# WHICH JOINT ANGLE CHANGES HAVE MOST EFFECT ON BALL RELEASE SPEED IN OVERARM THROWING?

**Nurhidayah Omar[1], Mark King[2] and Fred R. Yeadon[3]**

**Institute of Engineering Mathematics, University Malaysia Perlis, Malaysia[1]**
**School of Sport, Exercise and Health Sciences, Loughborough University, UK[2]**

An eight-segment angle-driven simulation model of the trunk and upper limbs plus ball was developed to determine which joint angle changes have most influence on ball release speed. 15 overarm throwing trials were recorded, and the joint angle time histories of each trial were input into the simulation model. Systematically replacing specific joint angle time histories with a constant value and observing the effect on ball release speed showed that overarm throwing was most sensitive to trunk extension/flexion, trunk ext./internal rotation, scapula ext./internal rotation, upper arm flexion/extension, upper arm add/abduction, upper arm ext./internal rotation and forearm extension/flexion. During coaching or performance, attention should be focused on these angles because any changes could have a substantial effect on the ball release speed.

**KEYWORDS:** simulation, three-dimensional, angle-driven model, sports biomechanics.

**INTRODUCTION:** Overarm throwing is a fast, three-dimensional movement with complex interactions between limb segments. It can be divided into six events: stride foot contact, beginning of ball deceleration, ball acceleration, initiation of forearm extension, initiation of upper arm internal rotation and the ball release (Hong & Roberts, 2001). The general kinematics of overarm throwing are comparable across disciplines (baseball, handball, water polo and javelin). Numerous studies have been carried out on overarm throwing to understand the biomechanics of overarm throwing as well as to propose techniques to improve performance (Hong & Roberts, 2001; Laudner et al., 2010; Milewski et al., 2012; Oliver & Weimar, 2016; Stodden et al., 2001; 2006). However, to date, it is not clear which joint angle changes have most effect on ball release speed. A simulation model can be used to determine the influence of one variable on performance which is difficult to be attained using experimental studies (King, 2011; Yeadon, 1998). A simulation model such as the angle-driven model allows individual joint angle changes to be controlled. Thus, the aim of this study was to develop an angle-driven model of overarm throwing and subsequently to utilise the model along with the kinematic data of overarm throwing to investigate the influence of each joint angle on ball release speed.

**METHODS:** A 16 camera motion analysis system operating at 300 Hz (Vicon, OMG Plc, Oxford, UK) was used to collect kinematic data of a fastball pitcher (age: 28 years, mass: 89.8 kg, height: 1.89 m). Forty-seven 14 mm retro-reflective markers were attached to the subject's body (Felton, 2014; Worthington, 2010) and four small pieces of reflective tape were attached on both sides of the ball. A portable baseball practise net with a strike zone in the centre was located 11.5 m from the throwing area. The data collection procedures were explained to the subject in accordance with the Loughborough University ethical guidelines and an informed consent form was signed. The subject was requested to perform 15 successful maximum effort two-seam fastballs from flat-ground towards the strike zone. Ninety-five anthropometric measurements of the subject were taken and input into an inertia model (Yeadon, 1990). The calculated segmental inertia parameters were used in the angle-driven model.
The Autolev$^{TM}$ sofware package (Version 3.4) was used to formulate the equations of motion for eight segment angle-driven model based on Kane's method to derive the equations of motion. The contact between the hand segment and the ball was modelled using massless linear springs in *x*-axis, *y*-axis and *z*-axis with the force in the springs dependent on the displacement and velocity of the springs. By considering the ball slipping from the hand to the fingertip at release, the position of the ball in the simulation model was assumed to be at

the distal end of the hand segment. Ball release in the experimental data occurred when the ball could no-longer be within the hand based upon geometry. Considering previous studies which indicated that peak knee extension of the lead leg has less of a role in transferring energy from lower limb to the ball (Milewski et al., 2012) and that pitchers rely more on energy created in the core and upper extremity (Laudner et al., 2010), it was decided to exclude a direct representation of the lower limbs from the angle-driven model. Instead the movement of the lower limbs was included by constraining the pelvis to translate in the same way as the recorded performances. The model had eight-segments (pelvis, trunk plus head, right and left clavicle as one segment, right and left upper arm, right forearm, right hand and left forearm plus hand) and frictionless pin joints were used to join the segments together (Figure 1, see Table 1 for details of degrees of freedom at each joint).

