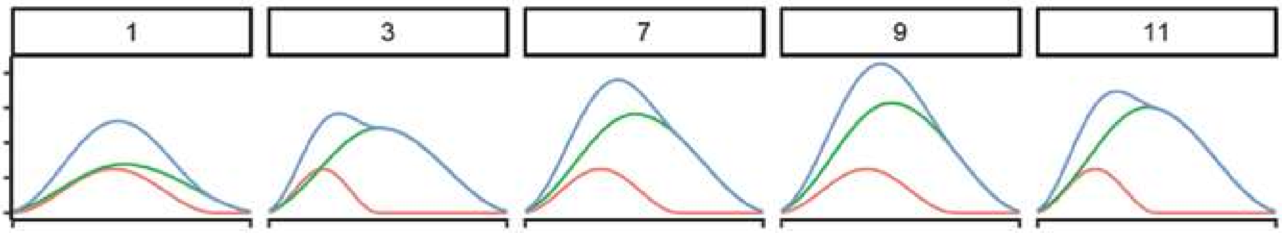

FIGURE 4: FORCE-WAVEFORM REPRESENTATIONS OF THE TWO-MASS MODEL FOR STEPS 1,3,7,9,11 FOR THE PRONE START.

put event that may require rehearsal under near-optimal conditions of readiness (Bezodis et al., 2018; Brazil et al., 2018). As such, a less technical yet consistent starting-stance for multiple sprint efforts within a training session is warranted.

From a staggered stance that is approximately two foot lengths apart, the crouch start (CS) places the athlete's center of mass approximate to that of a block start. Specifically, the athlete will descend their hips down into a "loaded" position while maintaining a long and braced torso. Once the squatting position has been established, the sprinter should take a deep inhalation while raising their front forearm/hand to their forehead while the back hand is taken to the hip. Just before driving out, the athlete may choose to "fall" into the start by slightly flexing/ dropping the lead knee so as to promote a more horizontal displacement during exit through the creation of a more positive shin angle. While Shinohara et al. (2018) discovered that the CS slightly differs from the block start with regard to spatiotemporal parameters within both early and later stages of acceleration, it may allow the sprinter to better orient force application into a more horizontal direction over the entire acceleration phase. Its kinematic similarities do, however, provide the athlete with as advantaged of a starting position as possible without the use of additional equipment. This gives the CS high practical utility in training sprinting athletes both on the track and in other sports. All considered, a full sprint from the CS will serve as the criterion for comparing the subsequent acceleratory tactics within this article.

REACTIVE ACCELERATIONS

Prone Start: As seen in Figure 3, the Prone Start is a training tool that places the athlete at the lowest possible point on the track. From a position that is approximate to the bottom of a push-up, the sprinter responds to an external cue (often a clap), pushing their center of mass up and out. This explosive start should be done while attempting to maintain a long and braced torso in order to counter the initial step's knee drive "toward the chest." Lastly, in order to prevent over-rotation and/or a premature vertical lift of the torso, the sprinter should emphasize aggressive and rapid foot strikes that coincide with "long and strong" arm cycles.

Considering the force-time wave forms, this training tactic appears to increase the total time to peak force in order to raise the body from an exaggerated starting position. As such, this drill led to a larger total impulse through the first 3 steps with a larger emphasis toward I1 in order to rapidly stabilize the up-and-ahead movement of the COM. Furthermore, the dataset used for this analysis demonstrates lower peak forces through most of the 12 steps, which could result from the more horizontally-oriented hip extension.

Taken together, this drill should be considered an advanced tactic as the sprinter must be strong enough to generate enough propulsion during I1 in order to displace horizontally, while still being able to 'hold themselves up' against the lowered COM. The alteration in force production demands relative to the CS through a kinematic constraint (i.e. exaggerated horizontal orientation) make the prone start a sprint tactic that allows the athlete to emphasize proper direction of force application. In addition, the prone start can be used to stage more traditional starts so as to potentiate subsequent efforts or to retain previously developed acceleration skills, which includes the sensation of aggressive pushing "down and back" (i.e. properly oriented force production).

