USE OF '2D-DLT' FOR THE ANALYSIS OF LONGSWINGS ON HIGH BAR

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The purpose of this study was to establish how closely a 2D DLT analysis compared with a normal 3D analysis during a longswing on the high bar. Repeated digitisations from two orthogonal camera views were averaged to produce 3D criterion data. Comparisons between 2D reconstructions from the left, right and from an additional perpendicular (2DP) camera view were made. Root mean squared differences (RMSD) for hip and shoulder angles (θ_H, θ_S) and angular velocities (ω_H, ω_S) were determined. Max RMSD was found to be θ_S= 0.06 rad viewed from the left camera and ω_S = 0.60 rad.s^{-1} from 2DP view. It is therefore recommended that 2D DLT can be used to analyse this skill and that added accuracy can be obtained using left or right camera views during ascending and descending phases respectively. This has direct implications for future research of this type of skill.

KEY WORDS: 2D-DLT, video, gymnastics, longswing, high bar

INTRODUCTION: Two dimensional (2D) image based motion analysis of the human performer can lead to inaccuracies. The major limitation of this approach being the assumption that human motion occurs in only one plane. Dainty *et al*. (1987) suggested that activities that may appear to occur in a single plane are still three-dimensional (3D). Bartlett (1997) has suggested that only a full 3D analysis can describe the performer's true spatial motion and is therefore closer to the reality of the actual movement. However in certain research designs this imposes logistical constraints. Williams (1985) investigated the validity of the assumption of symmetry during distance running and reported no significant differences (P>0.05) between 2D and 3D for angular displacement of the thigh, linear displacement and velocity of the shank, forearm and ankle suggesting that planar analysis was sufficient for most kinematic variables. However determining certain variables about the longitudinal axis of body segments were unachievable. Similarly, Rodano and Tavana (1993) investigated instep kicking in football and reported differences between 2D and 3D values for linear speed of the lower limb were in the region of 0.9-1.1%. However larger errors were observed in the angular speeds of the ankle, knee and hip with the maximum being 83.9%. The nature of kicking skills thus required a 3D analysis, however, this may not be the case in certain motor skills in artistic gymnastics due to the unique equipment constraints imposed on the performer. Takei and Dunn (1997) used planar image based motion analyses to collect performances of double backward somersault dismounts from the horizontal bar. Additionally, Okamoto *et al*. (1987) examined the basic backward longswing on high bar, again using 2D analysis. There are currently few specific studies comparing 2D and 3D analysis of what appear to be planar movements. The implications of conducting 2D analyses for certain skills are also dependent on the siting of the camera with respect to the movement. Therefore the purpose of the study was to establish whether a difference existed in the reconstructed co-ordinates of the longswing on high bar using 2D and 3D DLT reconstruction techniques.

METHODS: Data collection: Filming took place in the National Indoor Athletics Centre in Cardiff, Wales. After an appropriate warm-up, an international male gymnast (age = 23 yrs, mass = 70 kg, stature = 1.68 m) executed five longswings. A national level coach and qualified Federation of International Gymnastics judge, following the criteria of the FIG (2000) ascertained success of each element. Three 3-CCD digital camcorders (Sony, DSR-PD100AP) were used to record the images. Two camcorders were configured so that their optical axes converged orthogonally, in order to satisfy the conditions of colinearity (Abdel-Aziz, 1974), were located 18 m from the activity and at a height of 1.5 m. A third camcorder was located 18m perpendicular to the plane of motion of the performer and at a height of 1.5 m. Images were sampled at 50 Hz. A single calibration pole of height 5.176 m with 6 spherical markers located at approximately 1 m intervals was moved through 6 pre-marked locations to form a calibration volume of 1.5 m x 4.0 m x 5.176 m. The images of the calibration object and the longswings from each camera view were digitised using the TARGET motion analysis system (Kerwin, 1995). The gymnast's left and right fingers, wrists, elbows, shoulders, hips, knees, ankles and toes and the head were digitised. A DLT algorithm was used to reconstruct the co-ordinates in the object-space. Root mean square reconstruction accuracy from the DLT of less than 0.1% of the width of the field of view was regarded as acceptable. Any trials not meeting this standard were re-digitised. The reconstructed data were time synchronised to less than 0.001s by minimising the global mean RMS reconstruction error estimate for all digitised body landmarks as described by Yeadon and King (1999). A digital filter with a cut off frequency was implemented for random noise removal at 5 Hz Challis *et al*. (1997). Digitiser reliability and objectivity were assessed using limits of agreement analysis (Mullineaux *et al*., 1994).

