# A LONGITUDINAL CASE STUDY OF STEP CHARACTERISTICS IN A WORLD CLASS SPRINT ATHLETE

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The relative importance of step length (SL) and step frequency (SF) to maximum velocity sprinting is not yet fully understood. One elite male sprinter was studied during five months of training. Step velocity, SL and SF were calculated from 50 Hz video, using manual digitization and 2D DLT, for a total of 113 steps taken from the maximum velocity phase of training sprints. Mean values were calculated for each session and tracked against training diary information gathered from the athlete's coach. Chronological information showed that as the athlete's training progressed, a link between velocity and SF was maintained whilst mean session SL remained relatively unchanged throughout. For the athlete studied, changes in step velocity as a result of training were shown to occur as a consequence of changes mainly in SF.

**KEY WORDS:** track and field athletics, velocity, step length, step frequency

## INTRODUCTION:

Velocity is the product of step length (SL) and step frequency (SF). At submaximal velocities the relationship between SL and SF is readily acknowledged, with SL increasing more at lower velocities and SF more at higher velocities (Luhtanen and Komi, 1978; Kuitunen et al., 2001). At maximum velocity, however, findings are inconsistent across published data. Mero and Komi (1985) and Gajer et al. (1999) suggested that SL was the most important contributor to velocity and therefore sprint performance, whilst Mann and Herman (1985) and Ae et al. (1992) suggested that it was SF that was more important. Hunter et al. (2004) studied the performance of 28 male sportsmen at the 16 metre mark of a maximal sprint acceleration. As a group, SL was significantly related to velocity, although SF was not. However, an intra-subject analysis showed that there were no significant differences in SL between the fastest and third fastest trial for each subject, whilst SF was significantly greater in the fastest trial. It is clear that, at or near to maximum velocity, the relationship between SL and SF is not yet fully understood on an individual athlete basis. A longitudinal study during preparation for a competitive season, with training plan information, provides a novel opportunity to examine the relationship between these variables. Thus the primary purpose of this study was to understand SL-SF relationships in an elite athlete when sprinting velocity varied during a training season.

## METHODS:

**Data collection:** One world class male sprinter (height = 1.76 m, mass = 75.0 kg, age = 29 yrs, 100 m personal best = 9.98 s) gave written informed consent to participate in this study. The subject was fit and healthy for the duration of data collection, and reported no recent injuries. A total of ten data collection sessions were conducted at an indoor sprint track between the competition phase of the indoor season (late February) and the early competition phase of the subsequent outdoor season (late June).

Two digital cameras (Sony DCR-TRV 900E) were mounted on the wall 6.40 m apart, 4.25 m above track level and 7.20 m from the centre of the lane in which trials took place. Each camera was set up with a shutter speed of 1/600 s and a field of view of 6.2 m in the lane of interest. There was a 2.5 m overlap of the two cameras' views at the centre of the global field of view. The cameras were separately calibrated using six control points in each of two orthogonal planes. These were a 6.00 x 1.17 m transverse plane at track level, for the determination of SL, and a 5.50 x 2.06 m sagittal plane at the centre of the lane, for the determination of velocity. Data were collected during the course of the subject's normal training sessions, where the athlete was performing 'speed work'. Sessions typically comprised six to eight runs in the early spring and three to four runs by late spring. Video images of the runs were recorded during the maximal velocity phase of a sprint. The start of the combined 9.5 m field of view of the two cameras was at least 40 m from the start of the sprint. The subject was allowed normal training recovery after each run. Photocell times were used on most occasions to give coaching feedback to the athlete immediately after each run.