Chest Pass to Chase: The Chest Pass Chase is a medicine ball starting drill that can assist the sprinter in experiencing and developing a piston-like action against the track. The athlete will begin this sprint by placing themselves in a CS with a medi-

FIGURE 5: THE SET-UP, MEDICINE BALL RELEASE, AND EXIT OF THE CHEST PASS CHASE.

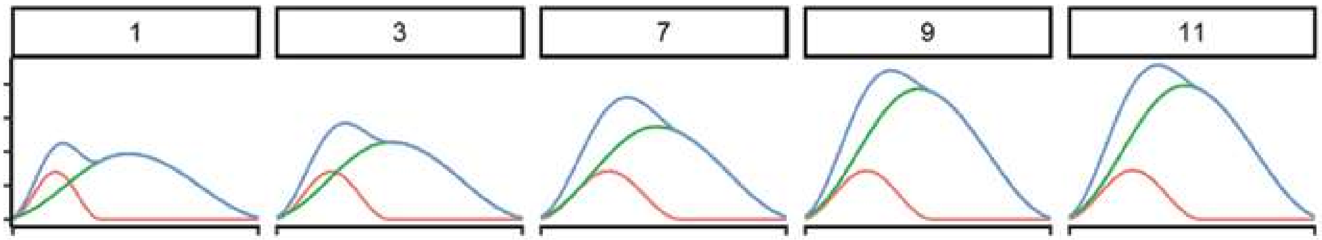

FIGURE 6: FORCE-WAVEFORM REPRESENTATIONS OF THE TWO-MASS MODEL FOR STEPS 1,3,7,9,11 FOR THE CHEST PASS CHASE.

FIGURE 7: THE COACH-SUPPORTED STARTING POSITION, RELEASE, AND EXIT OF THE FALLING START.

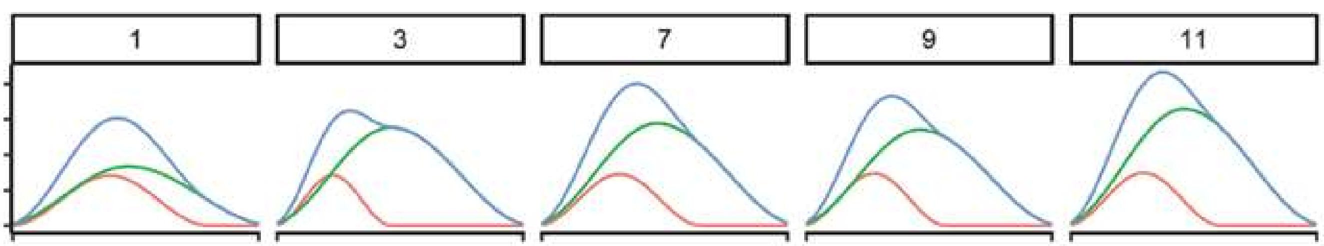

FIGURE 8: FORCE-WAVEFORM REPRESENTATIONS OF THE TWO-MASS MODEL FOR STEPS 1,3,7,9,11 FOR THE FALLING START.

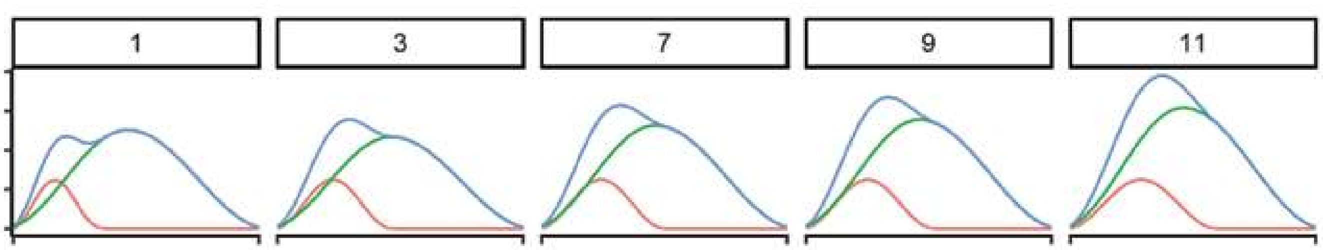

FIGURE 10: FORCE-WAVEFORM REPRESENTATIONS OF THE TWO-MASS MODEL FOR STEPS 1,3,7,9,11 FOR THE INCLINE SPRINT.

