

Research article

ASSESSMENT OF LINEAR SPRINTING PERFORMANCE: A THEORETICAL PARADIGM

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ABSTRACT

The purpose of this manuscript is to describe a theoretical paradigm from which to more accurately assess linear sprinting performance. More importantly, the model describes how to interpret test results in order to pinpoint weaknesses in linear sprinting performance and design subsequent training programs. A retrospective, quasi-experimental cross sectional analysis was performed using 86 Division I female soccer and lacrosse players. Linear sprinting performance was assessed using infrared sensors at 9.14, 18.28, 27.42, and 36.58 meter distances. Cumulative (9.14, 18.28, 27.42, and 36.58 meter) and individual (1st, 2nd, 3rd, and 4th 9.14 meter) split times were used to illustrate the theoretical paradigm. Sub-groups were identified from the sample and labelled as above average (faster), average, and below average (slower). Statistical analysis showed each sub-group was significantly different from each other (fast < average < slow). From each sub-group select individuals were identified by having a 36.58 meter time within 0.05 seconds of each other (n = 11, 13, and 7, respectively). Three phases of the sprint test were suggested to exist and called initial acceleration (0-9.14 m), middle acceleration (9.14-27.42 m), and metabolic-stiffness transition (27.42-36.58 m). A new model for assessing and interpreting linear sprinting performance was developed. Implementation of this paradigm should assist sport performance professionals identify weaknesses, minimize training errors, and maximize training adaptations.

KEY WORDS: Speed, sprint, sports performance, soccer, lacrosse.

INTRODUCTION

In an effort to physically maintain a competitive edge, today's athletes dedicate a significant portion of time to training year round. They hire sports performance professionals to help develop a high level of sport specific fitness. This is not a luxury reserved only for professional athletes, young individuals (10-20 years old) are regularly participating in sports camps and training programs in order to make the starting varsity line-up for high school teams or trying to earn a college scholarship. While training by trial and error has been minimized in certain areas of fitness (e.g., strength and power training), research is lacking in other areas such as acceleration and speed development.

Typically, athletes are tested prior to and following a designated training cycle. Using this bookend approach to monitor performance

adaptations can lead to arbitrary and apparently common training regimens from one athlete to the next. For example, college football players invited to the National Football League (NFL) combine regularly participate in 6-12 week programs specifically targeting a reduction in 36.58 meters (40 yard) sprint time. Other sports, such as soccer (36.58 meters) and baseball (54.86 meters, 60 yards) also use the timing of common distances as the benchmark for determining if someone is 'fast'. In fact, most texts used by sports performance professionals only provide normative standards for these distances (Baechle and Earle, 2000; Kirkendall, 2000). Therefore, it becomes increasingly difficult to avoid arbitrary assignment of drills and exercises which may improve a 36.58 or 54.86 meter sprint time, but completely ignore weaknesses that should be targeted during training. Total finish time provides an overview of a complete

puzzle; examining pieces of the puzzle however, is an essential element for sports performance professionals.

A greater understanding of linear sprinting performance can be accomplished by determining split times. Using the world record in the 200 meter race it is known that humans can move approximately $23.5 \text{ miles}\cdot\text{hour}^{-1}$; however, examining the final 20 meter split of an elite 100 meter race suggests $28 \text{ miles}\cdot\text{hour}^{-1}$ is possible (Dintiman et al., 1998). This strongly indicates the value of examining various splits during athletic performance assessment. The Australian Sports Commission provides split times (e.g., 4.57, 9.14, and 18.28 meter) for a variety of sports (Gore, 2000); however no interpretation is provided to allow for its use in program design. Dintiman (1998) suggests the use of splits to pinpoint weaknesses of an athlete. For example, he proposes using the difference in time between 40-80 meters and 80-120 meters as an indication of speed endurance. However, the total distance recommended (120 meters) is most likely prohibitive for most athletes except those participating in track and field.

