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Factors that differentiate successful and less successful sprinters

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Abstract
The intent of this study was to explore the similarities in the factors that contribute to the performance of the World's fastest human in the 100-meter race and that of high school sprinters. A total of 46 (male = 19 and female = 27) high school track and field sprinters were tested on their 30-meter spring and fly starts, air times, and ground times. Overall, male and female participants in this study spend more times on the ground reaction time compared with the successful Olympians. Participants in this study had similar times in the 30-meter sprint and fly starts and in the air times compared with the successful Olympians. It is suggested that track coaches improve athletes' ground reaction times if they want them to be successful.

Keywords: olympians**,** successful, less successful, sprinters

1. Introduction
Every four years, the world's attention is concentrated on a single global location where the best athletes from every corner of the planet congregate for the greatest sport spectacle known to man: the modern Olympic Games. The Olympic Games celebrate the pageantry and strength of the human spirit as athletes challenge themselves in the arena of sporting competition in events ranging from kayaking to tandem trampoline (Borzov, 1990) [2]. But the marquee event that captures the imagination of every spectator and fills the 100,000 plus Olympic stadium to over flow capacity culminates when the gold medal is awarded in the 100 meters heralding the World's Fastest Human (Mann, 2007) [13]. The 100-meter champion signifies the embodiment of the very highest level of human sporting performance.
The concern is what allows one man or woman to distinguish him or herself over so many other sprinters all hoping to win the prize. Were these human lightning bolts, more successful sprinters, destined to be faster? Was it their genetic make-up, or are there other factors contributing to performance allowing the more successful sprinter to outperform less successful sprinters? Understanding the keys to successful sprint performance presents major training implications for the sprint coach.

1.1 Factors that Affect Sprint Performance.
Sprinters' performance is affected by reaction time, acceleration, spring cycle (ground time and air time), and stride length and stride frequency.

1**.2 Reaction Time**. Reaction time is the time interval between the firing of the starter's gun and the moment the athlete is able to exert force and/or pressure on the starting blocks (Delalija, & Babic, 2008; Krzysztof, & Mero, 2013) [10]. Reaction time mostly depends on how fast the nerve impulses are transmitted from the body's auditory systems to the effector systems or the reacting muscle (Babic, 2009) [1]. It represents only one percent of the total contribution to a 100-meter performance, but is critical to the smooth transition of speed throughout the run. Reaction time is measured with pressure sensitive sensors embedded in the pedals of the starting blocks.

1.3 Acceleration. Acceleration is the rate of change of velocity and the rate at which an object changes its velocity (Bosch, & Klomp, 2005) [3]. The 100-meter race acceleration is a continuous series of transitions to top speed. The acceleration in a 100-meter race is broken down into the start position, the set position, the two-legged reaction push, the first and second steps (called pure acceleration), and top speed transitions covering the third to the twelfth steps (Mann, 2007) [13]. The first two to three steps out of the blocks in acceleration require the sprinter to concentrate on applying optimal force back into the blocks pedals and down into the track simultaneously (Hunter, & McNair, 2004) [6]. Since acceleration is not static but a continuous value, sprinters must compromise the need to push with excessive force while balancing the equally important decrease in the need to push as each step allows the athlete to go faster (Bosch, & Klomp, 2005) [3].

1.4 Sprint Cycle (Ground and Air Times). Every sprinter completes the spring cycle. The sprint cycle comprises of ground time and air time; the amount of time the athlete spends in contact with the ground during each running step (Mann, 2007) [13] measured in seconds. The more successful sprinters have been shown to produce high ground time forces in the first 20-30 meters of the 100-meter sprint (Krzysztof, & Mero, 2013; Thompson, 2009) [10, 16]. Because the sprinter is at zero velocity prior to the firing of the starter's gun, high force production is needed to unseat the sprinter as he/she attempts to move to maximum speed (Delalija, & Babic, 2008). Ground time values are two times higher as the sprinter leaves the blocks than are air time values. Excessive ground time slows down the acceleration process caused by power production (Fukuda, 2008) [5]. Ground time is the most indicative measure of more successful sprinters (Borzov, 1990) [2].

Air Time is the interval the athlete spends while airborne during each stride measured in seconds (Mann, 2007) [13]. Krzysztof and Mero (2013) [10] found that the amount of time in the air during the first two to three steps out of the blocks is half as long as the time spent on the ground. This is due to the increase force required to create velocity from a position of zero velocity. Airtime is one of the two descriptors (ground time being the other) which provide the greatest insights into how elite performances are accomplished. Successful and less successful sprinters exhibit little or no difference in air time results measured at 0.123 seconds for both men and women (Mann, 2007) [13].

