REDUCED 3D MARKER SET TRACKING OF ELITE SPRINT TRAINING

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The purpose of this study was to develop a system to measure step length, step frequency and step velocity variations in elite athlete sprint running. Three CODA CX1 scanners were sited parallel to an indoor running track to record markers on each foot of an elite 400 m athlete sprinting in a straight line and around Lane 1 of a banked track. The goals were to produce a system which could be used routinely in training and would be accurate enough to detect small changes in step kinematics to enable variability in constant speed sprinting to be studied. The system developed was able to produce the desired data, was convenient and could be applied equally to straight and bend running.

KEY WORDS: methodology, step length, step frequency, variability.

INTRODUCTION:

Traditionally, 3D tracking of human movement relies on multiple marker protocols (eg Helen Hayes, CODA) and invariably requires the use of segmental marker clusters with preliminary static or dynamic anatomical calibration. All of these are relevant and appropriate for use in a medical setting to determine a detailed range of gait parameters. When working with elite athletes, routinely logging running gait parameters, although desirable, automatic marker based tracking is not practical with standard marker sets. The alternative, video image based procedures, is very time consuming. In sprinting, step length (SL) and step frequency (SF) characteristics were identified as underlying determinants of sprinting speed and have routinely been studied in sprinting biomechanics (Hunter et al. 2004). When an athlete is accelerating, these two factors vary as speed increases, but what is not known is how much these factors vary when an athlete is running at maximum velocity. By studying elite athletes during training, it should be possible to obtain the necessary information to address this issue, but using standard video techniques would be a very onerous. The purpose of this study was to develop a minimally intrusive system for monitoring step length and step frequency variations for elite athletes during training.

METHOD:

All measurements were made using three linked CODA CX1 (Charnwood Dynamics, Leicestershire, UK) scanners in an indoor athletics centre. Straight and bend running were addressed. Three challenges were presented; (i) selecting a marker set which could describe the parameters accurately; (ii) providing a large enough measurement space to provide sufficient data to be of value for analysing variability in sprint kinematics; and (iii) developing a suitable calibration protocol to accommodate bend running on a banked indoor track. To address the first challenge a marker set which did not impact on the athlete’s performance, was quick to mount and was appropriate to provide the step kinematic data was required. A single CODA marker was secured to the upper surface of the instep on each of the athlete’s running shoes. Each marker’s associated driver box was located on the side of the shoe and directed towards the CODA scanners. To address the second challenge, a non-standard alignment of three CODA CX1 scanners was adopted. They were placed unilaterally at 6 m intervals along the side of an indoor running straight and the calibration files adjusted to allow for the three units to have different origins in the direction of the run. This required manual intervention of the alignment files prior to data collection, but enabled data to be collected over approximately 20 m of the straight track (Figure 1). To calibrate the bend, the banked track was lowered to the horizontal and the three CODA scanners setup inside Lane 1 with the X axis running parallel with the inner line of Lane 3 at the apex of the bend. After calibration, inbuilt hydraulic rams were used to raise the track surface into the normal banked position of 12º. The scanners were able to track data over a range of between 17 m and

19 m depending on which of the four lanes was used. Analysis of the data was initially undertaken manually within the CODA software by inspecting toe coordinates in synchrony with the animated graphics of the foot movement.

Figure 1: Three CODA CX1 scanners alongside running straight capturing toe marker data at 200 Hz

Later for convenience and speed of analysis, a programme, written in MathCad[13]™ (Adept Scientific, UK), was used to automatically determine the required step charactersitics. All data were sampled at 200 Hz for a period of 10 s. Data for any 'out of view' markers were removed, and the remaining coordinate data interpolated using a cubic spline. Next the unique instants when the left and right toe markers crossed during support were selected for each toe and used to define the time and position for each foot contact. Step lengths were determined from the respective differences between left and right toe positions in the direction of run (X). Step fequency was calculated from the recipical of step interval times. Finally the product of these two was used to specify the step velocity (SV). On the straight these calculations were based solely on the changes in the 'X' coordinates. However, for bend running, the movement from step to step in the direction of run was required for comparison with their straight line equivalents. For this purpose a theoretical 'running line', 10 cm beyond the inside running lane line was defined equivalent to the one used for competition distance measurements. The arc length along this line was defined using polar coordinates from the centre of the semi-circle and the radius to the 'running line' for each foot fall. As a demonstration of the system, data on a single international 400 m athlete running the straight and in Lane 1 of the bend have been presented. The athlete completed six straight and six bend runs in a single data collection session with appropriate rests between runs.