cine ball held at chest height, being stabilized by elbows "tucked" into the sides. After an initial fall with the aim of placing the "hips ahead of the heels", the runner will push and project their center of mass out in a manner to transfer momentum into the ball. Furthermore, the medicine ball's path dually serves as an external cue of both magnitude and direction of force application, with a linear toss being desired.

As noted in Figure 6, the chest pass chase appears to primarily influence the initial acceleration of a sprint run, likely as a result of an increase in ground contact time needed to stabilize oneself from the pronounced COM displacement. Specifically, there is an increase in the total time to peak force and a greater reliance on I2 during steps 1 through 3. Interestingly, the sprinter returns to near-baseline numbers once the traditional sprint form is regained. This tactic allows the athlete to emphasize and rehearse proper initiation of early acceleration initially while seamlessly progressing to open sprinting. Considering the information above, the chest pass chase could be a logical precursor to potentiate block starts where horizontal displacement and larger force production is desired. This versatile tool may be leveraged by coaches frequently in a long-term sprint skill development plan due to its versatility.

Falling Start: The Falling Start is yet another reactive drill that conceptually requires the runner to become comfortable with being "ahead of themselves" (i.e. horizontally-oriented). As the sprinter falls away from the coach's grasp, the emphasis should be on leading into the lean through the hips rather than the upper body. This is done to prevent a breaking of the waist that could limit terminal hip flexion which stages the first step. After falling "long and tall", the athlete should be cued to punch the ground hard and fast during the initial steps in order prevent over-rotation or the desire to "pop-up" during transition.

Considering the force waveform data, the falling start leads to increased stance times within the initial steps 1-3 coupled with a larger reliance on I2, perhaps resulting from the significant horizontal orientation of hip extension on exit in a somewhat similar manner to the prone start. However, explosive strength rises through step 9 likely as a combined result of optimal positioning and a taller COM compared to a traditional crouch or prone start. Combined, these findings suggest that the falling start may be a suitable drill to be performed prior to accelerative-transition work or top-speed training as it compliments and reinforces late-stage skill.

RESISTED SPRINTING

Incline Sprints: One form of increasing resistance to traditional sprinting is through altering environmental constraints. Theoretically, incline sprinting is thought to "bring the ground to the athlete" who may have difficulty managing and/or executing proper acceleratory mechanics. Specifically, the steady climb and rise of the ground permits a runner continuous opportunity to rehearse limb-actions and foot strikes that are propulsive in nature. While limited by subjects, Bingham and colleagues (2015) demonstrated that incline sprinting on a 5-degree slope created spatiotemporal characteristics that were similar to the first 5 steps from block exit on a flat track.

Noting Figure 10, it appears

FIGURE 9: THE STARTING STANCE, "FALLING AHEAD INTO A FORWARD LEAN" STRATEGY, AND EXIT STEPS OF THE SLED PULL.

