VARIATION IN MOTION ANALYSIS OF SPRINT HURDLES: PART I - CO-ORDINATE DEVIATION IN 3-DIMENSIONAL RECONSTRUCTION

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INTRODUCTION

An understanding of the different variation sources in experimental sport research is fundamental to technical analysis, especially when comparing the intra- and inter-subject differences (Yeadon, 1994). The paper concluded that the results can be interpreted incorrectly, particularly if the intra-individual variation is larger than the inter-individual variation. There are some variability and reliability studies of motion analysis systems in the biomechanical literature. However, these studies have mainly been carried out using opto-electric systems.

Individual variable level variation in the event of sprint hurdles was presented by Salo (1995). Looney (1990) studied variances of the centre of mass data 2-dimensionally, calculated from segmental endpoint digitising and Klein (1995) studied linear and angular accuracy of the Ariel Performance Analysis System (APAS) using test equipment (not human performance). However, all these studies produced results at the final variable level. Thus, the question arises, how much and in what part of the analysis does the variation propagate.

Looney (1990) stated that for reliability of co-ordinates, not only separate isolated frames need to be investigated but that the entire sequence must be considered. Thus, the aim of this study was to investigate the variation at the digitised co-ordinate level throughout the whole analysed sequence and carry out this particularly in the practical sport application of sprint hurdles.

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 APAS. 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.

From all files, the separate raw co-ordinates (u, v) of both camera views (1T and 2T) and the raw 3D co-ordinates (3D) after Direct Linear Transformation and zero factor quintic spline were transferred to Excel software. Standard deviation (SD) of eight digitisations for the all 18 body landmarks were calculated separately for every single analysed field. The lowest SD of each condition and each co-ordinate direction (including diagonal combination) was selected as a base unit. All other SDs within the same co-ordinate direction were standardised to these base units. Additionally, deviations of the 3D co-ordinates were calculated in metric units.

