CHANGES IN STEP CHARACTERISTICS BETWEEN THE MAXIMUM VELOCITY AND DECELERATION PHASES OF THE 100 METRE SPRINT RUN

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In a 100 m sprint race, athletes are unable to maintain their maximum velocity through the finish line. The aim of this study was to investigate the contributions of step length and step frequency to changes in velocity as athletes decelerate. Nine well-trained sprint athletes each performed between three and five maximal 100 m sprints. Velocity, step length and step frequency were measured for individual steps in the maximum velocity (30-40 m) and deceleration (70-80 m) phases. On a group level, velocity and step frequency reduced between the maximum velocity and deceleration phases ($p < 0.05$), whereas step length did not. Individual athlete analyses revealed that the fastest sprinters tended to maintain velocity in the deceleration phase by combining a significant reduction in step frequency with a significant increase in step length.

KEYWORDS: athletics, track and field, step length, step frequency, velocity, kinematics

INTRODUCTION: A sprint race, such as the 100 m, will be won by the athlete that maintains the highest average velocity throughout the race. The average velocity might be improved by increasing the initial rate of acceleration, achieving a higher maximum velocity, or reducing the amount of deceleration towards the end of the run. Recent evidence suggests that even in the current men's 100 m World Record performance (9.58 s), the athlete in question was not able to maintain maximum velocity to the end of the race (Helene & Yamashita, 2010). Furthermore, analyses of elite sprinters competing in a National Championships showed that deceleration might begin soon after the mid-point of the race (Gajer et al., 1999). Achieving an understanding of the changes in technique that occur as an athlete moves from maximum velocity to the deceleration phase of a sprint might help the biomechanist and coach to work proactively to diminish their effects on athletes' performance.

Previous studies of elite sprinters in 100 m competition have divided the race into 10 m sections, and measured mean velocity, step length (SL) and step frequency (SF) in each section. Results showed that as velocity began to decrease towards the end of the run, there was generally a large decrease in SF, coupled with a smaller decrease in SL (Ae et al., 1992; Gajer et al., 1999). In the last 10 m section, SL values tended to return to the values that they had shown at maximum velocity (Gajer et al., 1999). Other research has investigated the deceleration phase of a sprint in the 400 m (Sprague & Mann, 1983; Nummela et al., 1992), in the 100 m in Masters athletes over the age of 35 (Korhonen et al., 2003), and from a theoretical perspective (Ward-Smith, 2001). Furthermore, Morin et al. (2006) studied eight athletic males performing the 100 m and reported a significant decrease in velocity in the last 20 m, but no decrease in SF, and SL was not presented in that study.

To the knowledge of the authors, there is currently no published research that has investigated the step-by-step differences in velocity, SL and SF between the maximum velocity and deceleration phases of a 100 m sprint in well-trained senior sprinters. The aim of this study, therefore, was to develop an understanding of the contributions of SL and SF to changes in velocity as an athlete decelerates in a 100 m sprint.

METHODS: Data collection: Nine experienced university- to national-level track and field athletes (mean & SD: age = 20.6 ± 2.8 years, height = 1.80 ± 0.07 m, body mass = 77.3 ± 11.3 kg) gave written informed consent to participate, after institutional ethical approval was granted. The athletes were sprinters, hurdlers and horizontal jumpers who regularly partook in sprint running as a part of their training. The subjects reported no recent injuries, and were fit and healthy at the time of data collection, which took place in an indoor athletics centre. Athletes were required to undertake their own warm-up. Data collection was carried out on a

100 m sprint straight, with motion analysis information captured within two 10 m windows, at 30-40 m and 70-80 m along the straight. These represented the maximum velocity and deceleration phases of the sprint run. In each data capture window, two Codamotion CX-1 scanners (Charnwood Dynamics, UK), operating at 400 Hz, were aligned 6.0 m apart and 4.2 m from the centre of the lane of interest on the track, to give a field of view of 10.0 m of the right lateral aspect of the subjects in the direction of the run. Active CODA markers were attached to the lateral aspect of the fifth metatarsal head on the right foot and the medial aspect of the first metatarsal head on the left foot. Trials were initiated with a conventional starting command, and athletes were instructed to sprint maximally for 100 m. Three to five successful trials per athlete were gathered, after each of which normal training recovery was allowed. In total 95 steps were recorded from 30-40 m and 97 steps from 70-80 m.