1.5 Stride Length and Stride Frequency. Stride length and stride frequency are inter-related, and are present during the acceleration, transition to maximum speed, maximum speed, and speed maintenance (Fukuda, 2008) [5]. Stride length is the distance covered with each running step and is measured in meters (Mero, 1992) [14]. Optimal stride lengths are more desirable than maximum values because 100% stride length will have a negative effect on the production of stride frequency. The desire to generate a bigger stride is caused exclusively by elements the sprinter cannot control, leg length (Mann, 2007) [13]. Stride length remain balanced as long as the body position is kept almost completely perpendicular to the running surface (Vonstein, 1996) [17]. Successful sprinters possess enough strength to sustain stride length with high force production making improvement of the ability to produce power whether you are a taller man or a shorter woman (Schiffer, 2009) [15]. Stride frequency on the other hand is the leg turnover rate of the athlete (Mann, 2007) [13]. How quickly a sprinter moves his/her legs is one part of the running stride equation, which determines the quality of sprint performance. Successful sprinters have a sound combination and ability to manage both their stride length and stride frequency (Fukuda, 2008) [5].

1.6 Successful and Less Successful Sprinters. The practices used by coaches to draw out the qualities that make for successful sprinters come in the form of what are called "critical zones". Critical zones are psychological, physiological, tactical, and biomechanical elements which determine the success or failure of an individual at the height of stress and management (Johnson, 1995) [9]. Successful sprinters use high intensity phases of training on the track, resistance and flexibility training, technical competency drills, as well as plyometric or jump training (Coh, & Milanovic, 2001) [4]. In addition, they use the weight room and other training assistance drills that work on starting action (weight room squats and leg press), acceleration development (weight room power cleans, uphill sprints and grass field 5-bound jump exercises), pick up phase or maximum velocity workouts (grass field long bounds and depth jumps), and top speed work (towing and downhill) running (Bosch, & Klomp, 2005) [3].

In an attempt to develop more successful sprinters, knowledge has grown out of the discussions biomechanists and sprint researchers have used to describe what might be happening in the 100 meters (Mann, 2007) [13]. Research indicates that more successful sprinters possess several physical qualities and work vigorously to exploit superior execution of those qualities (Coh, & Milanovic, 2001) [4]. For example, the average height and weight of the more successful female sprinters are five foot nine inches (1.75m) and one hundred and twenty-six pounds (57.2kg), while the men check in at six feet (1.82m) and one hundred and eighty-two pounds (82.6kg). Successful sprint performers have a lower body fat index, which allows a greater percentage of energy and strength devoted to moving a lighter, stronger frame down the track (Hunter, & McNair, 2004) [6]. Also, longer legs with shorter bodies tend to produce better sprinters, in addition to having thicker more powerful gluteus muscles in the upper leg with smaller, leaner lower legs. Below in table 1 are the performance characteristics of successful female and male 100 meter sprinters over the last Olympic games:

Table 1.

	Ht.	Wt.	Steps	Stride Frequency	Maximum Velocity	End of Maximum Velocity	Loss of Maximum Velocity
Men	1.95m	94kg	45.5	4.52step/sec	11.56m/sec	80.5m	6.0%
Women	1.73m	64kg	49.6	4.49step/sec	10.43m/sec	73.8m	6.8%

Technical considerations are very important to the success of top flight sprinting. According to Schiffer (2009) [15] and Bosch and Klomp (2005) [3], the global approach to successful technical training requires: (1) an upright trunk with a slight forward lean so the driving leg is slightly behind the body when the take-off foot leaves the ground, (2) the forward drive from the lower leg comes from the ankle and the hip, (3) the front knee moves forward so the take-off mechanic can be completed, (4) there must be a synchronous balance between arm and leg movements, and (5) the head remains in normal alignment with the trunk.

The same technical conditions do exist for the less successful sprinters. However, less successful female sprinters are shorter, carry more body weight, and have a higher percentage of body fat than their successful counterparts. Performance characteristics of less successful female and male 100 meter sprinters produced the following data in table 2.

Table 2.

	Ht.	Wt.	Steps	Stride Frequency	Maximum Velocity	End of Maximum velocity	Loss of Maximum Velocity
Men	1.75m	90kg	47.4	4.44step/sec	10.83m/sec	70.7m	8.0%
Women	1.62m	71kg	51.5	4.53step/sec	9.79m/sec	68.7m	7.3%

The height of the less successful male sprinter is not as much a problem. However, the issue of increased weight and body fat represents a negative effect on performance as it does with the female less successful sprinter (Lipps, & Eckner, 2009).