RESULTS AND DISCUSSION:

The output of the foot 'X' coordinate profile for a sample trial of the straight run is shown in Figure 2 and, the equivalent for a bend run in Figure 3. Figure 4 shows the MathCad analysis output data set from the trials depicted in Figure 2. In each run the data for the three left and right steps were avearaged and have been presented in Table 1.

Table 1a SL for 6 straight runs showing the mean (±sd) or the left (L) and right (R) legs seperately and combined.

SL (m)	meanL	sdL	meanR	sdR	mean	sd
1	2.237	(0.057)	2.225	(0.082)	2.230	(0.073)
2	2.222	(0.053)	2.213	(0.084)	2.217	(0.073)
3	2.266	(0.092)	2.166	(0.050)	2.223	(0.091)
4	2.231	(0.049)	2.202	(0.052)	2.219	(0.052)
5	2.225	(0.102)	2.192	(0.115)	2.208	(0.110)
6	2.254	(0.069)	2.208	(0.086)	2.231	(0.081)

Table 1b SF for 6 straight runs showing the mean (±sd) or the left (L) and right (R) legs seperately and combined.

SF (Hz)	meanL	sdL	meanR	sdR	mean	sd
1	3.694	(0.070)	3.784	(0.067)	3.745	(0.082)
2	3.727	(0.016)	3.774	(0.050)	3.754	(0.046)
3	3.589	(0.084)	3.847	(0.060)	3.700	(0.148)
4	3.704	(0.024)	3.884	(0.031)	3.781	(0.093)
5	3.740	(0.076)	3.839	(0.135)	3.789	(0.120)
6	3.727	(0.043)	3.800	(0.093)	3.764	(0.081)

Table 1c SV for 6 straight runs showing the mean (±sd) or the left (L) and right (R) legs seperately and combined.

SV (m/s)	meanL	sdL	meanR	sdR	mean	sd
1	8.257	(0.055)	8.413	(0.199)	8.346	(0.172)
2	8.281	(0.166)	8.349	(0.273)	8.320	(0.235)
3	8.125	(0.166)	8.332	(0.162)	8.214	(0.194)
4	8.265	(0.181)	8.552	(0.155)	8.388	(0.222)
5	8.312	(0.217)	8.401	(0.253)	8.357	(0.240)
6	8.400	(0.201)	8.384	(0.184)	8.392	(0.193)

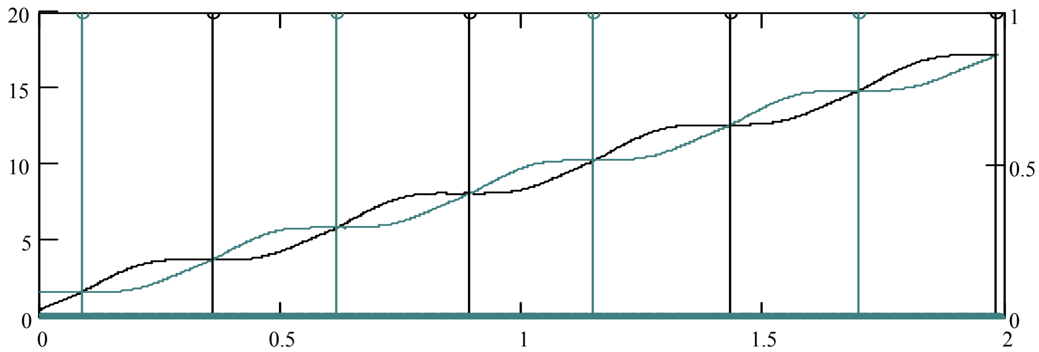


Figure 2: The *cross over* points in the X direction for a straight run, from which the step charactersitics were detemined. (Black=right toe, grey=left toe, vertical lines=cross overs)

