REPEATABILITY OF MOTION ANALYSIS AND REPRODUCIBILITY OF ATHLETES IN SPRINT HURDLES

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INTRODUCTION

There are few studies about the variation of human movement in the literature, especially when motion analysis is concerned. Grainger et al. (1983) studied day-to-day and trial-to-trial variability in walking. The results of this study did not reveal any statistical differences for the kinematic variables studied between the two days at the group level. After averaging across the two trials at the individual level, the results showed a maximum of less than 10 % variation between the days and less than 11 % variation between the trials. The authors concluded that two or three trials are necessary to generate tolerable data while a single trial results in only an approximate estimation (Grainger et al., 1983).

Craib et al. (1994) carried out treadmill running tests. Stride lengths revealed between 1.19-4.27% coefficient of variation over three various running speeds for individual mean values across 20 days. The reliability analysis of this study showed that beyond two days (consecutive or non-consecutive) limited practical increase was achieved in the accountability of step length variation. Robinson et al. (1993) found good intra-subject reliability for the spinal range of motion and spinal angular velocity. Intraclass correlations varied from .77 to .96 and from .75 to .97 for the 13 different range of motions and angular velocities examined respectively.

These studies indicate that motion analysis can be considered a reasonable reliable biomechanical research method under a careful set-up, particularly, if results are averaged across two or more trials. However, review of literature leads to the question: how reliable is the analysis of more complex tasks, which are commonplace in most applied sports research? The aim of this study was to investigate the repeatability of motion analysis and the reproducibility of athletes' technique in the event of sprint hurdles.

METHODS

Eight athletes (four females and four males) performed 2 sets of 4 trials over 4 hurdles in the training situation with approximately four minutes between the trials and 15 minutes between the sets. The training session was carried out outdoor on a synthetic track in November, 1994. Thus, due to the timing of the study during the beginning of the training season, the hurdle intervals were shortened 0.30 m (8.20 m and 8.84 m for females and males, respectively). The mean ± standard deviation (SD) age, height, mass and the range of personal bests in sprint hurdles were 30.1 ± 2.1 years, 1.76 ± 0.04 m, 62 ± 6 kg and 13.65 - 14.15 s for the female group and 24.5 ± 5.1 years, 1.82 ± 0.04 m, 81 ± 6 kg and 14.11 - 15.38 s for the male group.

Two video camera recorders (JVC GY-X1TC using S-VHS video tape) yielding 50 fields per second were located 29 m away from the third hurdle in front and symmetrically on both sides of the lanes creating a 90 ° angle from the midpoint of hurdle. The cameras were genlocked to ensure simultaneous exposure, with the midpoint of lenses at the height of 1.48 m above the track level and the shutter speed at 1/1000 s. The Peak Performance 24-point calibration frame (1.60 x 1.92 x 2.22 m, width, height and length, respectively) was located 0.50 m before the hurdle position and was videotaped before the session. The female athletes performed first, and after this session the camera views were slightly enlarged and calibrated again for the male group. The maximum possible digitising view was approximately 5.3 m and 5.9 m in the running direction for females and males, respectively, thus assuring as large an image size as possible.

The same operator digitised all the eight trials per subject. Additionally two trials (one female and one male) were randomly selected and re-digitised eight times. The daily digitising order of four trials (from different athletes) were randomised across the 20 days. The digitising process was carried out with an Arvis digitisation board interfaced to an Acorn Archimedes 440 microcomputer running the "Kine Analysis" software package (Bartlett, 1990). Direct Linear Transformation (DLT) algorithm was carried out to reconstruct 3-D co-ordinates of the 14-segment body model with two additional points, i.e. both upper corners of hurdle crossbar (presenting the reference of the hurdle height). The cross-validated quintic spline was used for smoothing and data calculation.

Linear and angular displacements, linear and angular velocities and temporal variables between the mid-stance phase before and after the hurdle clearance were analysed (mid-stance phase is defined as centre of mass (CM) passing the toe co-ordinate of ground contact leg). The coefficient of variation, CV = (SD/mean)*100, for 28 kinematic variables were calculated for each subject and for both re-digitised data sets independently.

RESULTS AND DISCUSSION

Minimum and maximum CVs of genders and CVs of re-digitised trials are presented in table 1. Individual CVs varied from 0.4% to 138.0% for the female athletes and from 0.8% to 181.2% for the male athletes. The range for the female and male re-digitised trials were 0.1-151.2% and 0.2-198.7%, respectively. Although, some of the CV's were rather high, there were only eight variables where one or more of the female athletes had over 10% CV (nine variables for males). For the re-digitised trial there were 16 and 13 variables for the female and male, respectively, in which the CV was under the 2% level. For most of the variables the re-digitised CV were substantially lower than the lowest individual CV. This indicates that generally the digitising and analysis process is sensitive enough to potentially separate technical aspects of performance. However, there were eight variables in both female and male groups, in which the CV of the re-digitised trial were greater than the lowest CV of individual athletes in the same gender. This implies that in these eight variables (which were not the same variables for both genders) the variation of results may be due to the digitising and analyses process.