Another common problem with the assessment of linear sprinting performance is the use of handheld timing devices. Track and field switched from manual to electronic timing in 1977, yet it is still extremely common for athletes to be tested using stopwatches. The use of handheld stopwatches is problematic for two important reasons. First, there is an average difference between electronic timing and handheld devices of 0.22 seconds (Olsson, 2001). Reduced accuracy will dampen the design of a subsequent training cycle and most likely attenuate performance improvements. Second, handheld time does not allow for the simultaneous measurement of various splits and only provides an absolute finish time. In other words, to determine 18.28 and 36.58 meter split times, an athlete would have to run both distances. If more splits were necessary the athlete would have to run increasingly more tests. This would greatly increase the duration of testing and most likely create fatigue, and negatively effect subsequent tests.

Bobbert et al. (1994) suggests answering three basis questions prior to training athletes: 1) what factors determine performance? 2) which factors can be changed? and 3) which changeable factors do we focus our training on? The first question is typically answered during a needs analysis of the sport and, if appropriate, a specific position. The second question, within the context of this paper is whether linear sprinting performance can be changed or improved. The answer is yes, and so the final question remains to be answered and can only be determined using the principles outlined below. The

goal is to create and implement an assessment paradigm that can depict the specific factors needing change, which will ultimately minimize ineffective training and maximize performance enhancement. Using one testing variable (i.e., 36.58 meter sprint time) leads to a quandary because two athletes may have identical finish times, however one might have poor acceleration (operationally defined in this paper as 0-10 meters) mechanics while the other could be restricted in the final 9.14 meters due to poor anaerobic metabolism. The quality and precision that is vitally important during the examination of an athlete's abilities can be accomplished by assessing various splits using infrared timing gates.

The purpose of this paper is to describe a new theoretical framework for assessing linear sprinting performance. The results are used to pinpoint weaknesses of traditional methods of assessment as well as assist in the interpretation of scores, which will subsequently have beneficial training implications.

METHODS

Retrospective analysis was performed using the performance scores of eighty-six (age = 19.6 ± 1.0 yr; height = 1.68 ± 0.06 m; body mass = 64.9 ± 6.4 kg) Division I college female athletes. The sample comprised of 61 lacrosse and 25 soccer athletes. Performance was assessed at the end of the off-season training cycle and completed in the morning between 0800-1100 h.

Linear sprinting performance was evaluated by positioning infrared sensors (Brower Timing Systems Inc.) at the start line and at 9.14, 18.28, 27.42, and 36.58 meters at a height of approximately 1.0 m. Subjects began in the standing position and self-selected which foot was put on the starting line. To eliminate reaction time, the athletes began when ready and were instructed to run at maximal speed through the final pair of sensors. Timing started when the laser of the starting gate was broken (i.e., first movement). Athletes performed two trials for all tests with a minimum of two minutes rest between all trials. The best score for each test was used for analysis. Test-retest reliability was high for all four distances ($r = 0.84-0.95$).

Individual and cumulative split times were defined as each independent 9.14 meter distance (i.e., 1st, 2nd, 3rd, and 4th 9.14 meter) and the summation of each 9.14 meter distance (i.e., 9.14, 18.28, 27.42, and 36.58 meter), respectively. The range for 36.58 meter sprint times (5.4 – 6.6 seconds) was used to trisect the entire data set (0.41 second ranges) into sub-groups labeled as above average (faster), average, and below average

Table 1. Descriptive characteristics of athletes. Data are means (\pm SD).

	Soccer (N = 25)	Lacrosse (N = 61)	Total (N = 86)
Age (yr)	19.7 (.8)	19.6 (1.1)	19.6 (1.0)
Height (m)	1.67 (.05)	1.69 (.06)	1.68 (.06)
Body mass (kg)	64.0 (5.3)	65.6 (7.1)*	64.9 (6.4)
36.58 m (sec)	5.97 (.29)	6.02 (.26)	6.00 (.27)

* 26 lacrosse players did not have body mass measured.

(slower). The sub-groups were created in order to examine if the difference in 36.58 meter times between sub-groups could be caused by a particular split.