Data analysis: Four 3D-DLT reconstructions of one longswing (133 images) were averaged to produce a criterion data set. Subsequently a further five independent test reconstructions were performed: 3D; 2D from the left (2DL) and right (2DR) camera views and repeat digitisations from the perpendicular view (2DP1, 2DP2). From the 3D data set, midpoints between each pair of digitised co-ordinates formed a pseudo data set of 'virtual' markers. Additionally, since one side of the gymnast's body was digitised in the perpendicular view, mean data for the two reconstructed sets from the perpendicular camera views were calculated (2DPT). The RMSD between the data for each test and criterion reconstruction data were determined. RMSD of hip and shoulder angular displacements and velocities were plotted against the angular position of the gymnast as he rotated around the bar to facilitate a direct comparison between of trials based on the gymnast's position. The data were plotted with the hang at 0º and rotated clockwise through 360º. Variance between the 4 reconstructions used to develop the criterion was also ascertained by determining the RMSD between a single trial and the average of the other three trials for hip and shoulder angular displacement (θ_H, θ_S) and hip and shoulder angular velocity (ω_H, ω_S).

RESULTS & DISCUSSION: Table 1.0 establishes that the differences between the criterion and the six test reconstructions were dependent on the method used. The maximum RMSD for the 2D reconstructions were θ_H = 0.05 rad and θ_S = 0.06 rad from the left camera view. These values were within 0.01 rad of the minimum values for these variables. The small variation in maximum and minimum values between the 2D reconstruction techniques was also evident in the angular velocity data with a difference of ω_H = 0.06 rad.s^{-1} and ω_S = 0.16 rad.s^{-1} respectively. Whether these values are acceptable is at the discretion of the researcher.

Table 1.0 RMSD Values for Hip and Shoulder Angular Displacement and Velocity Under Different Reconstructions

	3D	2DL	2DR	2DP1	2DP2	2DPT
θ_H rad	0.02	0.05	0.05	0.04	0.04	0.04
θ_S rad	0.03	0.06	0.06	0.05	0.05	0.05
ω_H rad.s^{-1}	0.19	0.37	0.37	0.38	0.43	0.38
ω_S rad.s^{-1}	0.27	0.49	0.46	0.44	0.60	0.47

The values presented in Table 2.0 are maximum values in the differences between the four 3D reconstructions and show that over 50% of the difference was accounted for by the variability in the criterion measure.

Table 2.0 Maximum RMSD for Hip and Shoulder Angular Displacement and Velocity as a Representation of the Variance Within the Four 3D Reconstructions used to Generate the Mean Criterion Value

	RMSD		RMSD
θ_H rad	± 0.03	ω_H rad.s^{-1}	±0.25
θ_S rad	± 0.02	ω_S rad.s^{-1}	±0.23

The differences in the reconstruction values were derived from a number of sources, these results illustrated that the absolute difference between these methods increased as the angular velocities of the hip and shoulder joint increased. This is shown in figure 1a for hip angular velocity where the maximum difference (1.1 rad.s^{-1}) occurred as the maximum velocity of this joint at 25º of rotation between perpendicular (2DPT) view and a 3D criterion value (crit).