**Data Processing:** Video data were imported into Target (Loughborough Innovations Limited, UK) for digitising. The last field before touchdown and the first field after touchdown were digitised for each contact. A 20-point model of the human body was used, with inertia data based on de Leva (1996), apart from the foot segment, for which Winter's data (2005) were used, with an extra 200 g added to account for the mass of the running spike (Hunter *et al.*, 2004). The toe of the ground foot was independently digitised three times during the first field after touchdown to minimise error in the calculation of SL. Digitised trial sequences were reconstructed using a 2D DLT routine (Walton, 1981). Calculation of variables for each individual step was always carried out with the data gathered from a single camera, ensuring that the respective calibration was used, i.e. no step variables were calculated from mixed views. Depending on the location of foot contacts within the combined field of view, either three or four steps per trial were analysed giving a total of 113 steps in this study.
Step lengths were calculated by subtracting the mean of the three reconstructed contact foot toe locations from one contact in the direction of the run from the corresponding mean contact foot toe location of the contralateral foot at the next contact. Step velocity (average CM velocity across the whole step) was calculated as the difference between the mean CM displacements from the two digitised fields at two consecutive contacts divided by the time between them. SF was calculated by dividing the step velocity by the SL. Further details of the calculations can be found in Bezodis *et al.* (2008). Mean values for step velocity, SL and SF were calculated for each individual training session. Training plan information was retrospectively gathered by interviewing the athlete's coach.

**RESULTS:**
Step velocity, SL and SF from each measured step are displayed in Figures 1a and 1b. Step velocity ranged from 9.65-11.23 m/s, SL from 2.12-2.38 m and SF from 4.12-5.05 Hz. A chronological representation of step velocity, SL and SF and training phase information is given in Figures 2a and 2b. The two fastest sessions, by mean step velocity, occurred on days 31 and 145, when mean SF was also at its highest. Day zero is the day of the first competitive 60 m performance of the athlete during the indoor season. Comparisons against known locations on the track surface and repeat digitisations in the horizontal plane revealed SL errors of ± 0.01 m. Comparisons of sagittal plane results to sequences in which all fields were digitised revealed velocity errors of ± 0.01 m/s, and hence errors in SF of ± 0.01 Hz.

