VARIATION IN MOTION ANALYSIS OF SPRINT HURDLES: PART II - THE INFLUENCE OF CO-ORDINATE VARIATION ON PERFORMANCE VARIABLES

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INTRODUCTION

Variation is one part, which determines repeatability and reliability in biomechanical studies. Yeadon (1994) indicated that uncontrolled variation may mask the effect of the experiment. Technical analysis of different sport events using motion analysis systems has increased around the world over the last few years. The lack of repeatability of an operator and reproducibility of athletes are the main sources of variation in such an analysis. Most of the variability studies in the biomechanical literature have been carried out using opto-electric systems and test equipment. Hence, these are not fully applicable for practical sport research situations with manual digitisation and human performance.

Salo (1995) presented coefficient of variation results for three female athletes in sprint hurdles. Individual differences were considerable, although homogenous variances showed that athletes varied their performances within the same limits in most of the variables. In the redigitisation process, 18 variables out of a total of 28 had less than 3% coefficient of variation. However, this paper studied variation at the final, fully processed variable level. Thus, the aims of this study were: to isolate variation due to an operator, to investigate the variation at the 3D co-ordinate level and to analyse the influence of this variation on performance variables.

METHODS

A training session of seven National level sprint hurdlers containing eight trials (2 sets of 4 trials over 4 hurdles) was carried out for this study series. Two normal speed video camera recorders (JVC GY-X1TC using S-VHS videotape, operating at a frame rate of 25 Hz, thus yielding 50 fields per second) were used to videotape the third hurdle clearances. The cameras, which were located at a 90° angle from the midpoint of the hurdle at a 29.0 m distance symmetrically in front and to the sides, were genlocked and 1/1000 s shutter speeds were used. The hurdle intervals of 8.20 m and 8.84 m (shortened by 0.30 m) for the females and males, respectively, with standard hurdle heights, were applied due to beginning of the training year (November).

The common videotaped views for both cameras were restricted to 6.7 m for females and 7.3 m for males in the direction of running. However, the video board cuts the edges of these views and thus the digitising views were approximately 5.3 m and 5.9 m, respectively, at a maximum. A standard Peak Performance 24 point calibration frame was located at approximately halfway in the clearances, 0.50 m before the hurdle and parallel with lane lines. Both horizontal and vertical directions were checked with a spirit level. The calibration was carried out separately for females and males.

From the total of 56 trials (7 athletes x 8 trials), two trials (one female and one male) were randomly selected and digitised eight times by the same operator using the Ariel Performance Analysis System. Digitising was started from the beginning of the contact phase at take-off and was concluded at the end of the contact phase at landing. This resulted in 28 and 33 fields of digitising for the female and male trial, respectively. A eighteen landmark model construction with four additional points (corners of hurdle) was used. The resolution of the screen, where the digitising cursor was moved, was 640 x 480 pixels.

DLT- and quintic spline algorithms were applied to digitised files. Smoothing was carried out separately to each landmark in each, x, y and z -direction (where x is horizontal forward, y vertical and z lateral direction). Smoothing factors were decided by an operator by evaluating the power spectrum of the velocity curve of the landmark in each direction. Next, the raw (zero smoothed), the smoothed 3D co-ordinates and 28 kinematic variables were analysed. Standard deviation (SD) values were calculated in each case. For the co-ordinates, SD of eight repeated digitisations was calculated separately for all 18 body landmarks in every single analysed field and at each x, y, z and diagonal (combined) direction.

RESULTS

Although an operator carries out combined errors in digitising (i.e. an operator does not separately differentiate directions of an error), all axes are presented in the results to observe, whether some directions are more sensitive than others. Furthermore, an operator may easily see the vertical height of a point (e.g. knee point), but may have a problem locating the joint centre laterally.

The grand mean (all landmarks, all fields) of the raw 3D co-ordinates yielded SD of 0.010, 0.006, 0.010 and 0.016 m for the female trial in x, y, z and diagonal directions, respectively. The respective values for the male trial were 0.013, 0.007, 0.012 and 0.020 m. However, single field SDs of individual landmarks varied considerably as can be seen in the minimum and maximum columns in table 1. The minimum deviation was achieved in landmarks of trail and lead leg knee and ankle points as well as the top of the head and trail leg hip points during different parts of the clearance. Thus, there are no clear patterns to indicate, that some points are more visible throughout the whole performance. The maximum deviations were gained in the trail leg knee points or some of contralateral arm points. These points are obstructed for the longest time from different camera views by other body parts. Thus, it is easier for the operator to lose the track of these points, and hence increase the deviation.

The largest minimum deviation of individual landmarks in a single field and the range of mean deviation in individual landmarks across all the fields are also presented in table 1. The largest minimum deviations showed that every landmark had less than 0.01 m deviation in x, y and z -directions at some part of the sequence. Thus, indicating that when the landmark is clearly visible, the digitisation process was very repeatable. The range of mean deviations in individual landmarks across all the fields showed that generally digitising is reliable in this practical application. Additionally, the results in table 1. indicate that the vertical direction is slightly less variable than the other directions.