Technically, the less successful sprinter tends to run out of position with an elevated chin, causing a bowing of the back which restricts leg drive (Ito, & Ichikawa, 1998; Ito *et al*., 2006). In addition, they tend to use an overly forceful arm swing, bend at the trunk causing over rotation of the torso, run too flat footed, tend to run with a side to side motion, and point their toes outward and not in a straight line down the track. Fixing these training errors allows the track coach to narrow their investigation into the reasons that separate the great from the average sprinter (Mackala, 2007). The intent of this study was to investigate factors that distinguish successful sprinters from their less successful counterparts.

2. Methods and Materials

2.1 Participants

In this study, Southern Californian male (n = 19) and female (n = 27) high school track athletes participated. There were 5(10.9%) freshmen, 10(21.7%) sophomores, 18(39.1%) juniors, and 13(28.3%) seniors. The participants' age ranged from 15 to 20 years (M = 16.75, SD = 0.55). The number of years the participants indicated they were affiliated with a track club ranged from one to five (M = 0.74, SD = 1.237). For these athletes, six (13%) lived in a large city, 15(54.3%) lived in the suburbs, and 15(32.6%) lived in a small city. Participants were purposely chosen for this study.

2.2 Dependent Measure

A questionnaire was developed for data collection. The questionnaire collected demographic information about participants' age, gender, race, height, weight, 100 meter personal best, year in school, years of high school track experience, years of track club experience, and where they lived.

2.3 Procedure of Data Collection

Institutional Review Board (IRB) approved the research protocol. Permission was obtained from the high school principal and the head track and field coach to use the athletes. Athletes were contacted and their voluntary participation in the study was solicited. Each participant completed an informed consent form. Minors took the informed consent form home for their parents' approval. All athletes with parents' permission volunteered to participate. Measurements were taking on participants' 30-meter sprint and fly starts, air times, and ground times.

3. Results

The purpose of this study was to investigate the factors related to successful sprint performance. Several One-Sample t-tests, Independent sample t- tests and One-way Anova were calculated to investigate performance differences between successful and less successful sprinters. The criteria or test values for the One-Sample t-tests were the semi-finals and finals of Olympic Games, World Championships, and World Athletic Finals over the last ten years.

3.1 Females

To investigate differences between female participants in this study and elite female 30-meter start times, a One Sample t-test was calculated. Results showed a statistical significant difference between the female participants in this study average 30-meter start and elite female 30-meter start times, t (17) = 14.31, p < 0.05. The female (M = 4.54, SD = 0.12) participants in this study had a slower 30-meter start time compared with the elite female 30-meter start time of 4.15 seconds.

A similar one-sample t-test investigating 30-meter average fly times revealed a statistical significant difference, t (17) = 17.12, p <.05. The female (M = 3.67, SD = 0.18) participants in this study had a slower 30-meter fly time compared with the elite female 30-meter fly time of 2.95 seconds. Further one-sample t-test revealed significant difference between female participants in this study and elite female ground times during a 30-meter fly run, t (17) = 12.79, p < 0.05. Thus, the female (M = 0.11, SD = 0.01) participants in this study had a longer ground times compared with their elite ground performance time of 0.083 seconds.

No statistical significant difference was found between the female participants in this study average air times and elite female air times during a 30-meter fly run, t (17) = 1.51, p > 0.05. The female (M = 0.13, SD = 0.01) participants in this study had an almost identical air time as the elite female air time of 0.123 seconds from the USATF Senior Championship data (Mann, 2007) [13].

3.2 Males

To investigate the differences between male participants in this study and elite male 30-meter average start times, a One-Sample t-test was calculated using a test value of 3.90 seconds; an elite male average start times of the semi-finals and finals from the Olympic Games, World Championships, and World Athletic Finals of the last ten years.

Results showed a statistical significant differences, t (15) = 7.86, p < 0.05, between the male (M = 4.19, SD = 0.145) participants in this study average 30-meter start and elite male 30-meter start times of 3.90 seconds. Male participants in this study were on average slower in getting out of the blocks.

Further statistical significant differences were found between male participants in this study and elite male 30-meter fly start times, t (15) = 11.89, and elite male ground times, t (15) = 5.93, all ps < 0.05. The data revealed that male participants in this study had a slower 30-meter fly time (M = 3.26, SD = 0.20) when compared with the elite male 30-meter fly time of 2.68 seconds and elite male ground time of 0.085 seconds, respectively. No statistical significant difference was found between male participants in this study and elite male average air times during a 30-meter fly run, t (15) = 1.64, $p > 0.05$. Male (M = 0.13, SD = 0.14) participants in this study had a similar average air time when compared with the elite male air time of 0.123 seconds.

In order to investigate differences between female and male participants in this study 30-meter performance from a start, Independent sample t-test was calculated. The results of the analyses showed a statistical difference between the male and female average 30-meter sprint starts, t (32) = -7.89, p = 0.00. The males (M = 4.19, SD = 0.15) in this study performed better than the females (M = 4.54, SD = 0.12) on the 30-meter sprint start.

