# POSSIBLE ERRORS IN MEASUREMENT OF SHOULDER ALIGNMENT USING 3-D CINEMATOGRAPHY

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## INTRODUCTION

Two- and three-dimensional cinematography have been recently used to measure the alignment of the shoulders (a line joining the acromion processes of both scapulae) relative to the plane of performance (Elliott *et al.* 1992, 1993) and relative to the hip or pelvic alignment (Stockill and Bartlett, 1992; Burnett *et al.*, 1995) in a bid to infer injury risk to the lower back in Cricket fast bowling. The Mixed technique has been defined using some of these measurements, and recommendations have been made with respect to minimising the hip-to-shoulder separation angle and the torsional load placed on the lower lumbar vertebrae. The hip-to-shoulder separation angle has also been used in the analysis of many athletic throwing events such as the discus, the hammer and the javelin in a bid to determine the optimal technique for propelling the implement in the most effective way (e.g. Bartlett, 1992). Despite considerable interest in this variable, however, it may be that the methods used are not ideal in terms of quantifying the degree of spinal rotation owing to problems with the method employed.

The aims of this study were:

1). To determine the possible magnitude of errors involved in measuring shoulder alignment and hence hip-to-shoulder separation angles owing to movements of the shoulder girdle.

2). To determine if there is a relationship between shoulder girdle mobility and possible error of measurement of shoulder alignment and hence hip-to-shoulder separation angles.

## METHODS

Following an extensive upper body warm-up and stretching routine 10 athletic male volunteers (mean age 25.1 yrs) were seated on a chair such that the top of the backrest was adjacent to the 7th thoracic vertebra (T7). Each subject was secured to the chair using straps around the lower abdominal region (to secure the pelvis) and the nipple line (to minimise lumbar and lower thoracic rotation). The object of this procedure was to allow for glenohumeral and scapular movement but to fix the lumber and lower thoracic regions and restrict, if not totally prevent, spinal twist below T7).

With the frontal plane parallel to the principal plane of movement, ranges of horizontal extension and flexion were measured for each volunteer to provide an index of glenohumeral joint and shoulder girdle flexibility. Subjects were then instructed to attain three different positions of the upper arms. Position 1 - upper arm abducted through $90^{\circ}$, Position 2 - maximal horizontal flexion of upper arm, Position 3 - maximal horizontal extension of upper arm. These positions were repeated for both arms resulting in 9 combinations, namely Left upper arm in position 1, Right upper arm in position 1 (L1R1), Left upper arm in position 1, Right upper arm in position 2 (L1R2) etc.

Two gen-locked Panasonic F15 video cameras were used to film each subject. One camera was placed approximately 12 m in front of the subject and the other was placed approximately 25 m to the left of the subject with optical axes set at 90°. A Peak Performance calibration frame containing markers of known co-ordinates was filmed prior to testing. Each of the 9 positions for each of the volunteers was digitised three times using an Acorn Archimedes microcomputer, and the mean of the three readings used for analysis. Reconstruction of the two sets of 2-D image-space co-ordinates into 3-D object space co-ordinates was performed using a DLT algorithm with corrections for lens distortion (Bartlett, 1990).

As the rest of the body was restrained in the chair and hence remained stationary, particular emphasis was placed on locating the exact position of the acromion processes, the elbows and the wrist joints in order to accurately assess shoulder alignment and hip-to-shoulder separation angles. Identification of these landmarks was aided by marking the skin with marker pen at the appropriate points.

## RESULTS

The measured shoulder alignment for each of the 9 combinations of movements are shown in Table 1.

**Table 1: Mean shoulder alignment for the 9 positions (mean ± S.D.).**

| Condition | L1R1 | L1R2 | L1R3 | L2R1 | L2R2 | L2R3 | L3R1 | L3R2 | L3R3 |
|---|---|---|---|---|---|---|---|---|---|
| Shoulder alignment (°) | 4.43 ±3.3 | 19.3 ±7.8 | -11.5 ±9.9 | -13.8 ±11.5 | 2.34 ±8.4 | -29.4 ±8.7 | 9.26 ±6.8 | 28.6 ±6.0 | 6.34 ±6.2 |