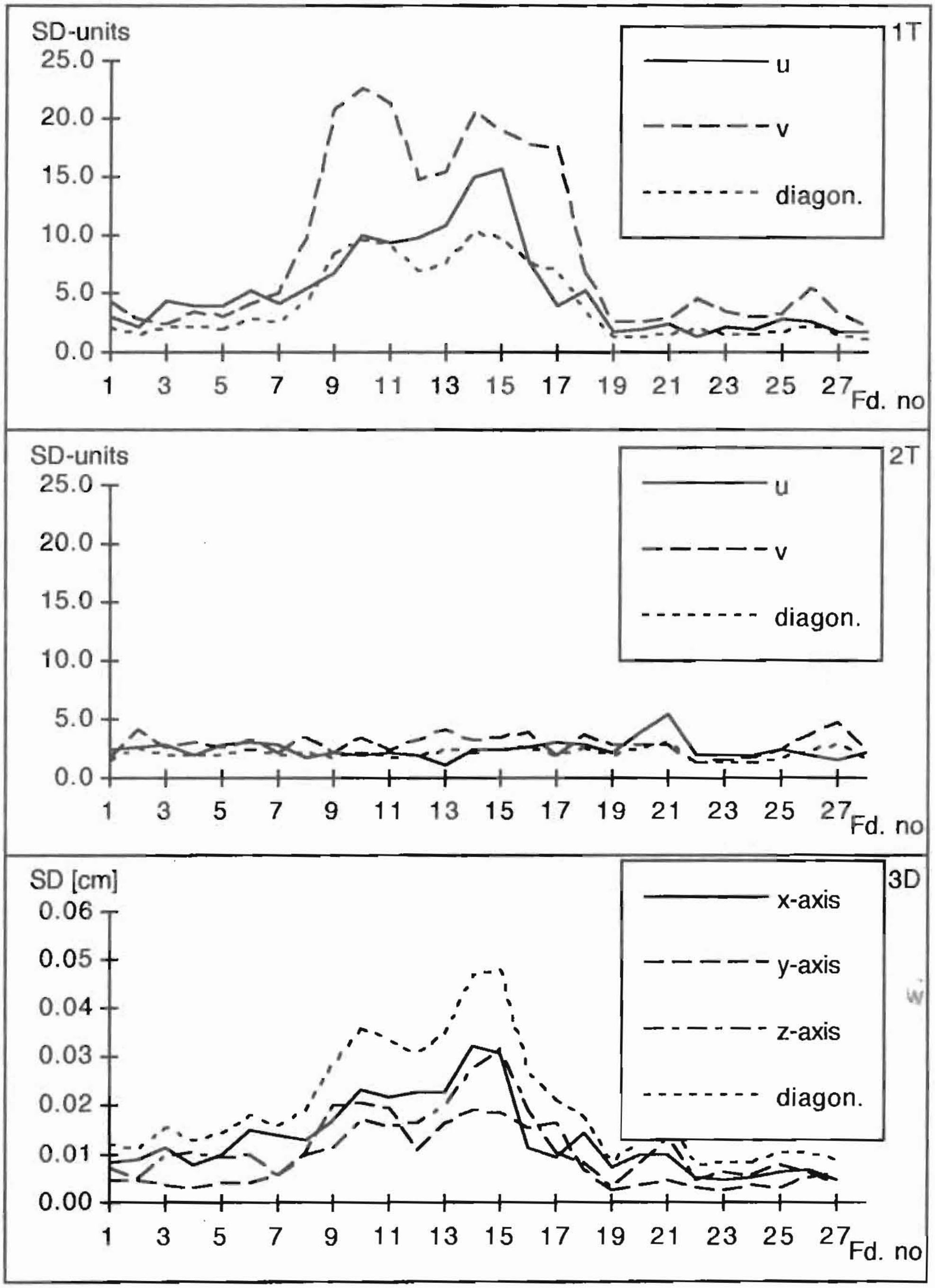
RESULTS

One of the problems of this kind of analysis is that there are no absolute measurement and thus the two different views and the 3D reconstructed co-ordinates cannot be directly compared. The lowest SD was selected for the base unit, as this presented the most accurate situation which an operator was able to reach in repeated digitising of a single point. The landmark having the lowest deviation varied in different views and different co-ordinates (including landmarks of foot, ankle, knee and wrist). Surprisingly, such landmarks as the top of the head and the hip, which are considered inaccurate for digitising, achieved the lowest deviation in some of 3D co-ordinates, showing that even these landmarks can be digitised precisely, if they are clearly visible for both cameras.

However, the SD of landmarks in individual fields of both views (1T and 2T) varied largely, i.e. from 1.0 to 22.5 and from 1.0 to 30.0 relative SD units for the female and male trial, respectively. When repeat digitising variability of a joint landmark reaches 30 times more than the minimum deviation, the digitising process cannot be considered as accurate. Fortunately, these large deviations were extreme situations and the influence of such a deviation can be limited depending upon whether it appears at a critical moment in the clearance and whether that landmark is related to variables around that part of the clearance.

For the male athlete, the trail leg and the ipsilateral arm were obstructed by the trunk for one of the camera views. This had only a slight effect on the maximum height of the centre of mass (CM) (SD= 0.01 m). However, the distance of the CM peak to the hurdle varied significantly (SD= 0.11 m). Due to lower trail leg path the same problem did not occur for the female athlete (SD= 0.00 and 0.01 m, respectively).

Figure 1. Deviations of a single landmark (right elbow, female trial) in both camera views (1T and 2T) and 3D reconstruction (3D). See text for further explanations.



Generally, most of the landmarks had less than 4 SD-units variation in most of the analysed fields showing reasonable repeatability of an operator and potentially leading to variable reliability. The mean SD of each landmark over all digitised fields in u- and v-directions (1T and 2T views) ranged from 2.3 to 8.7 (female) and from 2.6 to 7.1 (male) relative SD units. This variation resulted in SD of 0.017, 0.009, 0.016 and 0.025 m in x-, y-, z- and diagonal directions, respectively, for the female athlete as a maxima mean of an individual landmark in the 3D reconstruction. The respective SD values for the male trial were 0.017, 0.012, 0.018 and 0.027m. Thus, at an average level, the variation of raw 3D co-ordinates can be considered acceptable.

Deviations in individual landmark (right elbow of female athlete) in both camera views and 3D reconstruction over the analysed fields are presented in figure 1. to clarify deviation and the potential influence. In the middle part of the clearance, the elbow is obstructed by the trunk for the first camera view (1T) thus yielding large inaccuracies in repeated digitising. However, in 15, 13 and 18 fields (of total 28) for u-, v- and diagonal directions, respectively, deviation is under the 4 SD-units. The respective values for the second camera view (2T) are 27, 26 and 28 fields due to fact that elbow was visible for this camera all the time. When these views were combined, the 3D reconstruction (3D) yielded deviations between 0.0022 m (y-axis) and 0.047 m (diagonal) showing the whole range from excellent to questionable repeatability. The largest individual deviations of 3D reconstruction in a single field were diagonally 0.056 m (right hand point) for the female trial and 0.085 m (trail leg knee point) for the male trial.

CONCLUSION

The variation at the digitised co-ordinate level was investigated in this study. This was carried out particularly in the practical sport application: three-dimensional analysis of sprint hurdles. The deviation of landmarks in eight repeated redigitisation of one trial were generally acceptable. However, based on this study, it is clear that large variations occur in manual digitising at the co-ordinate level and this variation can have critical and important effects for variable values. The largest variation occurred, when the landmark was obstructed from a camera view by another part of the body. The influence of such variation depends upon whether it appears at a critical moment. Consequently, researchers are encouraged to consider carefully camera set-ups for minimising obstructions of landmarks while maintaining suitable camera angles and camera-object distances.

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