A CASE STUDY OF MAXIMUM VELOCITY SPRINT RUNNING PERFORMANCE AND TECHNIQUE CHANGES WITHIN AN ELITE TRAINING GROUP

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The purpose of this study was to identify the effect of a structured training programme on sprint performance and technique in three individual experienced sprinters. Velocity, step length, step frequency, temporal variables and segment angles were gathered from 50 m maximal sprints before and after two high volume four-week training blocks. Participant-specific analyses revealed that athletes' performance responded differently to training. Changes in velocity between sessions were attributable to different underlying variables across athletes, which matched with expectations based upon coaching observations. These findings have important implications for the design of sprint training programmes and for the timing of applied biomechanical data collection sessions for the purpose of analysis and feedback to coaches and athletes.

KEY WORDS: coaching knowledge, step frequency, step length, track and field, training

INTRODUCTION: Sprint running velocity is the product of step length (SL) and step frequency (SF). It has been shown that there is a negative interaction between SL and SF in maximal sprinting, where the increase in one variable tends to cause a decrease in the other (Hunter et al., 2004), and the athlete needs to optimise the interaction of SL and SF to maximise performance. To date, there is little consensus in the literature regarding the relative importance of SL and SF to velocity. Various studies have shown that SL is the most important contributor to performance (Gajer et al., 1999), SF is the most important (Ae et al., 1992) or that neither SL nor SF relate to performance (Debaere et al., 2013). However, these studies have taken a group-based approach to research design. Evidence has been published that athlete-specific responses to changes in velocity exist regarding associated changes in SL and SF (Bezodis et al., 2008; Bezodis et al., 2011; Salo et al., 2011).
A recent review (Bolger et al., 2015) highlighted the lack of research investigating the effect of resistance-based training programmes on sprint performance in trained athletes. In order to develop effective training programmes for sprinting it is important to understand the effects of all training programme components both in an acute and a chronic manner, so that athletes can perform effectively in competition and reach peak performance at the desired point in the season, based on the principle of periodisation (Bompa & Haff, 2009). The aim of this study was to identify whether athletes' performance changed after a period of training, and if so to investigate the biomechanical variables that underpinned that change.

METHODS: Data Collection: Three male sprinters (22.5 ± 4.4 years, 78.5 ± 9.3 kg, 1.821 ± 0.061 m, 100 m PB = 10.74 ± 0.12 s) gave written informed consent to participate after institutional ethical approval. The athletes were fit and healthy at the time of data collection and engaged with formal sprint coaching throughout the study. Two data collection sessions were conducted in an indoor athletics centre, 'collection one' in mid-March (end of the indoor season) and 'collection two' in mid-May (early in the outdoor season). Athletes performed their own, coach-directed warm-up. Testing took place during scheduled training sessions, and athletes performed five maximal 50 m sprints from blocks, with the exception of P03, who performed three trials at collection two. Five mini DV cameras (1 x Z5, 2 x Z1, 2 x A1E, Sony Corporation, Japan) were used to record the whole sprint as a part of a larger study. Cameras were set up 19 m from the running lane, perpendicular to the sprint direction, with overlapping 12 m horizontal fields of view creating a 52 m total volume. The cameras recorded in high definition (1440 x 1080 pixels) at 50 Hz, with an open iris and 1/600 s shutter speed. Cameras were calibrated with a 9-18 control point frame, to create five adjoined 10.00 x 2.17 m volumes. An additional camera (Z5, Sony Corporation, Japan) was placed perpendicular to the 30 m mark of the sprint, 5 m above the track and 40 m from the sprint lane. This camera recorded in high definition (1440 x 1080 pixels) at 200 Hz, with an open iris and 1/600 s shutter speed, and was panned to follow the athlete throughout the sprint. All cameras were synched with 20 sequentially illuminating LEDs (Wee Beastie, UK).