The results showed that the shoulder alignment and hence the hip-to-shoulder separation angles were variable (Range 2.34° (L2R2) to -29.4° (L2R3)) and in two conditions L2R3 and L3R2, showed considerable deviation from the zero line. In a normal, unrestrained position (i.e. during execution of a sporting movement) these data may suggest a large degree of spinal rotation, whereas the movement is mainly owing to the combined movements of the upper arms and shoulder girdle. This large degree of supposed spinal rotation could be interpreted as the subject being in an advantageous position, particularly in sports where large degrees of 'hip lead' are sought after, or in a disadvantageous position, particularly in sports where large degrees of hip-to-shoulder separation angles are avoided owing to a risk of injury. The need to minimise the degree of separation between the hip or pelvic axis and the shoulder axis seems in little doubt, based on the cinematographic and radiologic evidence reported by Elliott *et al.* (1992, 1993) and Burnett *et al.* (1995). Stockill (1994) also supported these data by showing that there was no benefit, in terms of speed, in adopting a technique which incorporated high degrees of hip-to-shoulder separation, especially in light of the high risk of injury occurring. The unequivocal findings of the role that 'hip lead' plays in performance maximisation in the athletic throwing events ((e.g. Bartlett (1992)), however, suggests that there may be scope for further investigation to determine more accurately the relationship between hip-to-shoulder separation angles and performance. It may be that a more accurate and more consistent protocol in determining the shoulder axis angle may provide more reliable and useful findings.

The degree of measured shoulder axis rotation varied across conditions and across subjects as is shown by the relatively high standard deviations shown in Table 1. It was evident that the most flexible subjects, as determined from the flexibility test performed prior to filming (Table 2), showed larger shoulder axis angle rotations than the less flexible subjects. This trend did not prove to be statistically significant ($P<0.05$) in all conditions when tested using Pearson Product Moment Correlations. Significant correlations between shoulder alignment angles and maximal horizontal extension of the left humerus in conditions L2R3 ($r=-0.72$) and L3R2 ($r=0.79$) were found. The data do suggest that it may be prudent to consider flexibility of the shoulder joint and girdle before determining the degree of stress that the lumbar vertebrae is subjected to as the apparent stress may be more due to the position of the humerus and shoulder girdle than spinal rotation.

**Table 2: Range of movement of the humerus in horizontal flexion and extension (relative to the upper arm in 90° of abduction), (mean ± S.D.).**

| | Left Arm | | Right Arm | |
|---|---|---|---|---|
| | Horizontal Flexion | Horizontal Extension | Horizontal Flexion | Horizontal Extension |
| Upper Arm Angle (°) | 139 ±11.0 | 30.4 ±12.2 | 135 ±13.2 | 28.5 ±10.2 |

Many researchers have reported problems in locating the joint centre of the glenohumeral joint particularly when the upper arm is in differing degrees of flexion, horizontal flexion and rotation, and the scapula is abducted and possibly elevated. These positions are common in many sports. It is for this reason that the acromion processes are often used to measure shoulder alignment in preference to the glenohumeral joint centre. It would be interesting to investigate the effects of estimating glenohumeral joint position rather than acromion process position in this context to discover the effect on the errors in measurement of the shoulder alignment and, more importantly, the hip-to-shoulder separation angle.

It is generally accepted that three-dimensional cinematography is the best method of measuring shoulder alignment currently available to the sports biomechanist, but there are inherent difficulties. These problems are increased markedly when other combined movements of the shoulder joint and girdle are apparent. For example movements such as flexion-extension or internal-external rotation of the humerus or abduction-adduction of the scapulae can serve to further complicate the process. Further problems are experienced when the shoulder joint is hidden from certain views as is often the case when using a two camera set-up to analyse a rotational movement. This latter complication prompted Burnett *et al.* (1995) to use a three camera system which minimised the error in location of landmarks. It may be that in the absence of an improved and preferably non-invasive method of accurately determining spinal rotation, alternative methods are utilised. Such methods would include the use of additional marker points on the trunk to help quantify trunk rotation or possibly further investigation into the mechanics of the shoulder girdle and glenohumeral joint and its relationship with lumbar and lower thoracic kinematics.

## CONCLUSIONS

The results highlight the problems involved in using shoulder alignment and hip-to-shoulder angles to accurately measure, or at least estimate, the degree of 'hip lead' or the degree of twist experienced in the lower back. It is important to note that this error in measurement can lead not only to an overestimation of torsional stress or 'hip lead', but also to an underestimation. Both can have serious implications for the athlete in terms of injury minimisation and performance maximisation. Alternative methods of determination of spinal rotation may provide a more accurate measure especially in activities which involve large degrees of shoulder girdle movement, which are unilateral and asymmetrical in nature.

The study showed that even in a relatively simple movement where location of the acromion processes is simple (i.e. subjects were unclad and joint markers were present), the use of shoulder alignment and hip-to-shoulder separation angles to infer lower back torsional stress is fraught with difficulties. In more complex movements which include trunk flexion-extension and lateral flexion the difficulties may become even more apparent.

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