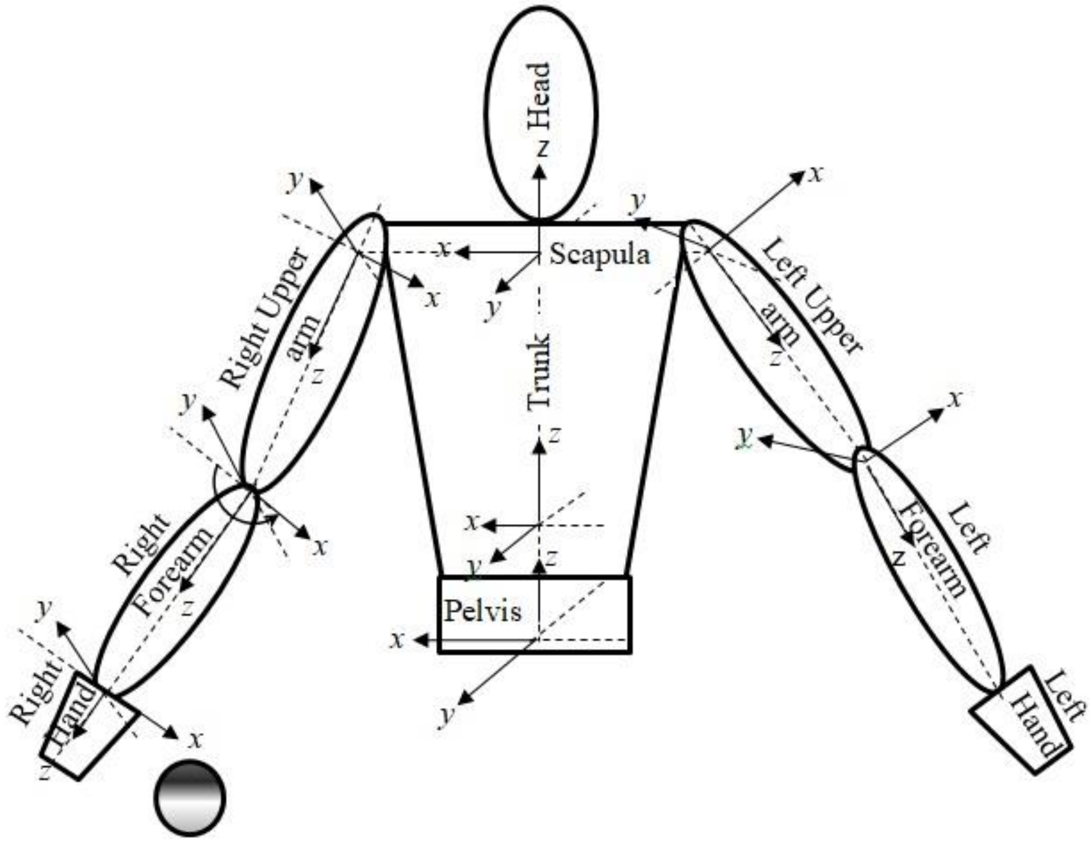


**Figure 1: Segments used within the angle-driven model.**

The angle-driven model together with the joint angle changes from the 15 individual trials were used to investigate which joint angle changes have more effect on the ball release speed. At first, the time history of each joint angle obtained from the 15 successful trials (Figure 2) were examined. Next, the angle-driven model was used to investigate how by allowing one joint angle to be constant can affect the ball release speed (the constant joint angle was chosen to be the specific joint angle at ball release).

**RESULTS:** Good agreement was found with the average difference in resultant ball release speed between the angle-driven model and the performance of 0.6 m/s (29 m/s for model, 29.6 m/s for performance) when all joint angles were allowed to vary as they did in each recorded performance. This demonstrated that the model used was appropriate to investigate overarm throwing.