Statistical procedures

All statistical procedures were performed using SPSS, Version 11.0 (SPSS Inc.). An independent t-test was used to compare 36.58 meter sprint times between soccer and lacrosse players prior to combining data sets. A one-way ANOVA was used to compare the three sub-groups. A Tukey's post-hoc analysis was used for pairwise comparisons. A repeated measures ANOVA was used to compare individual and cumulative split times. When appropriate, Tukey's post-hoc analysis was used to determine pairwise differences. An alpha < 0.05 was accepted as significant. All values are reported as mean \pm SD.

RESULTS

The independent t-test showed no significant difference between sports for any physical

characteristic or the 36.58 meter sprint, $t(84) = 0.70$, $p = 0.5$ (Table 1).

Figure 1 shows the comparison of trisected data. The ANOVA revealed a significant difference for each individual 9.14 meter split, $F(2, 83) \geq 25.1$, $p < 0.000$. Post-hoc analysis indicated all groups were significantly different from each other on each of the individual splits ($p \leq 0.001$).

Figures 2, 3, and 4 show select individuals from the above average ($n = 11$), average ($n = 13$), and below average ($n = 7$) classification, respectively. The athletes chosen within each group have a 36.58 meter time within 0.05 seconds of each other. The top portion of each figure displays the cumulative splits while the bottom portion shows individual splits. Each line in the figures represents an individual athlete.

DISCUSSION

There are two purposes for assessing athletic performance. First, and more common, is to quantitatively determine improvements made following a training cycle. This allows the athlete

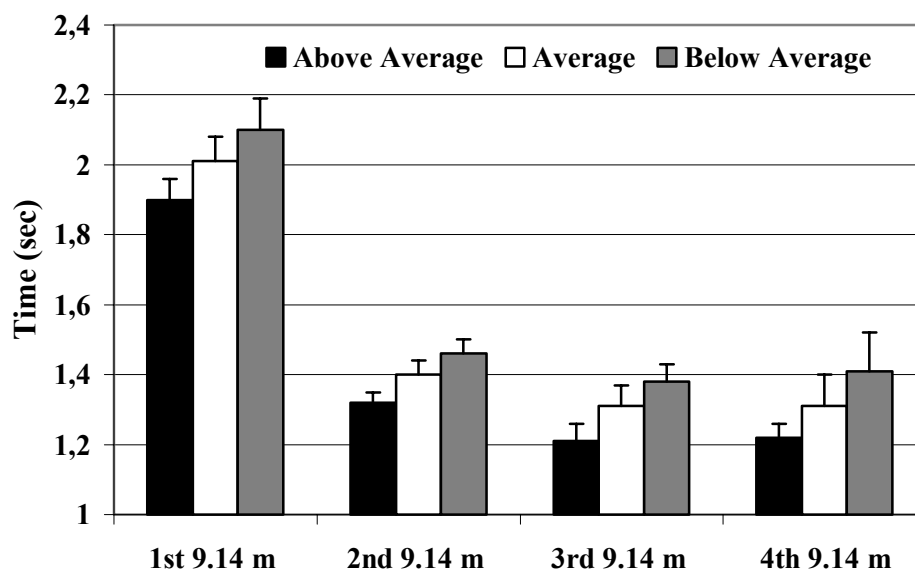


Figure 1. Individual 9.14 meter splits for the Above Average ($n = 22$), Average ($n = 44$), and Below Average ($n = 20$) sub-groups. Each split was significantly different between all three sub-groups.

and sports performance professional to examine if the training stimulus was sufficient to cause a positive adaptation. This method does not however, answer Bobbert's third question, which asks, 'Which changeable factors do you focus training on?' (Bobbert and Van Soest, 1994). Two athletes may perform the same during an assessment of 36.58 meter sprinting ability, but it only indicates they arrived at the same time and does not reflect how they traveled from start to finish. Therefore, a training cycle designed solely on a finish time will most likely include a plethora of arbitrarily chosen drills and exercises in an attempt to improve the outcome variable (36.58 meter time). Using this shotgun approach to program design will simply fail to focus on specific weaknesses and ultimately attenuate athletic development.