Table 1. Minimum and maximum CVs of both genders and CVs of re-digitised (RD) trials.

	FEMALES			MALES		
	Min.	Max.	RD	Min.	Max.	RD
TAKE-OFF VARIABLES						
Distance	1.6	3.4	0.3	1.5	4.4	0.3
Deviation angle	2.5	3.4	0.3	1.7	3.3	0.5
Take-off angle	5.0	7.9	5.9	3.6	6.6	3.6
Vertical velocity of CM	3.2	7.7	5.5	3.7	6.2	3.8
Horizontal velocity of CM	1.6	2.8	0.7	1.2	2.5	1.2
Knee angle of trail leg	1.0	1.8	1.2	1.4	2.1	1.1
Min. knee angle of lead leg	2.7	7.4	1.9	4.5	6.6	4.3
Height of CM	1.1	1.5	0.4	1.1	2.1	0.6
CLEARANCE VARIABLES						
Max. height of CM	2.4	3.9	0.9	4.2	5.4	2.9
Horiz. distance of CM peak from the hurdle	11.1	52.5	2.6	57.8	175.7	198.7
CM clearance height	2.5	4.2	1.1	4.4	5.3	3.0
Min. hip angle of lead leg	4.0	4.8	3.5	6.3	15.1	2.2
Max. knee angle of lead leg	0.4	3.1	1.0	1.0	2.0	0.6
Max. angular velocity of trail hip	5.9	9.9	6.5	10.0	15.1	13.7
Time of max. hip velocity	7.4	15.8	10.1	8.5	23.9	5.0
Max. angular velocity of lead hip	5.4	12.3	5.0	1.9	9.0	6.8
Time of max. hip velocity before the landing	57.0	138.0	151.2	46.6	181.2	75.6
LANDING VARIABLES						
Distance	3.0	8.2	0.3	6.8	8.3	0.5
Deviation angle	1.5	10.6	0.3	2.1	3.8	0.4
Knee angle of lead leg	1.3	3.3	0.5	0.8	2.3	0.5
Angular velocity of lead hip	5.1	13.6	4.8	4.8	13.5	8.4
Vertical velocity of CM	4.6	7.4	5.3	3.2	10.1	4.3
Horizontal velocity of CM	1.0	3.0	0.7	1.5	2.6	1.4
Height of CM	0.7	1.2	0.4	1.3	1.8	1.0
GENERAL VARIABLES						
Stride length	1.1	3.1	0.1	1.8	3.5	0.4
CM mean horiz. velocity	0.6	2.7	0.1	1.1	2.1	0.2
Horiz. velocity lost of CM	30.3	36.2	28.8	19.9	30.0	12.7
Lateral displacement of lead foot	6.2	25.8	1.3	13.9	22.0	2.9

Unfortunately, it was not possible to separate the digitising and analysing process. Thus, even small digitising error may propagate further errors (leading to large CVs) during the reconstruction and smoothing of co-ordinates which is enhanced in the differentiation of the data (e.g. linear and angular velocity variables). This propagation has probably had an effect on the variable of the horizontal distance of CM peak from the hurdle. The variable yielded 2.6 % CV for the female re-digitised trial implying repeatability of this variable. However, for the male trial this variable resulted in the highest CV of the whole study (198.7%) showing complete unreliability. The reason for this difference may be the special demands of clearance due to different heights of hurdles. By leaning substantially forward with the trunk during the clearance the male athletes also obstructed more body parts than the females. This might have led to potential digitising error producing the CM peak in different fields in different re-digitising of the male trial.

CONCLUSIONS

It can be concluded that one operator can perform the digitising process with repeatability and that in this context the analysis is reliable for most of the variables. This study, however, did not clarify the accuracy and reliability of motion analysis in absolute terms. The athletes were able to reproduce their performance within certain limits despite such a complex movement, although there were differences in reproducibility of the females and the males due to different clearance technique. In the practical application, it is clear that for some variables (e.g. deviation angle at landing) more digitised trials are needed to clarify individual technical aspects of performance. Furthermore, it should be remembered that variation may be due to digitising error propagation in later parts of the analysis, thus yielding unreliable results in these particular variables (e.g. time of maximal angular velocity of lead leg hip before landing). The authors feel that video analysis can be used successfully to study and support athletes' technical performance. However, it is recommended that researchers carefully select the variables and the amount of trials for digitising in such a sport science service.

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