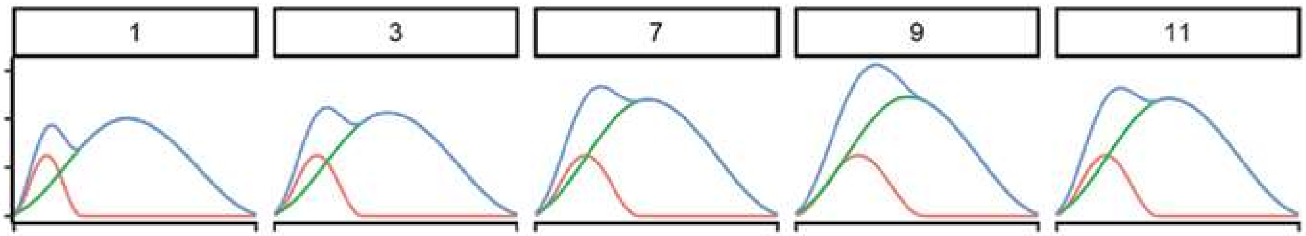

FIGURE 11: FORCE-WAVEFORM REPRESENTATIONS OF THE TWO-MASS MODEL FOR STEPS 1,3,7,9,11 FOR THE SLED PULL.

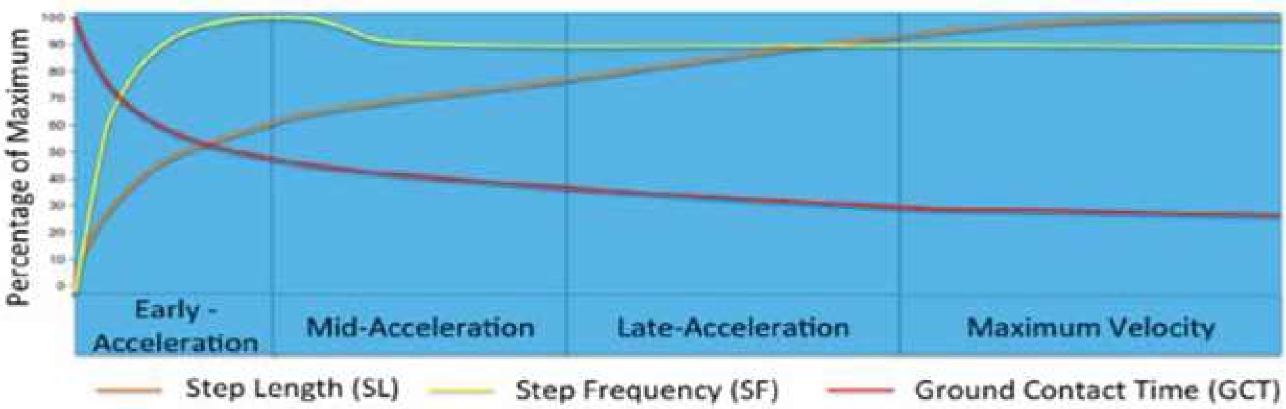

FIGURE 12: SPATIOTEMPORAL CHARACTERISTICS OF SPEED ZONES WITHIN A 100M DASH.

that a sustained reliance on I2 is required for the production of propulsive forces against a rising slope. While I1 continues to drive an asymmetrical wave-form through ankle stabilization, net impulse is shaped by the work to drive the athlete up and ahead of each stance phase. As such, it appears that increasing the inclination of the running surface is a suitable method to enhance accelerative ability early during the preparation period and could be a viable option for the retention of early-phase sprint qualities during competitive or more specific periods of the training year.

Sled Towing: Arguably the most popular, and perhaps the most-researched, resisted-sprint tactic is the sled pull (Alcaraz 2018, Bachero-Mena & Gonzalez-Badillo, 2014, Bentley et al., 2014, Harrison & Bourke, 2009, Morin et al., 2016). Sled pulls follow a similar logic to incline sprinting, aiming to alter the environmental constraints in order to emphasize certain aspects of acceleration skill. Fluctuating the external resistance can modulate (both increase and decrease) the demand of horizontally-oriented force application during each ground contact. Theoretically, this drill serves to aid in the staging of proper segment alignment while also facilitating greater ground forces when chronically applied to acceleration-based training.