Table 1. Selected co-ordinate deviations (SDs) of redigitising (raw data). See text for further explanations.

	minimum [m]	maximum [m]	largest min. [m]	range of means [m]
Female				
x	0.003	0.037	0.006	0.007-0.017
y	0.002	0.021	0.004	0.005-0.009
z	0.003	0.039	0.006	0.007-0.016
diagonal	0.007	0.056	0.012	0.012-0.025
Male				
x	0.003	0.063	0.008	0.009-0.017
y	0.002	0.027	0.005	0.005-0.012
z	0.003	0.056	0.007	0.008-0.017
diagonal	0.008	0.085	0.014	0.014-0.027

Table 2. Selected co-ordinate deviations (SDs) of redigitising (smoothed data). See text for further explanations.

	minimum [m]	maximum [m]	largest min. [m]	range of means [m]
Female				
x	0.002	0.033	0.005	0.005-0.015
y	0.001	0.018	0.003	0.003-0.007
z	0.002	0.026	0.005	0.004-0.012
diagonal	0.005	0.042	0.009	0.008-0.020
Male				
x	0.002	0.047	0.007	0.006-0.013
y	0.001	0.021	0.004	0.003-0.009
z	0.002	0.046	0.006	0.006-0.013
diagonal	0.006	0.066	0.012	0.010-0.021

Occasional large deviations at the co-ordinate level did not reveal particularly large deviations at the variable level. Twenty-eight variables can be divided into 9 linear displacement, 5 linear velocity, 8 angular displacement, 3 angular velocity and 3 other variables. Linear displacements with zero smoothing yielded deviations of less than or equal to 0.01 m in all cases on both genders except in the variable of horizontal distance of centre of mass (CM) peak to the hurdle for the male trial, which yielded SD of 0.11 m (see further). Values less than or equal to 0.01 m SD can be considered accurate enough for the purpose of such measurement. Angular displacement deviations yielded deviation mainly from 0 to 2° (3° in maximum knee angle of the lead leg for the male athlete).

As can be expected, differentiation (linear and angular velocities) revealed increased deviations. Linear velocity deviations varied from 0.1 to 0.2 m/s. Variables with the SD of 0.2 m/s should receive careful evaluation, whether these variables are usable or not. The largest absolute SD of angular velocity was 113°/s (mean 777°/s) for the female trial and 140°/s (mean 1046°/s) for the male trial (maximal angular velocity of trail leg hip). Such deviations indicate that these variables can be used only as an approximate estimation of the technique.

Smoothing decreased variations clearly both at the co-ordinate level (see table 2.) and generally at the variable level. One function of smoothing is to cut down random digitising error and thus some of the excessive inaccuracies are reduced, which can be seen in the maximum deviation columns in the tables. Some increased deviations for variables with zero smoothing were reduced to inside tolerable limits after the smoothing. However, special concern should be applied when analysing the variables, which gained originally large deviations.

The smoothing factors used in this study were not particularly high. However, in certain situations the effect of smoothing was detrimental. For example: the centre of mass (CM) parabola is relatively flat and for the female trial in this study, certain smoothing values changed the peak of this parabola to different fields of the videotape in different digitising repetitions. Thus the distance of CM peak to the hurdle varied from 0.36 ± 0.01 m in the raw data (mean ± SD) to 0.25 ± 0.07 m for smoothed data. However, exactly the opposite happened for the male trial: the smoothing changed the peak of parabola from different fields to the same field in different digitising repetitions. The values changed from -0.12 ± 0.11 m to -0.01 ± 0.01 m (minus means that the peak of CM was after the hurdle). Obviously, the latter value is more correct than the first. However, this resulted only with certain smoothing factors (see methods).

CONCLUSION

The repeated digitising process in this study showed that generally digitising is reliable in this practical application. However, when the SD of pointing at the landmark reaches five to nine centimetres, the accuracy is not desirable, although it is understandable, because this occurred, when the landmark was obstructed from the camera view by the other body parts. The practical influence of such digitising error may be limited at the variable level and this influence varies for different variables. In manual digitisation, an operator unfortunately always produces pointing errors. Some of the excessive inaccuracies due to this human factor can be reduced by smoothing the data. Thus, it is not recommended to obtain final variable values from manual digitising without smoothing the co-ordinates. However, over- (or under-) smoothing can also have an undesired effect on the data.

It is clear that manual digitising has problems, but it is still the only usable system in the sport situation, especially if competitions are to be filmed. Based on this study, most of the kinematic variables used in this test, revealed acceptable repeatability. The authors of this study feel, that by carefully evaluating variables separately, the manual digitisation method with this kind of set-up is applicable for analysing the technique of athletes and that the researchers are able to give reliable feedback to athletes and coaches, which is the ultimate goal of such applied research.

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