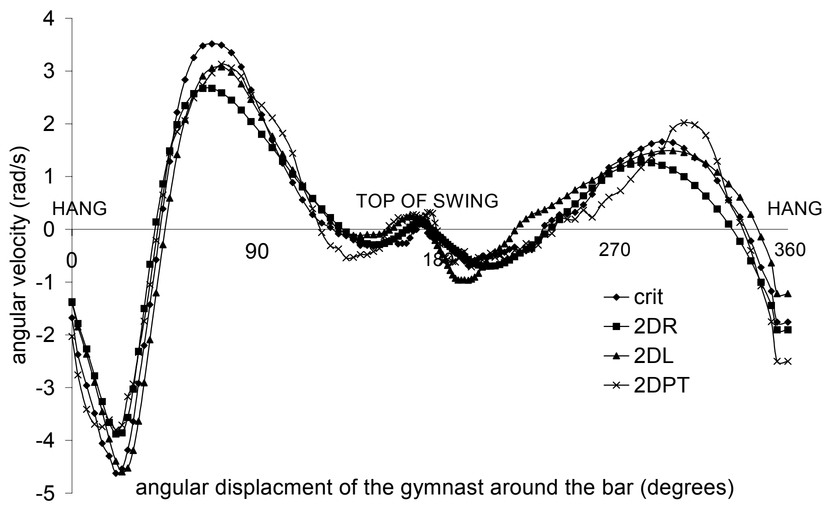

Figure 1a - Hip angular velocity (rad/s) during a longswing on horizontal bar derived from 2D DLT from both left (2DL) and right (2DR) views and perpendicular (2T) view and a 3D criterion value (crit).

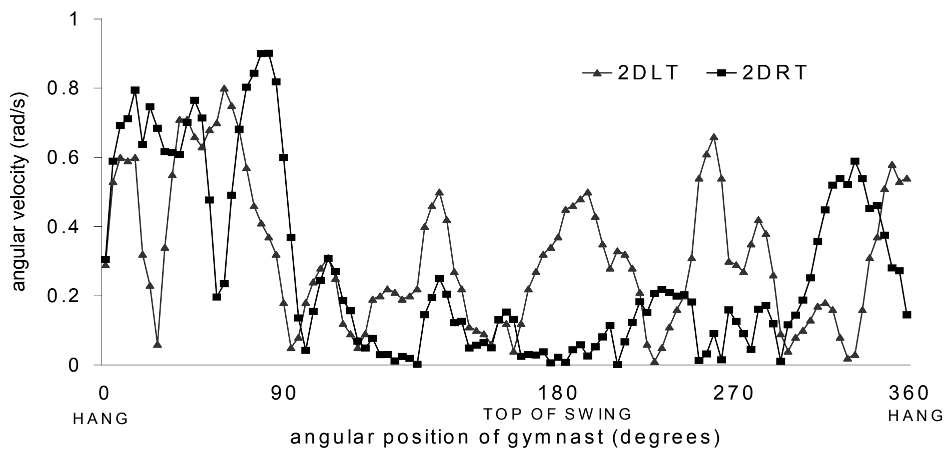

Figure 1b Absolute difference between the hip angular velocity (rad.s^{-1}) of the 3D criterion and 2D left and 2D right camera views for a longswing on horizontal bar.

In the 2D perpendicular view the mean of two digitisations provided a more appropriate comparison with the 2D DLT data since these were based on the average of the projections of the left and right co-ordinates onto a 2D calibration plane. Differences between left and right camera views were seen for different angular positions of the performer. In the ascent phase of the longswing there was a relatively poor view of both sides of the gymnast. As the gymnast continued to swing towards handstand the error increased in the left camera view as points became more obscured. Data from the right camera view suffered as the gymnast descended. The locations of cameras for 3D video analysis have implications on the errors in the data, but if a planar approach is to be undertaken, camera siting would appear to be even more important.

CONCLUSIONS: The maximum RMSD for the 2D reconstruction for hip and shoulder angular displacement was θ_H = 0.05 rad and θ_S = 0.06 rad respectively both from the left camera view. For angular velocity of the hip and shoulder the maximum RMSD was 0.43 $rad.s^{-1}$ and 0.60 $rad.s^{-1}$ respectively from a single digitised perpendicular view. These differences were due to variance within the criterion measure (50%), angular displacement of the gymnast during the longswing and the velocity of the joint. It is therefore suggested that 2D DLT can be used to analyse this skill and that added accuracy can be obtained using left or right camera views during ascending and descending phases respectively. This has direct implications for future research of this type of skill.

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