As a result of the external resistance, sled pulls have more programming considerations than other sprint-skill development tactics — particularly optimal load selection. While this continues to be a point of dialogue and debate within the coaching and scientific communities, the authors do not feel it is within the scope of this article to spend considerable time on this topic. However, it is worth noting that the authors feel that is most appropriate to rely on sled loads that are towards the modest-end of external resistance, especially within a more mature or established track & field team environment. Briefly, conservative loading allows 1) more similar step

FIGURE 13: THE TRANSITIONAL MECHANICS OF LATE-ACCELERATION SPRINTING. NOTE THE VERTICAL SHIN COUPLED WITH A NEAR-ERECT TORSO. THE TORSO SHOULD CONTINUE TO RISE GRADUALLY OVER THE NEXT SEVERAL STEPS TO A POINT THE JOINTS ARE “STACKED” ENTERING MAXIMUM VELOCITY.

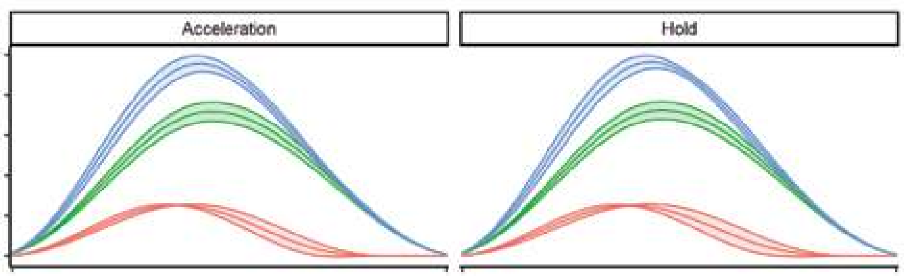

FIGURE 14: FORCE WAVEFORM REPRESENTATIONS OF THE TWO-MASS MODEL FOR THE LAST SEVERAL STEPS OF THE “ACCELERATION” ZONE COMPARED TO THE FIRST SEVERAL STEPS OF THE “HOLD” ZONE.

kinematics to unresisted sprinting, 2) more similar segment kinematics to unresisted sprinting, 3) better fatigue management, and 4) maintenance of elastic-reflexive mechanisms found in unresisted sprinting. Furthermore, it is the authors’ contention that similar programming considerations should be made in sled pulls as in resistance training (e.g. loading variation) to create an environment that exploits physiological phenomenon (e.g. post-activation potentiation) and exposes the athlete to a broader spectrum of output demands. The thoughtful manipulation of loading likely allows the athlete to both physically develop specific physical aspects relevant to sprinting as well as promote a more robust learning environment from a motor skill standpoint.

Programming nuances aside, sled pulls have considerable evidence supporting their use in improving sprint ability in distances less than 20m and coaches are warranted in frequently leveraging this tool (Alcaraz 2018). Considering the figure below, a moderately-loaded (~55% BW) sled pull led to an overall increase in ground contact time while producing a decrease in total force. Though initially counterintuitive, this may have resulted from a more horizontal orientation of the COM relative to the ground, where the athlete used the sled as an off-set in order to support a greater propulsive position. In addition, total impulse increases 7-12% for steps 1-10, largely from an increase in I2, theoretically through an overload of the skill of transitioning through stance phase. With this new information, it may be advantageous for the coach to emphasize that the athlete drives their hips ‘through’ the belt or apparatus that is tethering them to the sled during the pull.

SHORT SPEED - TRANSITORY

Acceleration Hold: While Bezodis et al. (2012) and others suggest movement behavior is slightly nuanced and “self-selected” even at the elite level of competition, multiple sources have demonstrated that a 100m dash can be broken down into definable zones based on kinetic and kinematic similarities (Mackala, 2007; Nagahara et al., 2014a; Manzer 2016). Specifically, these zones can be summarized as the Early-Acceleration, Mid-Acceleration, Late-Acceleration, and Maximum Velocity as noted in Figure 12 (Bellon, 2016).