Data Processing: The three-dimensional coordinate data (x-mediolateral, y-anteroposterior and z-vertical) were low-pass filtered at 20 Hz. Individual steps were identified in each trial using the vertical acceleration data of the toe marker of the initial touchdown leg to identify initial ground contacts (Bezodis *et al.*, 2007). A single step was defined between contra-lateral foot touchdown events, and was identified as either left [L] or right [R] according to the leg initiating ground contact during that step cycle. Step characteristic variables for the straight runs were determined for each individual step as follows: Step length [SL = y displacement between successive touchdown foot marker locations], step frequency [SF = 1/time between successive touchdowns] and step velocity [SV = SL*SF].

All data were checked for normality. For each individual, an independent t-test assuming unequal variances was used to test for differences in SL, SF and SV between all steps measured in the maximum velocity and deceleration phases. Steps were then grouped for each athlete according to phase, and mean and standard deviation of SL, SF and SV were calculated. The percentage changes in each mean value for each individual from the maximum velocity to deceleration phase were also calculated. A dependent samples t-test was then used to test for differences between mean SL, SF and SV values in the maximum velocity and deceleration phases across all athletes. The statistical significance level was set *a priori* to $\alpha = 0.05$.

RESULTS: As a group, step velocity significantly decreased from 9.42 to 9.17 m/s from the maximum velocity to the deceleration phase of the sprint (Table 1). Mean step frequency also significantly decreased from 4.40 to 4.25 Hz between the two phases, whilst there was no change in step length (2.15 to 2.17 m).

Table 1
Step frequency, step length and step velocity in the maximum velocity and deceleration phases of the 100 m sprint, and percentage change from the maximum velocity to the deceleration phase

Athlete	Step Frequency [Hz]			Step Length [m]			Step Velocity [m/s]		
	30-40 m	70-80 m	% Diff.	30-40 m	70-80 m	% Diff.	30-40 m	70-80 m	% Diff.
1	4.86	4.72	-2.8	1.91	1.84	-3.7*	9.28	8.68	-6.4*
2	4.06	3.81	-6.1*	2.44	2.56	4.6*	9.91	9.74	-1.7
3	4.19	4.09	-2.3*	2.18	2.19	0.6	9.13	8.97	-1.7*
4	4.21	4.13	-2.0*	2.13	2.14	0.6	8.96	8.83	-1.4*
5	4.28	4.25	-0.6	2.14	2.13	-0.5	9.16	9.06	-1.1*
6	4.43	4.28	-3.5*	2.25	2.31	3.0*	9.96	9.89	-0.7
7	4.57	4.41	-3.4*	1.98	1.98	0.0	9.04	8.73	-3.4*
8	4.80	4.48	-6.5*	2.01	2.05	2.4*	9.63	9.21	-4.3
9	4.24	4.12	-2.9*	2.29	2.28	-0.6	9.72	9.38	-3.5*
Mean	4.40	4.25	-3.4*	2.15	2.17	0.8	9.42	9.17	-2.7*

(* = p <0.05)

Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

On an individual athlete level, six athletes showed a significant decrease in velocity between the maximum velocity and deceleration phases, whilst the remaining three showed no change. Seven athletes had a significantly reduced step frequency later in the run, whilst two displayed no change. One athlete significantly reduced step length from the maximum velocity to the deceleration phase, whilst three others significantly increased their step length and the remaining five athletes revealed no change in step length.

DISCUSSION: The aim of this study was to develop an understanding of the contributions of SL and SF to changes in velocity as an athlete decelerates in a 100 m sprint. This study found that whilst SV and SF decreased between the maximum velocity and deceleration phases of the sprint in the group of athletes, there was no change in SL. However, as can be seen from the results (Table 1), the relative contributions of SL and SF varied depending upon whether the data were analysed on a group or individual athlete level.

At the group level, the decrease found in this study in SV and SF between the maximum velocity and deceleration phases and relative maintenance of SL were similar to those reported by Korhonen et al. (2003) in a group of Masters athletes and Gajer et al. (1999) in a group of national level sprinters. Both of those studies calculated step characteristics as mean values within 10 m sections of the sprint, rather than from individual steps, as was the case here. Morin et al. (2006) found velocity to decrease from maximum velocity to 80-100 m, but reported no change in SF in the last 20 m of the sprint in a group of physical education students. Results presented by Gajer et al. (1999) and Korhonen et al. (2003) showed that SL tended to increase in the last 10-20 m of the run. Due to restrictions in data capture volume, the last 20 m of the sprint was not analysed here, although it is possible that SL might have increased in the athletes tested here towards the end of the run. It should also be noted that data from this study were gathered in a training situation, whereas those presented in Gajer et al. (1999) and Korhonen et al. (2003) were gathered in competition, where athletes' dipping at the finish line in order to minimise their finishing time may have influenced technique and therefore the results published.