Data Processing: Video images were extracted using Dartfish Team Pro 6.0 (Dartfish, Switzerland), then converted to .avi format and de-interlaced in VLC 2.1.3 (VideoLan, France). They were then imported into Matlab (version R2014a, MathWorks Inc., USA) and digitised using the open source DLTdv5 package (Hedrick, 2008). The panning camera footage was used to identify the instants of touchdown and take-off at each ground contact by digitising a single point in the relevant frame. The exported .csv files were processed in a custom-written Matlab function to identify touchdown event times, as well as contact, flight and step times for each step. Touchdown events were synchronised with the static cameras, for which three frames around touchdown were digitised at each contact using an 18 point whole-body model. Digitised trials were exported as .csv files and reconstructed in Matlab using an open source 2D DLT camera calibration and point reconstruct function (Meershoek, 1997) which was modified to include lens correction (Walton, 1981). Reconstructed coordinates were then processed using a custom-written Matlab function. Centre of mass (CM) position was calculated based on de Leva (1996), with foot segment data taken from Winter (2005) and the mass of each athlete's running spike added. The following variables were calculated at the instant of touchdown of each step: CM horizontal position, horizontal position of the toe of the ground foot, horizontal displacement between the toe and CM (TD distance), and segment angles relative to the horizontal of the trunk and shank. Segment angles were plotted by step throughout the whole trial and smoothed using a 3-point moving average. Temporal and CM variables were then used to calculate the following step-based values: step velocity – the CM horizontal displacement between consecutive touchdowns divided by the step time; step length (SL) – the horizontal displacement of the toe markers between consecutive touchdowns; step frequency (SF) – step velocity divided by SL.

Data were grouped and analysed on a within-athlete, between session-basis. All data were checked for normality, then an independent samples t-test, or Mann-Whitney U test, as appropriate was conducted for each variable to test for significant between-session differences. The alpha level was set *a priori* to $p < 0.05$. Effect sizes were calculated using Cohen's d (>0.2 = small effect, >0.5 = medium effect, >0.8 = large effect). Athletes' training programmes and competiton schedules were documented and used in the analysis to assist with understanding and explaining the changes that were observed, along with qualitative coaching observations of changes in technique.

RESULTS AND DISCUSSION: Only one of the three athletes ran faster at collection two than collection one (Table 1). P01 showed a large and significant increase in velocity, from 9.77 to 9.93 m/s, accompanied by a significant and moderate increase in SL of 0.06 m and a negligible decrease in SF of 0.03 Hz. P02 decreased in velocity from 10.54 to 10.37 m/s, accompanied by a small and non-significant increase in SL of 0.02 m and a moderate and significant decrease in SF of 0.12 Hz. P03 displayed a moderate, non-significant decrease in velocity from 10.50 to 10.45 m/s, which was accompanied by a small decrease in SL (0.03 m, ES = 0.27) and a negligible increase in SF (0.02 Hz, ES = 0.13), both non-significant.

During the indoor season, prior to collection one, training was focused on maximising competitive 60 m performance, explaining the high velocities of P02 and P03 in March. P01 had been injured in the indoor season and returned to training two weeks before collection one. Between the two testing sessions the athletes underwent two high volume four-week training blocks, comprising a markedly increased volume of lifting work, a greater number of specific endurance sessions and reduced focus on speed work. Ten days prior to collection two, all three athletes took part in the outdoor national university championships, which coincided with the end of the high volume loading phase. This was followed by a recovery week before collection two. Following collection two the athletes undertook two three-week race preparation training blocks with reduced volume and increased intensity. The training programme for P02 and P03 was designed for them to peak for the national under 23 championships in late June, where both ran 100 m PBs, taking 0.29 and 0.26 s from previous bests, respectively.

Table 1: Mean ± standard deviation of step characteristics, temporal variables and segmental kinematics for each athlete at collection one (March) and collection two (May). Within-athlete, between-session effect sizes (ES) are also presented.