Success within the aforementioned transition or “late acceleration” phase requires the athlete to stay patient and unhurried as the torso opens up and “sits on top” of the previously established vertical shin. Unfortunately, less skillful sprinters rush through this phase in order to “pop up and run”, sacrificing the last few meters of acceleration in order to satisfy the sensation of moving fast. This impatience can blunt maximum velocity through the compromise of posture, which can appear “seated” if the athlete fails to thoroughly drive themselves tall. And while a sprint

FIGURE 15: THE ENTERING MECHANICS OF A FLY-IN SPRINT RUN, HIGHLIGHTED BY A TALL RIGID TORSO THAT PROVIDES FREEDOM FOR A FULLY-FLEXED THIGH AT THE TERMINATION OF SWING PHASE. THIS STAGES A MORE PROXIMAL GROUND CONTACT, PRESERVING THE SSC. IN ADDITION, ATTENTION SHOULD BE PAID TO THE NEUTRAL KNEES AT MID-STANCE (WHEN BOTH THIGHS ARE "UNDERNEATH THE HIPS".

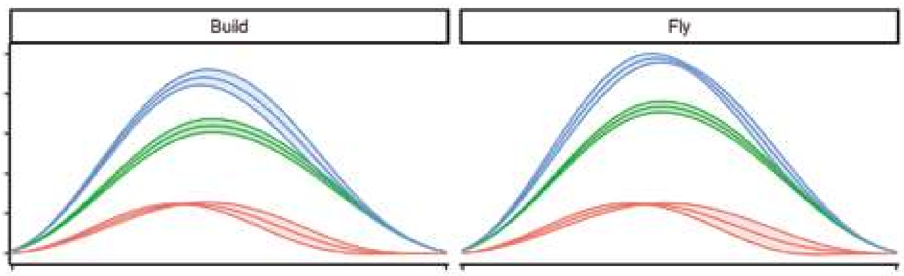

FIGURE 16: FORCE WAVEFORM REPRESENTATIONS OF THE TWO-MASS MODEL FOR THE LAST SEVERAL STEPS OF THE "BUILD" ZONE COMPARED TO THE FIRST SEVERAL STEPS OF THE "FLY" (MAXIMUM VELOCITY) ZONE.

should be seen as a fluid movement that is devoid of abrupt disruption, dividing the race into distinct stages may provide the coach with themes for the design of practice agendas. As such, the acceleration-hold serves as a drill to (a) bridge between acceleration training and top speed, while (b) permitting the athlete time to maintain patience and drive toward pure upright mechanics.

Referring to the work of Mackala (2007), and Manzer (2016), this training unit attempts to provide the athlete with an opportunity to graduate through the initial and extended acceleration phases while being tasked with a controlled rise of the torso. Specifically, the coach will instruct the athlete to accelerate maximally from a crouch or block start up to a cone or landmark that is approximate to the onset of vertical shins. From here, the athlete can be cued to "maintain inertia or speed" by "not pushing on the gas pedal any further". While "holding speed", the sprinter should then allow the torso and head to "uncurl and rise in unison" as they "drive their hips up and through" to a top-speed "stacked" posture.

In addition to the opportunity for a rehearsal of transitional mechanics, acceleration holds also serve as a bridge between programming tactics. For instance, this training tool can be used to regulate the exposure to higher velocities through the judicious placement of a hold cone. Practically speaking, a coach may place the cone at or before the vertical shin to limit intensity or move the cone ahead so as to introduce higher running speeds.

For example, Figure 14 visually represents the phase-to-phase characteristics of an acceleration hold where the sprinter's vertical shin was identified to occur at approximately 35 meters. From here, the athlete was instructed to aggressively build speed from a crouch start up to a cone placed at the 35m mark, and then to "hold speed" while patiently unfolding the torso over the next several steps. Therefore, the last 6 steps of the "acceleration phase" are compared to the first 6 steps of the "hold phase".