The current results were analysed on an individual-athlete basis to reveal trends that may have been masked by the grouping of data (Dufek et al., 1995), and when this was done, new patterns became apparent. Six of the nine athletes tested showed a significant decrease in velocity between the maximum velocity and deceleration phases of the sprint. The three athletes who did not show a reduction in velocity in this study were the only three who showed an increase in SL between the maximum velocity and deceleration phases of the sprint (see Table 1). Furthermore, when defined by mean maximum running velocity across all steps, the three athletes whose SV did not decrease were three of the four fastest sprinters in this study. It is possible, therefore, that better sprinters are able to mitigate the causative factors of deceleration in a 100 m sprint by adapting their SL to overcome the potential loss of velocity. These three athletes were, however, those that showed the largest percentage decrease in SF from within the sample. If velocity is to remain constant, it is to be expected that an increase in one step characteristic would lead to the concomitant decrease in the other step characteristic, due to their negative interaction (Hunter et al., 2004). It is possible that there is an underlying mechanism within a 100 m sprint whereby the trade-off of a reduction in SF combined with an increase in SL is the most effective method of maintaining velocity at near maximum levels. Further investigation of sprint technique in the different phases of the run, including analyses of joint kinematics and kinetics would be necessary to provide further explanation of, or evidence for, this potential mechanism. Also of note here is that the only sprinter who showed a significant decrease in SL between the maximum velocity and deceleration phase of the sprint was the athlete whose reduction in velocity between those two phases was the greatest in percentage terms.

Since, at present, even the best athletes in the world are not able to maintain maximum velocity throughout a 100 m sprint (Helene & Yamashita, 2010) it is important to try to understand the technique factors that contribute to the reduction in velocity. Doing so would allow coaches and biomechanists to attempt to proactively develop technique in sprinters in order to attempt to reduce the amount of deceleration commonly seen in sprint races.

CONCLUSION: Group level data presented here suggest that in the deceleration phase of a 100 m sprint, athletes lose velocity due to a decrease in step frequency. Individual analyses suggested, however, that the fastest sprinters were able to maintain their velocities by combining a relatively large decrease in step frequency with an increase in step length. The mechanisms underlying this strategy require further investigation in order to be fully understood.

REFERENCES:

Ae, M., Ito, A., & Suzuki, M. (1992). The Scientific Research Project at the III World Championships in Athletics: Preliminary Reports: The Men's 100 metres. *New Studies in Athletics, 7(1),* 47-52.

Bezodis, I.N., Thomson, A., Gittoes, M.J.R., & Kerwin, D.G. (2007). Identification of Instants of Touchdown and Take-Off in Sprint Running Using an Automatic Motion Analysis System. In H.-J. Menzel and M.H. Chargas (Eds.), *Proceedings of the XXVth Symposium of the International Society of Biomechanics in Sports* (pp 501-504). Ouro Preto, Brazil. ISBS.

Dufek, J.S., Bates, B.T., Stergiou, N., & James, C.R. (1995). Interactive effects between group and single-subject response patterns. *Human Movement Science, 14,* 301-323.

Gajer, B., Thépaut-Mathieu, C., & Lehénaff, D. (1999). Evolution of stride and amplitude during course of the 100m event in athletics. *New Studies in Athletics, 14(1),* 43-50.

Helene, O., & Yamashita, M.T. (2010). The force, power, and energy of the 100 meter sprint. *American Journal of Physics, 78(3),* 307-309.

Hunter, J.P., Marshall, R.N., & McNair, P.J. (2004). Interaction of step length and step rate during sprint running. *Medicine and Science in Sports and Exercise, 36,* 261-271.

Korhonen, M. T., Mero, A., & Suominem, H. (2003). Age-related differences in 100-m sprint performance in male and female master runners. *Medicine and Science in Sports and Exercise, 35(8)*, 1419-1428.

Morin, J.-B., Jeannin, T., Chevallier, B., & Belli, A. (2006). Spring-mass model characteristics during sprint running: Correlation with performance and fatigue-induced changes. *International Journal of Sports Medicine, 27(2)*, 158-165.

Nummela, A., Vuorimaa, T., & Rusko, H. (1992). Changes in force production, blood lactate and EMG activity in the 400-m sprint. *Journal of Sports Sciences, 10,* 217-228.

Sprague, P., & Mann, R.V. (1983). The Effects of Muscular Fatigue On the Kinetics of Sprint Running. *Research Quarterly for Exercise and Sport, 54(1),* 60-66.

Ward-Smith, A. J. (2001). Energy conversion strategies during 100 m sprinting. *Journal of Sports Sciences, 19(9),* 701-710.

Acknowledgements

This work was funded by EPSRC grant number EP/D076943.