Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

KINEMATIC AND COORDINATION VARIABILITY OF THE THROWING ARM DURING THE WATER POLO SHOT

Paul Taylor, Raul Landeo and Jennifer Coogan

Australian Catholic University, Centre of Physical Activity Across the Lifespan, School of Exercise Science, Sydney, Australia

The purpose of this study was to quantify, in the water polo shot, (1) variability in the kinematic and coordination variables of the throwing arm, (2) ball release parameters and (3) differences in variability profile between successful and unsuccessful shots. Seven female participants performed 10 simulated 5 m penalty shots. Mean, standard deviation and coefficient of variation percentage were calculated for elbow and wrist angular displacement, wrist linear velocity and ball release parameters. Coordination was quantified using cross correlation. Variability was present in all measures and generally decreased close to or at release, particularly in successful shots. There was evidence of compensatory coordination. The results could guide practitioners on how to assess and influence technique in the throwing arm during a water polo shot.

KEY WORDS: movement variability, outcome, success, compensatory coordination.

INTRODUCTION: In the past movement variability has been classified as random noise within neuromuscular systems and, as such, was considered detrimental to performance (Davids et al., 2003). However, recent research suggests that movement variability may play an important functional role, specifically, facilitating adaptation, compensatory coordination and consistency in movement outcome (Bartlett, et al., 2007). Movement variability has been quantified in a wide range of sporting movements including baseball, golf and basketball (Bradshaw et al., 2009; Button et al., 2003; Fleisig, et al., 2009). However, unlike these sports, water polo does not have a fixed base of support and, as such, differences may exist in the variability present in the kinematics and coordination profiles of water polo skills, particularly the shot.

In addition to quantifying variability within sporting populations there has been recent interest in understanding the interaction of variability with movement consistency and movement outcome (Mullineaux & Uhl, 2010). Understanding whether any differences exist between successful and unsuccessful movements in the variability of throwing arm kinematics, coordination and release variables, as well as the magnitude of those differences may provide practitioners with important information affecting the assessment and understanding of shooting technique. The purpose of this study was to quantify, in the water polo shot, variability (1) in the kinematic and coordination variables of the throwing arm, (2) ball release parameters and (3) differences in variability profile between successful and unsuccessful shots (Hit and Miss).

METHODS: Seven injury free participants (21.14 ± 2.73 years, 168.84 ± 5.36 cm, 76.01 ± 9.03 kg) from the top grade of the Sydney women's water polo competition provided informed consent to participate in this study. After completion of a self-selected warm up, each participant performed 10 simulated 5 m penalty shots at a central target (25 cm square) within an imitation water polo goal. To maintain high levels of ecological validity, participants performed the shots from within a commercial water tank (1.90 m diameter; 1.60 m high, water level 1.55 m). Throwing arm motion was captured using a six camera (250 Hz) motion capture system, analysed using Vicon Nexus (Vicon, Oxford Metrics, Oxford, UK). In order to reduce ghost marker reconstructions (caused by splash) the participants were asked to begin the shot with their throwing arm above the water surface. This is consistent with the rules of water polo but represented a modified action for some participants. Ball motion was captured using a two dimensional digital video camera (250 Hz; Fastcam PCI R2; Photron USA, San Diego, CA, USA) manually digitised and analysed using Peak Motus (Vicon, Oxford Metrics,

Oxford, UK). Shot success (Hit or Miss) was determined via digital video (50 Hz; Sony Handycam, Sony, Tokyo, Japan).
Three segments (upper arm, forearm and hand) were defined, and three dimensional angles of the elbow and wrist of the throwing arm calculated. In addition linear velocity of the wrist was calculated. All time series were normalised to 100% of throwing time, with 0% being the start of wrist movement toward the target and 100% (termed release from here forward) being the point of peak wrist linear velocity. Peak wrist linear velocity was chosen as three dimensional and digital video capture was unsynchronised, the wrist marker was closest to the ball centroid and a high correlation exists between peak wrist linear velocity and ball release velocity from the two dimensional data ($r(53) = .899$, $p < 0.001$). Ball release velocity (at break of contact with the fingers), angle (to the horizontal) and height (above the water) were calculated from the two dimensional data.
Following control for marker reconstruction error, trial numbers analysed for each participant‘s limb kinematic variables were (All, Hit, Miss); Participant one (7, 3, 4), two (9, 2, 7), three (8, 3, 3; shot success data unavailable for 2 trials), four (8, 2, 6), five (7, 3, 4), six (4, 1, 3; excluded from “hit” analysis) and seven (10, 5, 5). All trials were analysed for release parameters bar participant three (two shots excluded). Mean and standard deviation (SD) values of elbow and wrist angular displacement as well as wrist linear velocity at 20, 40, 60, 80 and 100% of the movement were calculated for all participants trials and coefficient of variation percentage (CV%) calculated from these values. This was repeated for all successful (Hit) and unsuccessful (Miss) trials. These values were then collapsed across the group to produce the mean CV% for each condition (all trials, Hit and Miss). Similarly individual participant mean, SD and CV% were calculated for the ball release variables for all three conditions. Additionally, coordination was assessed using cross correlation of the elbow and wrist joint time series for each trial. Coordination variability was determined by calculating the peak mean correlation coefficient (Max r), SD and CV%. Consistent with the literature a CV% value of less than 10% was considered to represent low variability (Atkinson & Nevill, 1998).