Data collected during this training session demonstrates that the overall ratio of I1 to I2 remains relatively unchanged as ground contacts hasten between the entry to and exit from "late-acceleration", which is bookmarked by the vertical shin and subsequent vertical torso. This may suggest that nuances for this drill then, are not necessarily in biomechanics, but in the art of coaching. Though the waveforms presented in Figure 14 may initially seem insignificant, they provide evidence that a properly executed hold produces similar kinetics as an open sprint, but at reduced velocities. This indicates that the acceleration hold fits best as a transitionary tool to longer sprints, but only if the athlete can demonstrate the necessary patience as they unfold at the hip during transition, which may be required in order to produce wave-form similarities. Future investigation should examine this drill using a diverse range of sprint abilities to determine if this is the manifestation of a learned effect of high-level sprinters, as was used in the current discussion.

TOP SPEED TACTICS

Fly-In: As described by coaching pioneers Seagrave (1996) and McFarlane (1993), the Fly-In drill is designed to isolate top-speed mechanics through the prescription of a pre-defined zone of no more than 4 seconds that is staged by a near or full build-up. Once at top-speed, the athlete should

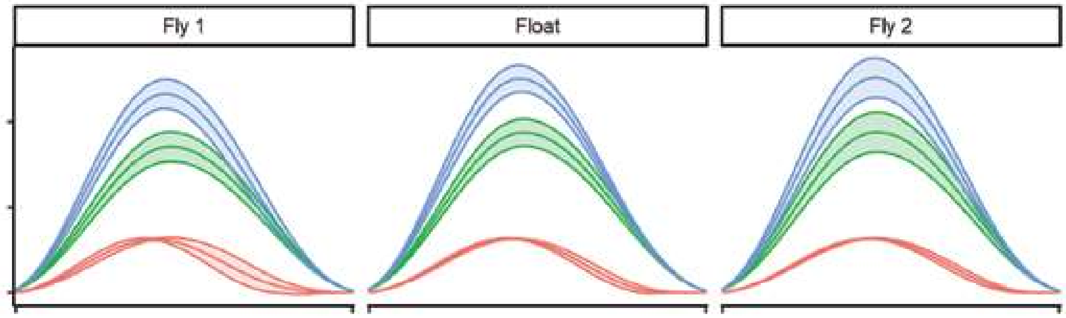

FIGURE 17: FORCE WAVEFORM REPRESENTATIONS OF THE TWO-MASS MODEL COMPARING THE LAST 5 OF THE FIRST "FLY" (BUILD) ZONE, THE MIDDLE 5 STEPS OF THE "FLOAT" ZONE, AND THE FIRST 5 STEPS OF THE FINAL "FLY" (REAPPLY) ZONE.

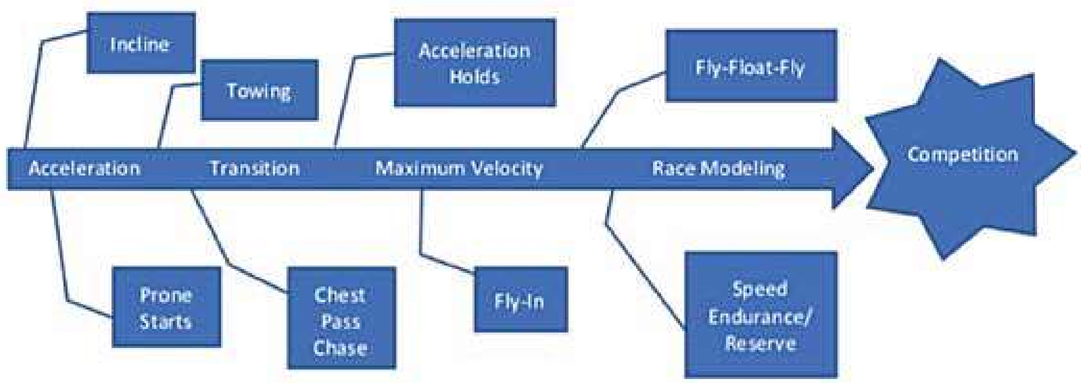

FIGURE 18: CONCEPTUAL FRAMEWORK FOR THE PLACEMENT OF SPRINT TACTICS WITHIN A TRAINING PLAN THROUGH THE CONSIDERATION OF SKILL MATURITY AND FOOT-TO-GROUND FORCE INTERPLAY.

demonstrate a "stacked" posture alongside full and unhindered upper- and lower-body limb cycles that permit a proactive and deliberate foot-strike "down and through" the track. This action attempts to maintain an optimal hip height through a more proximal touchdown, which serves to the maximize the SSC.