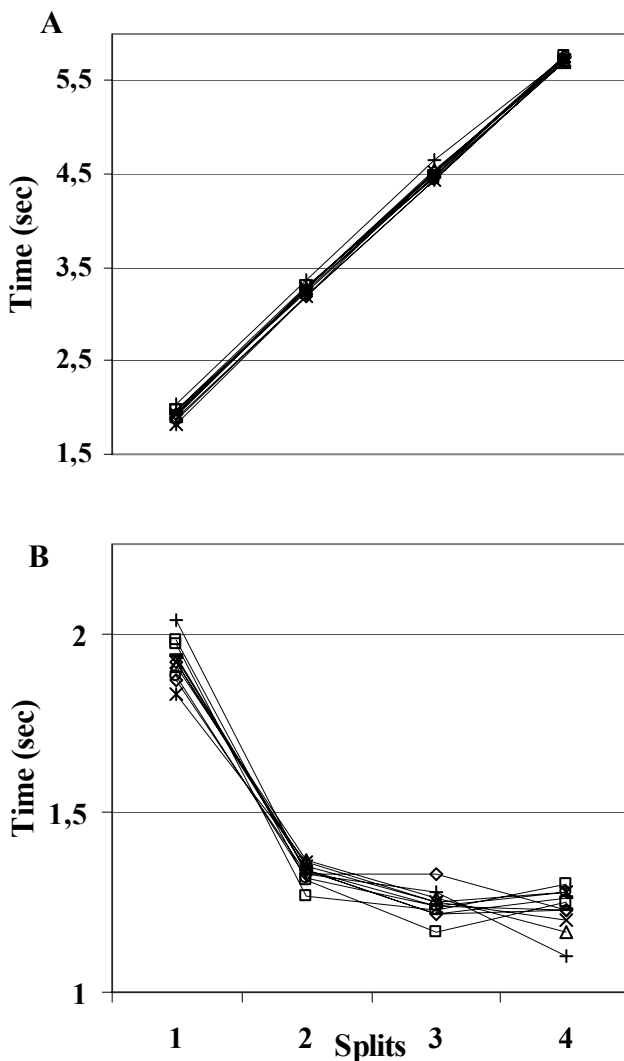


Figure 2. Cumulative (A) and individual (B) splits during a 36.58 meter sprint, however it remains difficult to pinpoint faults. For example, with the exception of one or two individuals, the lines all run parallel to one another and are closely related within

The second purpose of athletic assessment is to pinpoint specific weaknesses in linear sprinting performance utilizing various splits. Determining splits requires the use of infrared timing sensors, whereby a gate is set at specified distances (in the current paper every 9.14 meters). This design allows for the collection of 9.14, 18.28, 27.42, and 36.58 meter times (cumulative splits) and also allows each 9.14 meter split to be examined independently (individual splits). To the author's knowledge using split times to examine specific breakdowns in athletic performance and subsequently design a targeted training program focused on identified weaknesses is not common practice among sports performance professionals. A paradigm was designed using a sample of Division I female soccer and lacrosse players.

Physical characteristics and 36.58 meter sprint times were similar between sports (Table 1). Based on 36.58 meter finish times the data was subsequently trisected (range = 0.41 seconds) to establish sub-groups, which were labelled above average (faster), average, and below average (slower). The rationale for creating these sub-groups was to determine if the paradigm could provide similar information within distinct classifications of performance. Statistical analysis showed significant differences between the sub-groups on the total finish time as well as each 9.14 meter split (faster < average < slower; Figure 1).

Select individuals were chosen from each sub-group to demonstrate the appropriate use of split times. A range of 0.05 seconds was arbitrarily chosen since it was thought to represent nearly identical finish times for this sample of athletes. The athletes from the faster, average, and slower sub-groups had 36.58 meter times of 5.73 ± 0.02 , 6.13 ± 0.02 , and 6.27 ± 0.02 seconds, respectively. Simply examining these times would lead most to prescribe comparable training regimens within a particular sub-group, resulting in 'faster' athletes. This philosophy lacks depth and does not allow the sports performance professional to determine if there is a breakdown in acceleration or if metabolic inefficiency exists which prohibits maintenance of speed throughout the entire testing distance. The use of predetermined splits should provide some insight. Figures 2-4 display both cumulative (A) and individual (B) splits for the above average, average, and below average sub-group, respectively. Each line represents an individual athlete.