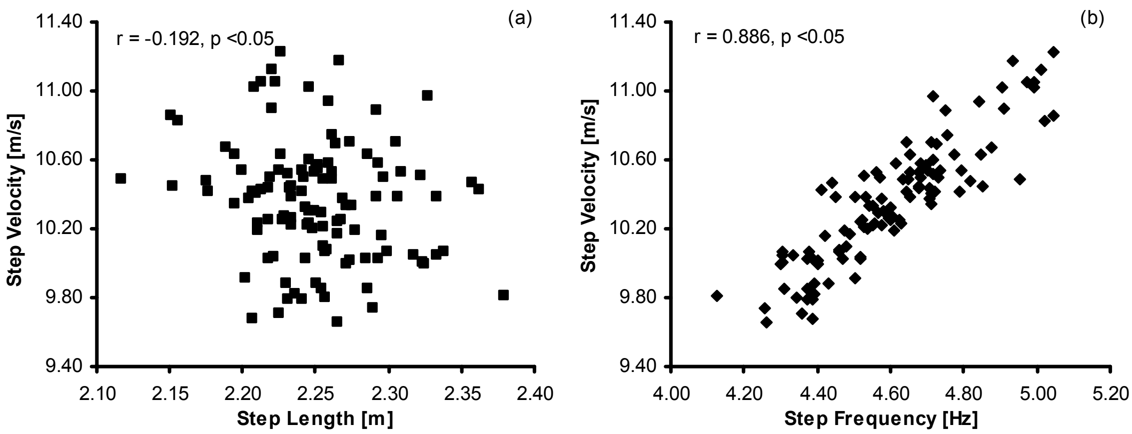


**Figure 1: Step velocity against (a) SL and (b) SF for all measured steps**

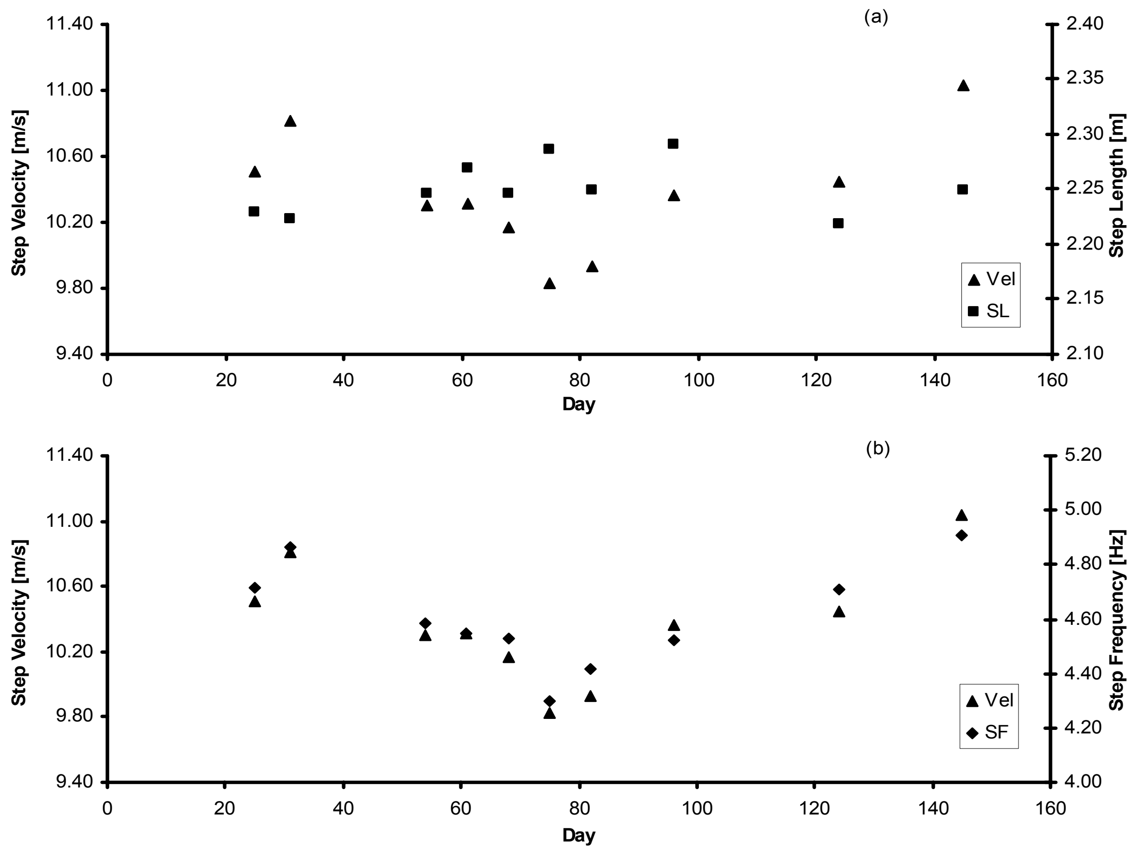


**Figure 2: Chronological representation of (a) mean step velocity and SL; and (b) mean step velocity and SF for each individual training session.**

**DISCUSSION:**

The data displayed in Figure 1 clearly shows that, for the specific sprinter studied, step velocity was positively related to SF but not SL. Additional chronological information shown in Figure 2 shows that as the athlete's training progressed between competitions, the link between velocity and SF was maintained, whilst mean session SL remained relatively unchanged throughout. The athlete studied had a relatively high maximum SF and low maximum SL compared to other elite sprinters (e.g. Mann and Herman, 1985; Ae et al., 1992), which could in part be due to this athlete's relatively small stature. Previous cross-sectional studies have published differing conclusions regarding the importance of SL and SF to sprint velocity and, partly due to methodological inconsistencies, debate on the relative significance of these two variables is ongoing. However, Hunter et al. (2004) speculated that a longer SL is achieved through long term development of strength and power whilst SF may be the more decisive short term factor in developing greater velocity. Detailed examination of the training plan of the athlete throughout the time these data were gathered gives a greater insight into concurrent changes in velocity and SF that occurred due to the training plan.