Compared to acceleration or transitional sprint techniques, the fly-in is reliant on a sharp rise in I1. Recall that I1 relates to the time it takes to stabilize the shank upon ground contact. Thus, the faster an athlete can steady the shank at top speed, the more economical that stance may be. This is demonstrated well in the figure below, with the athlete delivering a high relative contribution to the total impulse from I1 during these strides taken following an 40m build. The stronger and more skilled athletes will be able to provide a substantial magnitude and rate of force production, resulting in a more prominent I1. The overall strength of the leg musculature allows the athlete to aggressively initiate contact with the ground during stance phase, causing positive or neutral vertical hip displacement. This positive or vertical hip displacement coupled with a foot-strike just ahead of the center of mass at permits 'clean' ground contact and facilitates very high force production under a time constraint of approximately 90-100ms. Thus, the force waveforms presented below not only serve to further elucidate the efficacy of this tactic; but may also be useful in evaluating the quality of ground contact. Because top-speed is the crowning component of a short-to-long progression, this could serve as a means of final evaluation of program efficacy prior to race modeling or competition.

The "Fly-Float-Fly" (FFF) also known as the "Sprint-Float-Sprint" is another top speed training tactic of which practitioners have long speculated is more advanced due to the increased time spent at maximum velocities. Specifically, the FFF evolves from the fly-in by exposing the sprinter to a pair of fly-zones separated by a "float" zone that is thought to permit a brief neurologic recovery. Similar to the fly-in, the top speed zones are brief (2-4 seconds), but combine to yield a larger sum of stimulus through the double peaks at maximum velocity running. Furthermore, it has been postulated that the second "fly" zone will result in the highest velocities due to the potentiating nature of the run if the sprinter "maintains inertia" during the float "recovery" zone.

Historically, this effect has been noted through the capture of average velocity over the fly-zones through the assistance of timing eyes. However, kinetic and kinematic data that provides greater insight into how a sprinter modulates tactics in order to achieve similar velocities within the zones has gone unknown. For instance, based on the data used in Figure 16, both fly-zones demonstrated a greater reliance on I1 as compared to the float-zone while total impulse remained nearly unchanged. In addition, it appears that practitioners may indeed be correct as I1 reaches its highest magnitudes in the second fly zone.

As a result of the information collected through the average zone velocities and the force waveforms, the FFF is indeed an advanced tactic that should be used within the SPP or Pre-Comp to isolate and exploit top speed mechanics. In addition, this type of training unit can be morphed into speed-reserve/ speed-endurance sessions through the elongation of runs, while still avoiding the creation of the dynamic stereotype as identified by Ozolin (1978).

CONCLUSION

Though many of the drills discussed throughout this paper have been well established within track & field, variance in instruction and prescription continue to exist. Therefore, the purpose of this paper was twofold: First, the authors hope to promote coaching continuity through the description of drill design, cueing strategies for set-up and execution, and optimal placement within the training plan (Figure 18). Second, the authors provide ecologically-valid monitoring data that helps illuminate how these properly-instructed drills influence sprinting outcomes.

Why does this matter? In summary because sprinting, like all other forms of human locomotion, is a skill. The waveforms introduced within this paper speak to the elegance of movement quality in a way that traditional variables such as step time, length, and frequency cannot. Specifically, these waveforms demonstrate shape and scope of force production that factors into the sprinter's technique.

The question, now, is not if there exists a universally-applicable technical model or how much strength is needed to run fast; rather, we should ask ourselves how much latitude exists in either direction from an individual athlete's preferred movement signature before we attempt to exploit a given tactic. Perhaps the monitoring and study of stance waveforms provides us with that answer.

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