RESULTS and DISCUSSION: Group mean variability (CV%) traces can be seen in figure 1. Individual values ranged between 1.58 – 23.46% (all trials), 0.36 – 20.56% (Hit) and 0.38 – 27.05% (Miss). Wrist variables displayed a trend of decreased variability toward release (100%) and low variability at or close to release (80 – 100%). Elbow variables increased in variability closer to release (100%). In addition, variability was generally lower at release for successful shots (Hit). This suggests that consistency in wrist kinematics is important at or close to release in the water polo shot, particularly for accurate shots.
Results for release parameters can be seen in figure 2. Variability in release height and velocity were generally low. Variability for release angle was high with all participants producing values over 25% (Atkinson & Nevill, 1998). However, absolute means and SD were relatively small (3.03° ± 0.37°). As such CV% should be interpreted with consideration of the measure’s limitations as the mean score approaches zero. There was a trend of lower variability across all release variables for successful shots (Hit). Variability values for release angle and height were generally higher for shots that missed. It is understandable that low variability in release variables is important in producing a successful shot as they ultimately determine the trajectory of the ball toward the target. The relatively higher variability in release angle values may suggest that this variable acts as the final actuator and as such may offer the last opportunity to determine or change shot trajectory. This may explain the increase in wrist angular displacement variability at release (figure 1).

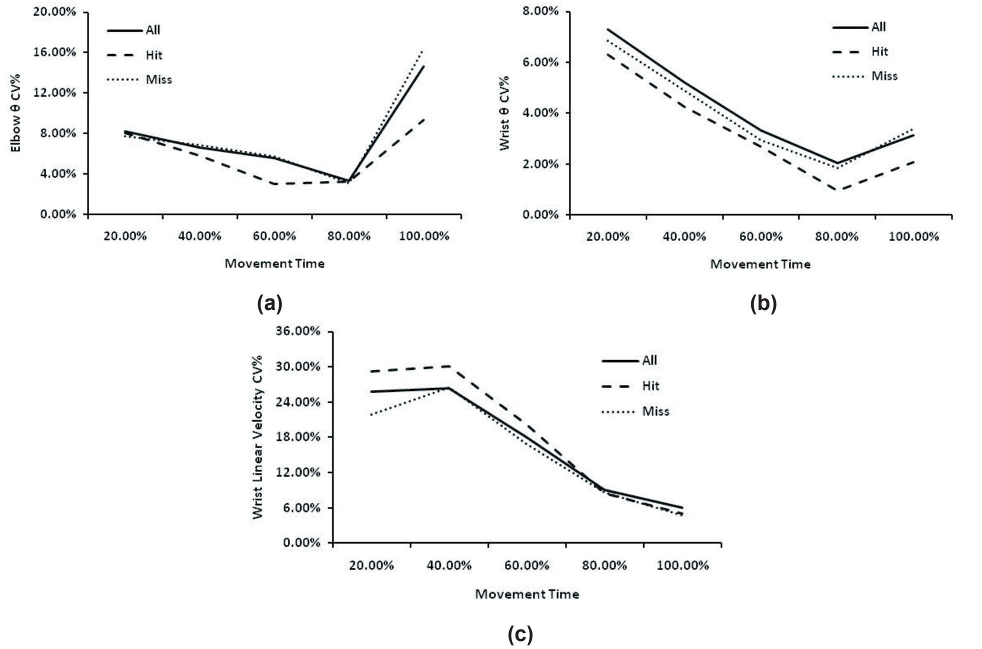

Figure 1: Mean coefficient of variation (CV%) traces for unsuccessful (Miss), successful (Hit) and combined trials (All) for (a) elbow angular displacement (Elbow θ), (b) wrist angular displacement (Wrist θ) and (c) wrist linear velocity.