Cumulative splits provide additional information regarding an athlete's performance

a given sub-group. It does appear some separation exists for the first 9.14 meter cumulative split, which is more evident in the slow sub-group. However, not enough meaningful evidence exists to establish future training protocols which target specific areas of breakdown. Therefore, using cumulative splits remains a limiting factor for determining a specific training focus and does not clearly express strengths and weaknesses in linear sprinting performance.

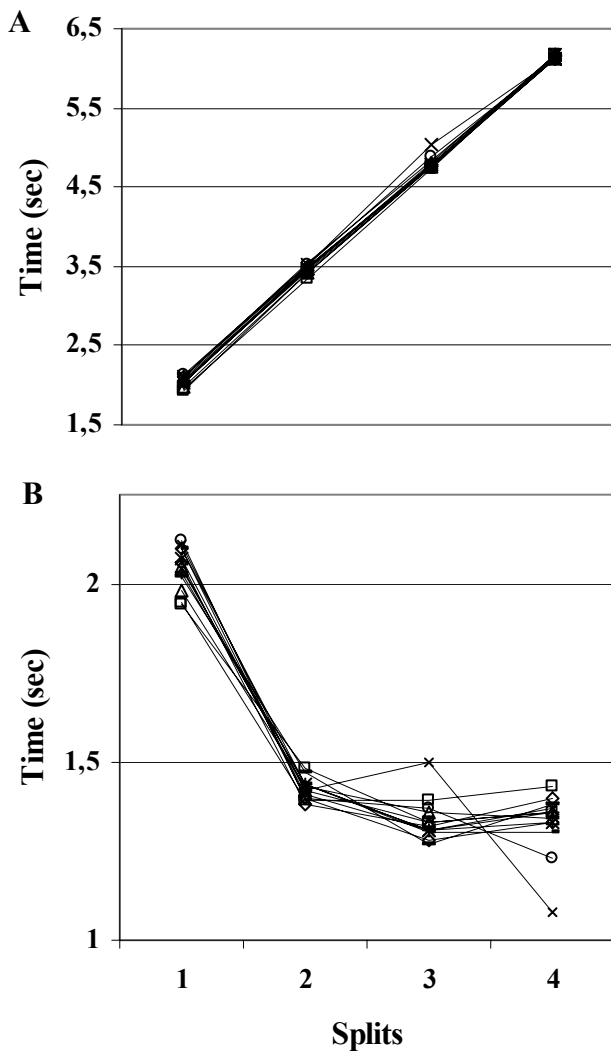


Figure 3. Cumulative (A) and individual (B) splits for average athletes ($n = 13$). Each line represents an individual athlete. Range of scores = 6.11-6.16 seconds.

On the other hand, individual splits (Figs 2-4B) provide a drastically different picture compared to 36.58 meter time or cumulative splits. It becomes clearly evident how any given athlete travelled from start to finish. In fact, three distinct phases can be observed, which have been operationally defined as: initial acceleration (split 1), secondary acceleration (splits 2 and 3), and metabolic-stiffness transition (split 4).

From a static start to 9.14 meters all athletes will increase velocity due to a rise in both stride length and frequency, hence the term initial acceleration. Schmolinsky (2000) clearly shows that between 10 and 30 meters velocity continues to rise, primarily due to an increase in stride length. However, the change in slope is not as steep compared to the initial acceleration (as reported by Schmolinsky (2000)) and therefore secondary acceleration is used to describe the combination of splits 2 and 3. Beyond 30 meters both stride length and frequency have reached a plateau (Schmolinsky, 2000) and so the ability to maintain speed beyond this distance will depend heavily on two factors: 1. anaerobic metabolism and 2. active muscular stiffness. Women tend to show a plateau in velocity sooner than men (Schmolinsky, 2000) and this could lead to a heightened reliability on anaerobic metabolism to maintain speed. Active muscular stiffness minimizes the vertical displacement of the center of mass (via knee and ankle stability) during the support phase (Kyrolainen et al., 1999). Research has shown women have 20-45% less stiffness compared to men during sprinting in conjunction with greater muscular activation (Granata et al., 2002a; 2002b). It is for these two reasons the phrase metabolic-stiffness transition is used to operationally define the final 9.14 meter split. It must be noted that while distinct phases of the 36.58 meter test have been identified in this paper, certain trainable aspects should not be considered specific to a particular phase, and will be interdependent with one another.