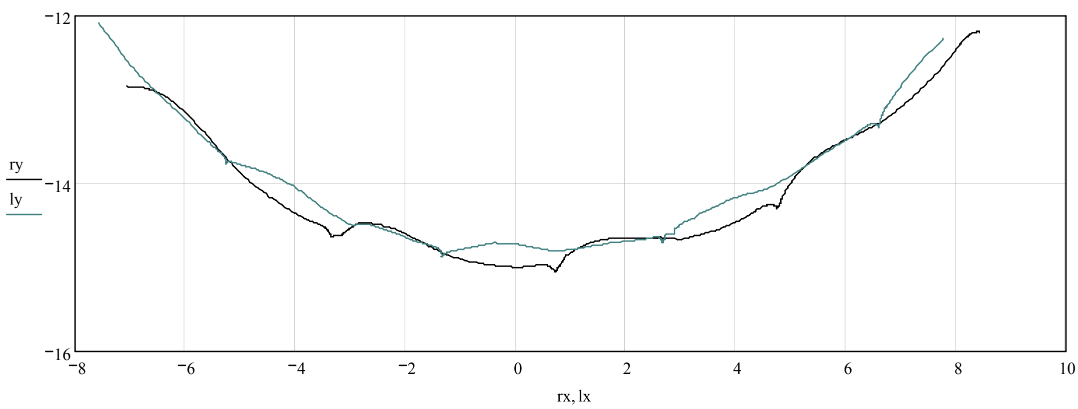
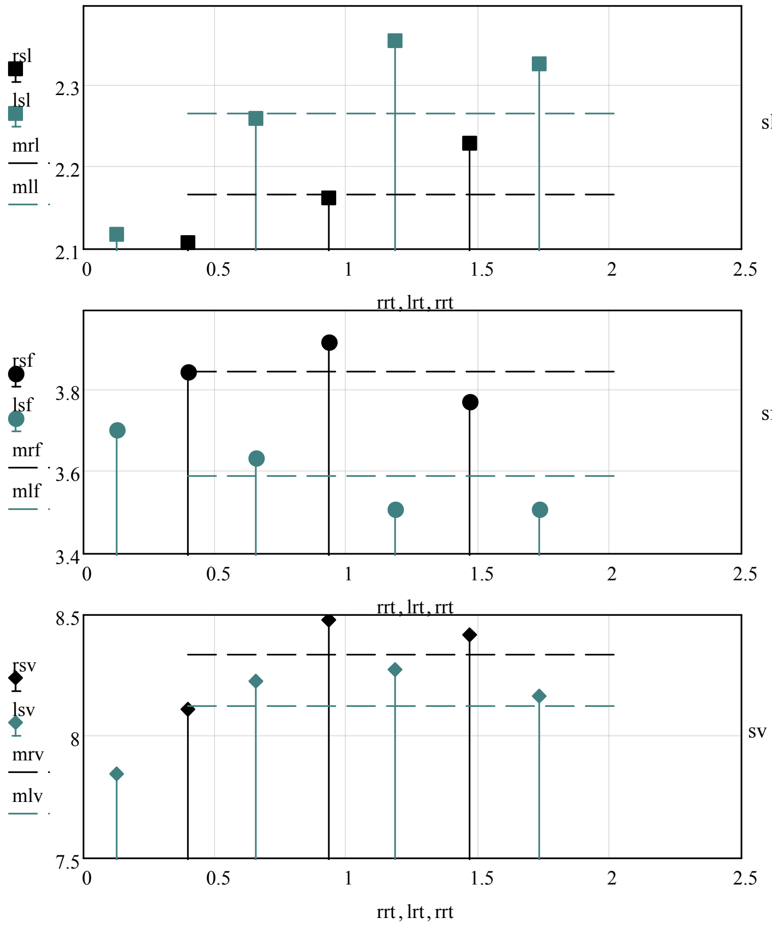


Figure 3: Bend run in Lane 1 for a single trial showing the trajectories of the right (black) and left (grey) toe markers in the xy plane



sl =

	0
0	2.118
1	2.108
2	2.261
3	2.162
4	2.357
5	2.230
6	2.327

sf =

	0
0	3.704
1	3.846
2	3.636
3	3.922
4	3.509
5	3.774
6	3.509

sv =

	0
0	7.844
1	8.106
2	8.222
3	8.477
4	8.269
5	8.414
6	8.164

Figure 4: MathCad[13] output for straight running trial (mean velocity = 8.21 m/s), showing variations in SL, SF and SV. Mean step variable values shown as dashed horizontal lines.

A convenient and accurate system has been demonstrated with which step length, step frequency and hence step velocity variations can be measured for straight and bend running.

CONCLUSION:

This study has identified that with minimal intrusion using two markers and a modified CODA scanner alignment, it is possible to readily measure step length, step frequency and step velocity for straight and bend running and hence has demonstrated a means of monitoring and providing feedback to elite athletes in training.

REFERENCES:

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