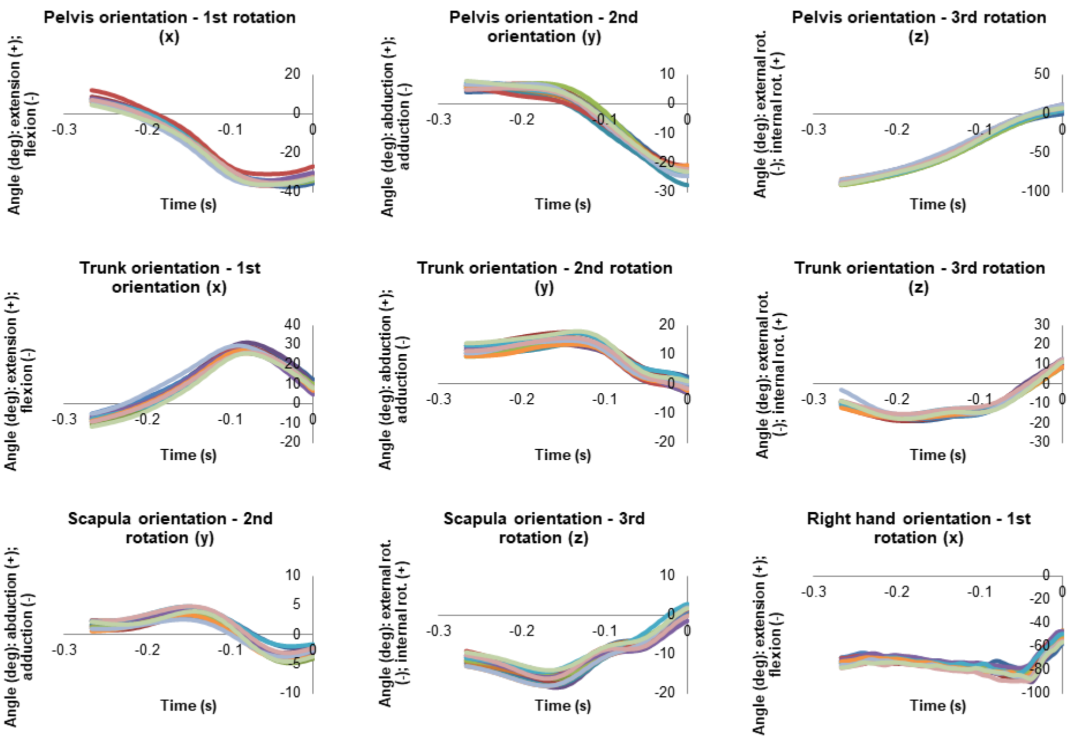


**Figure 2: Key joint angle time histories for the 15 recorded trials (ball release at time zero).**

The mean differences in ball release speed when each joint was kept constant are presented in Table 1. A positive value denotes there is an increase in ball speed, whilst a negative value means there is a decrease in ball speed.

**Table 1. Change in ball release speed as each joint angle was kept constant**

| Constant joint angle | Mean difference in *x*-axis (m/s) | Mean difference in *y*-axis (m/s) | Mean difference in *z*-axis (m/s) | Mean difference in resultant speed (m/s) |
|---|---|---|---|---|
| Pelvis ext./flexion | 0.00 | 1.36 | -0.59 | 1.48 |
| Pelvis add/abduction | 0.37 | -0.07 | -0.11 | 0.39 |
| Pelvis ext/internal rot. | -0.26 | -1.64 | -2.04 | 2.63 |
| Trunk ext./flexion | 0.84 | -5.24 | -0.53 | 5.33 |
| Trunk add/abduction | 2.06 | -0.01 | -0.76 | 2.20 |
| Trunk ext./internal rot. | 0.30 | -2.74 | -1.63 | 3.20 |
| R. Upper arm ext./flexion | -1.52 | 3.10 | -3.32 | 4.79 |
| R. Upper arm add/abduction | 1.07 | 4.75 | -2.26 | 5.37 |
| R. Upper arm ext./internal rot. | 12.13 | -9.82 | -4.85 | 16.34 |
| R. Forearm ext./flexion | -11.79 | -14.86 | -1.58 | 19.03 |
| R. Forearm add/abduction | 0.31 | -0.34 | -0.19 | 0.50 |
| R. Forearm pro/supination | -0.03 | 0.07 | 0.06 | 0.10 |
| R. Hand ext./flexion | 0.47 | -2.08 | -4.56 | 5.03 |
| R. Hand ulnar/radial deviation | 0.00 | 0.00 | 0.00 | 0.00 |
| Scapula add/abduction | -0.31 | 0.05 | 0.30 | 0.43 |
| Scapula ext./internal rot. | 0.21 | -1.39 | -2.26 | 2.66 |