Graphic representation of the individual split times associated with the three phases provides the necessary information to critique performance and create a focused training plan. For example, the 1st 9.14 meter split time (i.e., initial acceleration) can identify an individual that requires work in that area regardless of their total finishing time. In other words, one athlete considered fast and another considered slow could both have deficiencies in acceleration which require similar attention during a training cycle. In contrast, two athletes considered slow may require acceleration development, but show different faults for their poor start. One may need form and technique development while the other requires explosive power training. Clearly the data will not identify which factor is responsible for the deficit in acceleration. Visual assessment is a necessary component at this point to decipher which aspect should be the primary focus during the subsequent training cycle. An athlete that has technique flaws should develop the appropriate motor skills prior to initiating strength or power training. For example, if over-striding and heel strike

occur during initial acceleration, specific instructions should be provided and drills performed to correct this particular deficiency. On the other hand, an individual who displays proper sprinting form will most likely benefit from strength and/or power development. Pinpointing a weakness and subsequently determining the cause will provide greater focus and heightened returns during training.

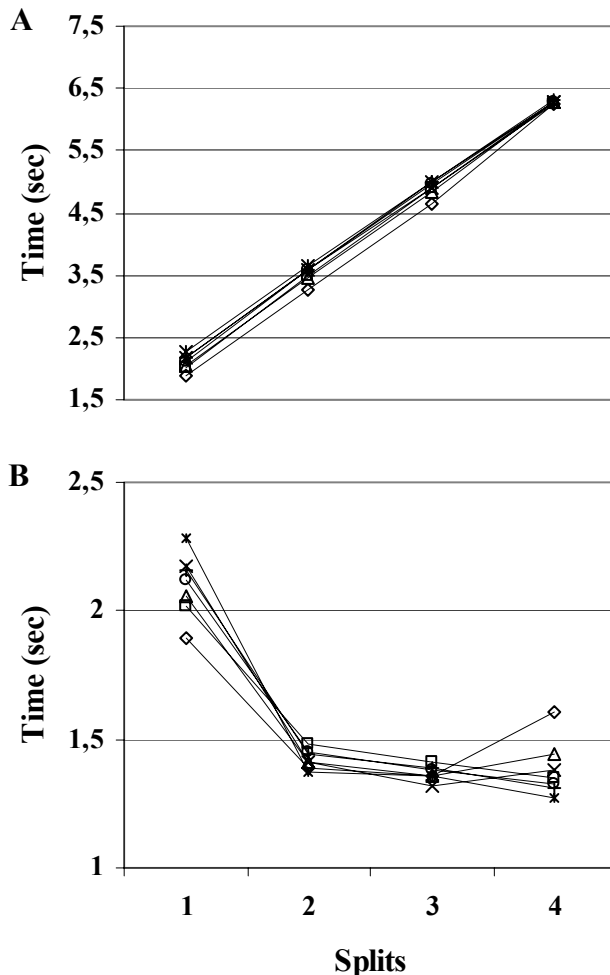


Figure 4. Cumulative (A) and individual (B) splits for below average athletes ($n = 7$). Each line represents an individual athlete. Range of scores = 6.25-6.30 seconds.