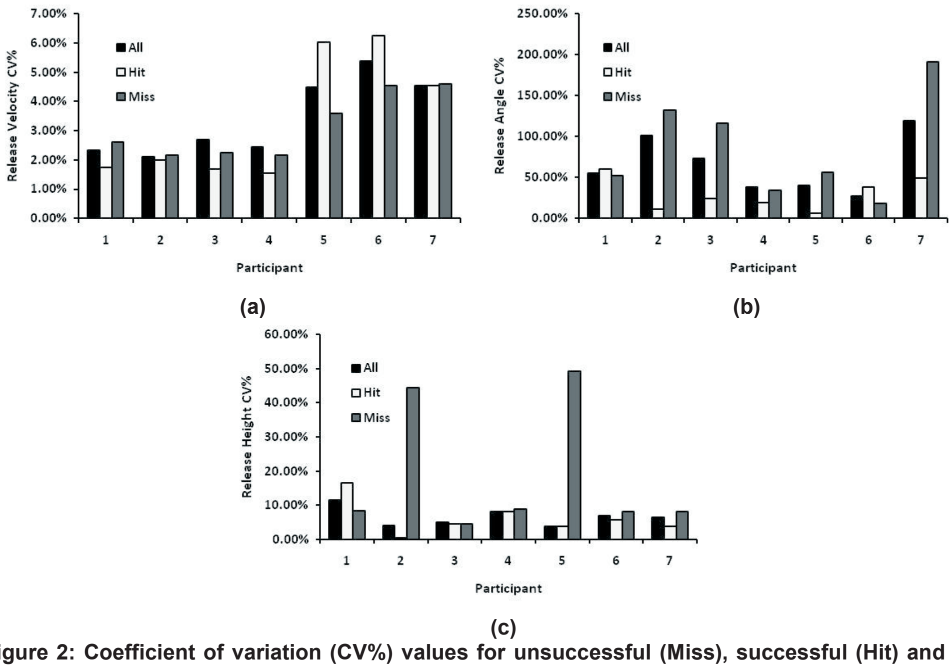

Figure 2: Coefficient of variation (CV%) values for unsuccessful (Miss), successful (Hit) and combined trials (All) for each participant for (a) release velocity, (b) release angle and (c) release height.

Results of coordination (cross correlation) analysis can be seen in table 1. There was a split in participant trends with four displaying strong coordination between the elbow and wrist joints and three exhibiting lower values. There was a trend toward higher correlation values and lower variability values for successful shots compared with unsuccessful trials as well as all trials combined. This suggests that coordination between the elbow and wrist is important for successful production of the water polo shot. Additionally, when considered with the variability traces presented (figure 1) it may provide support for theories of compensatory coordination, that is a compensatory relationship between the wrist and elbow where the wrist is able to correct for any errors the performer may detect in elbow displacement. The fact that all bar one participant exhibited a positive lag (correlation larger on a time delay) may provide further support for this. Moreover, this may be the mechanism by which participants were able to produce the consistent release parameters reported.

Table 1
Peak mean cross correlation coefficient (Max r), standard deviation (SD) and coefficient of variation (CV%) results for participants 1 – 7 for unsuccessful (Miss), successful (Hit; participant 6 had insufficient data for analysis) and combined trials (All)

	All			Hit			Miss		
	Max r	**SD**	**CV%**	**Max r**	**SD**	**CV%**	**Max r**	**SD**	**CV%**
1	.871	0.122	14.03%	.910	0.040	4.43%	.842	0.142	16.81%
2	.773	0.059	7.68%	.806	0.028	3.52%	.764	0.064	8.43%
3	.711	0.173	24.31%	.644	0.211	32.81%	.748	0.179	23.88%
4	.856	0.082	9.64%	.862	0.081	9.44%	.854	0.090	10.51%
5	.183	0.345	187.83%	.240	0.261	108.66%	.392	0.116	29.63%
6	.325	0.096	29.64%	-	-	-	.312	0.114	36.39%
7	.459	0.223	48.62%	.522	0.218	41.69%	.399	0.232	58.11%

CONCLUSION: This study sought to quantify the variability present in the kinematic and coordination variables of the throwing arm and ball release parameters during the water polo shot. Variability was present in all measures. The movement was characterised by lower variability in wrist kinematics at release and ball release variables, particularly for successful movements. Cross correlation results may provide evidence of compensatory coordination between the elbow and wrist joints. When assessing and instructing on shooting technique, practitioners may prioritise producing consistent release parameters to facilitate consistent outcomes as opposed to completely invariant (repeatable) techniques.

REFERENCES:

Atkinson, G., & Nevill, A. M. (1998). Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Medicine, 26*(4), 217-238.

Bartlett, R., Wheat, J., & Robins, M. (2007). Is movement variability important for sports biomechanists? *Sports Biomechanics, 6*(2), 224-243.

Bradshaw, E. J., Keogh, J. W. L., Hume, P. A., Maulder, P. S., Nortje, J., & Marnewick, M. (2009). The Effect of Biological Movement Variability on the Performance of the Golf Swing in High- and Low-Handicapped Players. *Research Quarterly for Exercise & Sport, 80*(2), 185-196.

Button, C., MacLeod, M., Sanders, R., & Coleman, S. (2003). Examining movement variability in the basketball free-throw action at different skill levels. *Research Quarterly for Exercise & Sport, 74*(3), 257-269.

Davids, K., Glazier, P., Araujo, D., & Bartlett, R. (2003). Movement systems as dynamical systems: the functional role of variability and its implications for sports medicine. *Sports Medicine, 33*(4), 245-260.

Fleisig, G., Chu, Y., Weber, A., & Andrews, J. (2009). Variability in baseball pitching biomechanics among various levels of competition. *Sports Biomechanics, 8*(1), 10-21.

Mullineaux, D. R., & Uhl, T. L. (2010). Coordination-variability and kinematics of misses versus swishes of basketball free throws. *Journal of Sports Sciences, 28*(9), 1017-1024.