Further statistical test investigating differences between male and female participants 30-meter fly performance showed statistical significant difference, t (32) = -6.35, p = 0.00. Again, the male (M = 3.26, SD = 0.20) participants in this study performed better than the female (M = 3.67, SD = 0.18) on the 30-meter fly run. Similarly, significant difference was found between male (M = 0.10, SD = 0.01) and female (M = 0.11, SD = 0.01) participants ground time during a 30-meter fly run, t (32) = -2.70, $p < 0.05$. Thus, the male participants performed better than the females. No statistical significant difference was found between male and female participants on the 30-meter fly run.

3.3 Ethnicity

In order to investigate the differences among participants ethnicity and 30-meter sprint start times, separate One Way Anova's were calculated. Results showed no statistical significant difference among ethnicity and the average 30-meter sprint start time, F (3 30) = 0.477, $p > 0.05$, ethnicity and the average 30-meter fly time, F (3 30) = 0.638, $p > 0.05$, ethnicity and the average air time during a 30-meter fly run, F (3 30) = 0.244, $p > 0.05$, and ethnicity and the average ground time during a 30-meter fly run, F (3 30) = 0.351, $p > 0.05$. Thus, participants' ethnicity does not affect sprint performance.

4. Discussion

The purpose of a successful 100-meter sprint performance is to cover a required distance in as short a time as possible. There are limiting factors that exist in any human performance event, and those limitations must be identified and taken into consideration to gain a better understanding of what makes a great sprint performance.

All the female and male participants in this study failed to approach the elite 30-meter sprint start values of 4.15 seconds for the women and 3.95 seconds for the men. The time of year this study was conducted might be a possible reason for this poor performance. In the United States, athletes are expected to peak for important competitions during the months of May through July. The participants in this study were tested in December when their best starting abilities were not quite peaking and the amount of acceleration work might not be sufficient to ensure best starts over 30 meters.

The results of the 30-meter fly sprint indicate that male and female participants were 13% and 14% slower than the elite. Plausible reasons for the slower fly runs could be the poor acceleration through the fly zone (the 20-meter acceleration zone used before hitting the top speed 30-meter zone) and top speed posture which can negatively affect overall technical competency. Few high sprinters have enough experience running fly sprints, so had this testing been done after a period of adaptation to the test demands, may be the 30-meter fly sprints could have yielded better results.

The similarity in the 30-meter fly sprint air time measurements between participants in this study and the elite athletes confirm findings in the literature. Hunter and McNair (2004) [6] and Mann (2007) [13] indicated that air time values seldom change significantly between elite and less successful sprinters. Air times for both male and female participants in this study were within acceptable levels almost matching the elite sprinters. This finding indicates that air time is not a significant factor in determining sprint times.

Ground time, however, is a limiting factor in that high force application within a short time frame is the primary speed quality. Both male and female participants in this study had ground times longer than the elite athletes. The fact that these study participants were not in peak sprint condition did have some effect on the ground time. However, superior ground times are an indication of efficient and powerful force application requiring the need for strength and power training by the less successful sprinter. Whether a sprinter has a superior acceleration or fly speed ability, the ground time connects both phases of the sprint resulting in an elite or world class performance. Therefore, superior sprint performance comes from athletes that minimize any performance limitations, but more importantly, ground time.

With that in mind, the questions of what to coach, when to coach it, how to coach it, and why you coach certain elements of speed development can be more easily addressed with ground time being the most significant training goal. Often coaches measure their successful training regimens by whether or not the sprinter runs fast. This investigation changes that notion. Sprint coaches should depend on quantifiable means and methods of assessing talent, training compatibility and outcomes. By understanding starting speed effectiveness (dealing with starting strength and energy expenditures), as well as flying speed efficiencies (maximum speed efficiency and technical competency), a coach now has a blue print that acts as a road map guiding the coach and the sprinter from the beginning of the training year through the competition and championship phase.

5. Conclusion

Findings from this study serve as a baseline for athletes and coaches to compare the numerical and statistical analysis of the variables associated with how some can run fast while others cannot. Once the variables to elite sprinting have been identified, a task specific training periodization can be applied and can enable a sprinter to exploit their physical and genetic potential. In addition, the sprinter must deal with the variances of size, strength, power, and the willingness to train at a level representative of elite success. The final piece to the puzzle is to procure a coach whose understanding and knowledge base concerning successful sprinting will enable the sprinter to achieve optimum sprint efforts. It is for the later that this study was undertaken: in an effort to afford coaches the tools to bring their sprinter to peak performance with capacity for world class performance.

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