For the purpose of this paper we have operationally defined secondary acceleration to indicate the distance between 9.14 and 27.42 meters (i.e., 2nd and 3rd splits). Because the 2nd and 3rd splits are an intermediate phase for this particular distance, determining the cause of a potential weakness in secondary acceleration may be difficult. Metabolic deficiencies could occur in this phase, however this is unlikely due to the fact that the duration from 9.14 to 27.42 meters is approximately 2 – 5 seconds. Nevertheless this cannot be ruled out as a cause since poor anaerobic power could reduce performance. Muscular power could also be a cause

of poor performance in secondary acceleration. A recent study examining male field sport athletes reported that faster individuals showed shorter support (i.e., ground contact) phases (Murphy et al., 2003). Although not addressed in that investigation, it should be assumed that greater amounts of horizontal power were accomplished by the faster athletes since a shorter ground phase alone would not necessarily be beneficial to sprinting speed. Blazeovich and Jenkins (2002) reported an improvement in 20 meter speed following seven weeks of training, but found no difference between groups when comparing high versus low velocity resistance training. So, while power production is important, the specific training stimulus for its development is unclear. Definitive answers will only be provided with further research.

Finally, metabolic-stiffness transition, as we have operationally defined it, occurs during the last 9.14 meter split. The directionality of this particular segment indicates how an athlete finished during the 36.58 meter sprint. A line shifting to an upwards direction is shown for several individuals in each sub-group, which indicates a reduction in speed during the final 9.14 meters. While some might argue that athletes slow down prior to crossing the finish line, it was hypothesized that inadequate anaerobic metabolism is partly responsible for the decrease in speed. Additionally, the use of duplicate trials minimized any faulty interpretation of test scores due to an athlete simply slowing before the finish. Mathematical modeling of the world champion 100 meter sprint finals indicated that deceleration began after approximately six seconds of sprinting (Arsac and Locatelli, 2002). It should be expected that athletes of less caliber (e.g., college athletes) would begin to decelerate sooner and therefore rely to a greater extent on anaerobic metabolism to maintain speed. Pilot work from one of the authors (TB) has shown that an eight week program using interval conditioning improved the final 9.14 meter split time by an average of 0.11 ± 0.04 seconds for a group of high school female soccer players (unpublished data), suggesting a possible remedy for this particular weakness. Recent research has shown that short (< 10 seconds) sprints can alter enzymatic activity and improve 40 yard time after only six weeks (Dawson et al., 1998). This implies that a link exists between speed and speed endurance, and by improving metabolic efficiency an athlete can consequently impact, and in fact improve, speed (Matveyev, 1981).

Complex motor skills, such as sprinting, may also rely on ankle and knee joint stiffness, but to what extent active muscular stiffness contributes to better performance is debatable (Granata et al., 2002a; 2002b; Kuitunen et al., 2002). Mechanical

and neural properties responsible for the control of active muscle stiffness cannot be assessed using simple timing devices, but requires expensive laboratory equipment. Nonetheless, Hennessy and Kilty (2001) showed drop jump performance accounts for approximately 62% of the variance for 30 meter sprint time. Therefore, using drills with specific instructions to jump for maximal height or distance and require minimal contact with the ground should provide the necessary stimulus for improving active muscle stiffness and consequently sprinting ability.

CONCLUSIONS

The aim of this paper was to develop a theoretical framework for assessing and interpreting linear sprint performance. The results indicated that individual splits are necessary for the most accurate assessment of sprinting ability. Therefore, the following paradigm was created: Evaluate, Educate, Eliminate, and Enhance (E⁴ SM). *Evaluate* individual splits for linear sprinting. *Educate* the athlete regarding their specific weaknesses and the methods that will be used during subsequent training. *Eliminate* the weaknesses identified by using focused training design. *Enhance* performance while minimizing training by trial and error.

Simply identifying an athlete as fast or slow will only provide a limited view of performance. Therefore, regardless of total finish time, athletes can be categorized by specific weaknesses. In addition, athletes with identical finish times can display drastically different deficiencies. Implementing this paradigm will enable sports performance professionals to assess specific variables, appropriately interpret assessment results, and subsequently design a training program based on sports science, which will ultimately maximize athletic improvements.

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E⁴ is a service mark of The Essential Element, LLC.

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KEY POINTS

- Assessment of linear sprinting should include splits for a greater understanding of performance.
- Individual split times can be used to identify specific areas of weakness.
- Appropriate training strategies can be developed and used to improve the identified weaknesses.

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