Variable	P01			P02			P03		
	March	May	ES	March	May	ES	March	May	ES
Number of steps recorded	25	23		22	22		20	12	
Step velocity [m/s]	9.77 ±0.12	9.93 ±0.16	0.98*	10.54 ±0.10	10.37 ±0.07	1.42*	10.50 ±0.08	10.45 ±0.08	0.57
Step length [m]	2.21 ±0.06	2.27 ±0.07	0.72*	2.26 ±0.07	2.28 ±0.07	0.25	2.31 ±0.10	2.28 ±0.05	0.27
Step frequency [Hz]	4.42 ±0.15	4.39 ±0.17	0.19	4.67 ±0.14	4.55 ±0.15	0.75*	4.56 ±0.19	4.58 ±0.09	0.13
Contact time [s]	0.105 ±0.003	0.102 ±0.004	0.76*	0.093 ±0.004	0.093 ±0.004	0.06	0.096 ±0.004	0.095 ±0.004	0.33
Flight time [s]	0.121 ±0.007	0.127 ±0.006	0.86*	0.122 ±0.005	0.126 ±0.006	0.73*	0.122 ±0.010	0.122 ±0.005	0.02
Step time [s]	0.226 ±0.009	0.229 ±0.008	0.36	0.215 ±0.006	0.219 ±0.007	0.64*	0.218 ±0.009	0.217 ±0.005	0.19
TD distance [m]	0.42 ±0.05	0.40 ±0.05	0.52	0.40 ±0.06	0.36 ±0.04	0.84*	0.33 ±0.05	0.36 ±0.03	0.64
Trunk angle [°]	85.5 ±2.0	87.4 ±1.2	0.97*	85.0 ±1.3	83.4 ±1.4	1.02*	82.6 ±1.7	84.8 ±1.1	1.20*
Shank angle [°]	97.5 ±2.8	96.5 ±3.0	0.36	98.0 ±2.1	93.6 ±1.4	1.54*	88.9 ±1.3	89.2 ±2.1	0.23

(* = p <0.05)

For P01 the increases in velocity and SL between sessions were accompanied by a moderate and significant decrease in contact time of 0.003 s and a large and significant increase in flight time of 0.006 s. Previous research has shown that athlete's velocity can be individually reliant on either SL or SF (Salo et al., 2011), and evidence presented here suggests that P01 increased velocity by increasing SL, whilst reducing contact time. This is supported by coaching observations that the athlete tends to reduce contact time when running faster as the necessary forces are created at a greater rate. These observations can be supported by empirical measurements taken as a part of future research.

The decrease in velocity for P02 and P03 can be explained by the timings of the data collections within the season, as previously shown by Bezodis et al. (2008). Collection two closely followed two high volume training blocks, and return from a training camp which induced considerable jet lag, but preceded the specific race preparation blocks. Therefore, those athletes participated in the collection in a relatively fatigued state. Future research will coincide data collections with the latter stages of race preparation blocks to measure performance at the local maximum. There is a need to work closely with coaches to ensure that cycles of training are considered when collecting and analysing data and giving feedback. For P02 the decreases in velocity and SF between sessions align with coaching observations that the athlete is reactive and particularly reliant on SF for high performance. The reduction in TD distance at collection two might be explained by the athlete bringing the contact foot closer to the CM in an attempt to maintain SF to overcome fatigue. The contrasting responses of the three athletes studied here regarding performance and underlying step characteristics provides further information to support previous evidence (Salo et al., 2011) that individual athletes can be reliant on either SL or SF when performing at maximum velocity. Further research is required to investigate and fully understand the mechanisms that underlie this.

CONCLUSION: This study identified that individual athlete's performance responds differently to training, and that changes in performance are not consistently matched by changes in SL and SF across a group of athletes, even with the same coach. Careful consideration should be given to the timing of data collections with elite athletes to ensure that measurements taken are reflective of the desired level of performance relative to peak.

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