**DISCUSSION:** The results indicated that the pelvis extension/flexion, pelvis adduction/abduction, trunk adduction/abduction, scapula adduction/abduction, right forearm adduction/abduction, right forearm pronation/supination, right hand ulnar/radial deviation, left upper arm and left forearm when kept constant resulted in a relatively small difference of less than 2.1 m/s in ball release speed in *x*, *y* and *z directions*. Although the right-hand extension/flexion demonstrates a higher difference in the *z*-axis, observation on the angles from the 15 trials shows that it is almost constant prior to ball release. Right upper arm extension/flexion, adduction/abduction and external/internal rotation exhibit a greater difference in each axis. Although scapula external/internal rotation shows a quite small difference in ball speed in each axis, when considering the angles from the 15 trials, it can be seen that prior to ball release the slope of the curve is quite high, this warrants further investigation. Previous research shows that the role of pelvis is more to help stabilise the upper body. Although the pelvis external/internal rotation does contribute to ball speed, it occurs between the periods of the beginning of ball deceleration to the start of ball acceleration. Starting from ball acceleration to the start of upper arm internal rotation, trunk external/internal rotation appears to be the major contributor to ball speed (Feltner & Nelson, 1996; Stodden et al., 2001; 2006).

**CONCLUSION:** This study has described the development and use of a three-dimensional angle-driven model to investigate overarm throwing. Overarm throwing is a complex 3D movement and this study has highlighted the key joint angle changes that contribute to ball release speed.

**REFERENCES**


Feltner, M.E. & Nelson, S.T. (1996). Three-dimensional kinematics of the throwing arm during the penalty throw in water polo. *Journal of Applied Biomechanics*, 12, 359-382.

Felton, P.J. (2014). *Factors limiting fast bowling performance in cricket*. Loughborough University: PhD Dissertation.

Hong, D.A., Cheung, T.K. & Roberts, E.M. (2001). A three-dimensional, six-segment chain analysis of forceful overarm throwing. *Journal of Electromyography and Kinesiology*, 11, 95-112.

King, M. (2011). Computer simulation modelling in sports biomechanics. *Portuguese Journal of Sport Sciences*, 11, 19-22.

Laudner, K.G., Moore, S.D., Sipes, R.C. & Meister, K. (2010). Functional hip characteristics of baseball pitchers and position players. *The American Journal of Sports Medicine*, 38, 383-387.

Milewski, M.D., Ounpuu, S., Solomito, M., Westwell, M. & Nissen, C. W. (2012). Adolescent baseball pitching technique: lower extremity biomechanical analysis. *Journal of Applied Biomechanics*, 28, 491-501.

Oliver, G.D. & Weimar, W.H. (2016). Hip and shoulder range of motion in youth baseball pitchers. Journal of Strength and Conditioning Research, 30, 2823-2827.

Stodden, D.F., Fleisig, G.S., McLean, S.P., Lyman, S.L. & Andrews, J.R. (2001). Relationship of pelvis and upper torso kinematics to pitched baseball velocity. *Journal of Applied Biomechanics*, 17, 164-172.

Stodden, D.F., Langendorfer, S.J., Fleisig, G.S. & Andrews, J.R. (2006). Kinematic constraints associated with the acquisition of overarm throwing. Part I: Step and trunk actions. *Research Quarterly for Exercise and Sport*, 77, 417-427.

Worthington, P.J. (2010). *A biomechanical analysis of fast bowling in cricket*. Loughborough University: PhD Dissertation.

Yamaguchi, G.T. (2006). *Dynamic modelling of musculoskeletal motion – a vectorised approach for biomechanical analysis in three dimensions*. Springer Science & Business Media Inc.

Yeadon, M.R. (1998). *Computer simulation in sports biomechanics*. ISBS Conference Proceedings Keynote Lectures.

Yeadon, M.R. (1990). The simulation of aerial movement – II. A mathematical inertia model of the human body. *Journal of Biomechanics*, 23, 67-74.


**Acknowledgement:** Thank you to the Ministry of Higher Education Malaysia for funding this study.