The athlete measured in this study won the European Indoor Championships 60 m in a time of 6.55 s on day 35. Training during the period from day zero to day 35 was centred on 'speed', with running sessions being low volume but high intensity. After two weeks of light training, on day 50 the athlete returned to basic training. This typically comprised two high volume (4 exercises x 3 sets x 6 reps x 75% max) and one pyramid (to increase maximum strength) lifting sessions per week. There were also three running sessions per week; one interval session emphasising endurance, one speed session and one speed endurance session. The residual effects of the indoor competition season were still seen in this period, with the velocity gradually decreasing to its lowest value in the last session in this period.

From day 78 to 98 training developed in preparation for the outdoor competition season, with a reasonable volume maintained, but focus shifted more towards maximum weights and

specific high intensity sprinting. In the two sessions recorded in this period there is a trend of velocity and SF increasing. After this period, up to day 126, specific competition preparation training was undertaken. This involved one or two lifting and three running sessions per week, all centred on speed. The influence of the shift from lifting to rapid leg work during running sessions can be seen in the velocity and SF increase in the session monitored during this period. From day 127 on, the competition season was underway, and training was based initially on preparing for the National Championships on day 161. Weekly training included one session of lifting plus a short circuit and three running sessions, again focused on speed. The effect of this training can be seen in the highest velocity and SF measured in this study on day 145. The athlete recorded a 100 m time of 10.13 s on day 136.
The clear relationship between SF and velocity throughout the sessions measured in this study, and the link with the content of the training plan showed that, for the athlete studied, focus on speed work led to the development of higher step frequencies and therefore faster velocities. These results suggest for this athlete the development of a high SF is of greater importance to the attainment of maximum sprinting velocity. This supports the speculation of Hunter et al. (2004) that SF may be the more decisive factor than SL in the short term development of velocity. Further in-depth study of joint kinematics and kinetics would be necessary to understand the mechanisms that cause this relationship.

**CONCLUSION:**
A novel longitudinal approach was used to study the interaction between step velocity, SL and SF in an elite sprinter in context of the training plan used. Changes in velocity as a result of training were shown to occur as a consequence of changes mainly in SF.

**REFERENCES:**

Ae, M., Ito, A. and 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., Kerwin, D.G. & Salo, A.I.T. (2008). Lower-Limb Mechanics during the Support Phase of Maximum-Velocity Sprint Running. *Medicine and Science in Sports and Exercise, 40*, 707-715.
de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*, 1223-1230.
Gajer, B., Thépaut-Mathieu, C. and Lehénaff, D. (1999). Evolution of stride and amplitude during course of the 100m event in athletics. *New Studies in Athletics*, *14*(1), 43-50.
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.
Kuitunen, S., Komi, P.V. and Kyröläinen, H. (2002). Knee and ankle joint stiffness in sprint running. *Medicine and Science in Sports and Exercise*, *34*, 166-173.
Luhtanen, P. and Komi, P.V. (1978). Mechanical factors influencing running speed. In E. Asmussen and K. Jørgensen (Eds). *Sixth International Congress of Biomechanics* (pp 23-29). Baltimore, University Park Press.
Mann, R.V. and Herman, J. (1985). Kinematic Analysis of Olympic Sprint Peformance: Men's 200 Meters. *International Journal of Sport Biomechanics*, *1*, 151-162.
Mero, A. and Komi, P.V. (1985). Effects of Supramaximal Velocity on Biomechanical Variables in Sprinting. *International Journal of Sport Biomechanics*, *1*, 240-252.
Walton, J. (1981). *Close-range cine-photogrammetry: A generalised technique for quantifying gross human motion.* Unpublished Doctoral Thesis. The Pennsylvannia State University.
Winter, D.A. (2005). *Biomechanics and Motor Control of Human Movement*. Hoboken: John Wiley and Sons, Inc.


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