BIOMECHANICS ANALYSIS OF WATER POLO THROWING

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The purpose of this study is to investigate the parameters of displacement, velocity, and acceleration of water polo over arm throwing. Six water polo athletes participated in this study. Kwon 3D was utilized to analyze arm movement of water polo shooting, including the displacement, velocity, and acceleration of wrist, elbow, shoulder, and ball. The results indicated, first, the displacement of arm movement was quadratic polynomial at a frequency of 0.6 second with maximum distance of 130.97 cm for ball, 117.17 cm for wrist, 107.04 cm for elbow, and 94.22 cm for shoulder. Second, the velocity of arm movement was a cubic curve with maximum speed of 25.368 m/s for ball, 20.092 m/s for wrist, 19.732 m/s for elbow, and 23.846 m/s for shoulder. Moreover, the change of maximum velocity of ball and wrist occurred after 1.5 seconds, while the velocity of elbow and shoulder both decreased for 0.5 seconds. Third, the acceleration of arm movement showed a 6^{th} order polynomial at a frequency of 0.2 second with maximum acceleration of 505.082 m/s^2 for ball, 545.526 m/s^2 for wrist, 401.82 m/s^2 for elbow, and 568.26 m/s^2 for shoulder.

KEY WORDS: Water Polo, Throwing, Kinematics, Biomechanics

INTRODUCTION: There are few contests still played since the beginning of the Olympic Games (1908). Water polo is one of them. This sport, similar to handball, is a competition of attack and defend between two teams in water and also is called 「water-football」. After about 100 years, Women's water polo made its Olympic debut during the 2000 Sydney Games. Water polo gets scores by throwing the ball into goal. So, players have to pass the ball as soon as possible to create opportunities to shoot the goal. It is clear that the players' skill and teamwork is necessary for this game. Water polo becomes more and more popular in Taiwan. Most swimmers are also Water polo's players because Water polo is such a diversified game.

Throw is a common action in all games, such as in football, baseball, handball, and canoe polo, the overarm throwing can be found all the time. Researches classify throw into underarm throw, sidearm throw, and overarm throw (Adrian & Cooper, 1995; Luttgens & Hamilton, 1997). Overarm throw is the most common way for Water polo players and has faster speed and better accuracy. (Adrian & Cooper, 1995; Cochrane et al., 1996; Ellitt & Armour, 1988; Sakurai, 2000). Researchers found that there are 90% pass movements done by overarm throw (Elliott & Armour, 1988). Therefore, how to enhance the throw power and speed in order to increase the chance to score is a very important topic for Water polo.

In order to analyze throw movement, it is necessary to understand the joint action among shoulder, elbow, wrist, and fingers. Upper extremity movement concludes shoulder, elbow, wrist, and fingers. Upper extremity movement is a recombination movement, every part is connected like chains. Upper extremity movemen can be classified into to type: open kinetic and close kinetic chain. Open kinetic chain can be presented as baseball's throw action and close kinetic chain can be presented as pull-up. This article will not discuss about close kinetic chain. There are two features in open kinetic chain: one is a rotation serial, and the other is backswing. When people do open kinetic chain, the power is proceeding from the former to next. In this situation, the former part becomes slower and the later part creates energy by the movement. So we can find that the sequence of throw is continuing movement from lower extremity, pelvis, trunk, shoulder, upperarm, forearm, to hand.

There is no research about Water polo overarm throw in Taiwan most researches are from foreign. It is because Water polo's researches have to be done in water. It is difficult to get the necessary equipments in Taiwan. When Water polo's players do the throw action, their feet have to do the eggbeater kick to keep their body erective. Therefore they can use single hand to throw the ball. The throw momentum is generated by the eggbeater kick, body, and acceleration of hand (Zatsiorsky et al., 1998). Elliott and Armour (1988) found that the Water

polo players' throw is done in the order of shoulder, elbow, and wrist. And when the ball leaves, the speed elbow and wrist became the maximum. Other research found that the Water polo's ball gets its speed from the throw arm and body's rotation (Feltner and Nelson, 1996).

This study is trying to find the Kinematics parameters of overarm throw of Taiwan's Water polo players. Hoping to get practical data to help coaches to train players.

The purposes of this study are as following:

1 Analysis the segment displacement of upper extremity during overarm throw in water polo player.

2 Analysis the segment velocity of upper extremity during overarm throw in water polo player.

3 Analysis the segment acceleration of upper extremity during overarm throw in water polo player.

METHODOLOGY:

Subject:

For the skilled male subject, a setter on the Taipei Physical Education College men's water polo team was selected. Six subjects had a mean age of 22 years, 174.7 cm heights and 75 kg weights. The kinematics parameter data were collected on water polo players during overarm throwing to investigate the relationship of ball, wrist, elbow and shoulder on these displacement, velocity and acceleration.

Laboratory set up:

Condition of Experiment: Figure 1 shows the condition of the experiment and the laboratory set up.

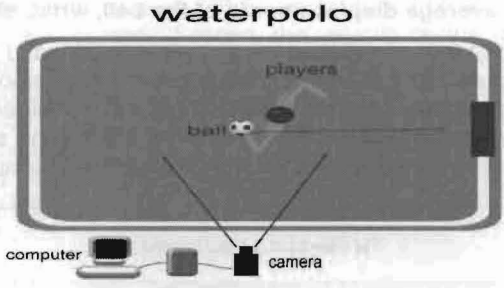

Figure 1 laboratory set up.

Procedure:

A high-speed video camera operating at 1000 Hz were synchronized to record the subjects performing the throwing movement in Water Polo players. Following a brief warm-up period, each subject was asked to perform five successful overarm throwing trials. It is four meter distance form goal to throwing position of subject.

Data Analysis:

Four landmarks of upper extremity (shoulders, elbows, wrists, and ball) were digitized with the Kwon 3D motion analysis system. The Butterworth function with the optimal filtering option was used to filter the row data. For the analysis we adopted a Cartesian reference system with "x" horizontal, in the direction of the throwing, "y" vertical upward. In this way we obtained a type of description of the trajectories that doesn't depend on the direction of the executed throwing. The coordinates (x and y) of each trajectory were fitted by a polynomial of 3-6th degree of time, allowing the calculation of the displacement, velocities and accelerations of the balls, wrist, elbow and shoulder.

RESULTS AND DISCUSSION: The raw data have been analyzed by Kwon 3D motion analysis software and which results shown in Figure 2,3 and 4. Every figure showed the kinematic parameters of the mean values extracted from five shoots by each six athletes. It was showed that the displacements of the ball, wrist, elbow and shoulder all were nearly

quadratic curves in Figure 2 and which maximum displacement were about 130.97, 117.17, 107.04 and 94.22 cm respectively. Note that the maximum displacement changes were taken place after 1.5 second and which duration were 0.6 second.

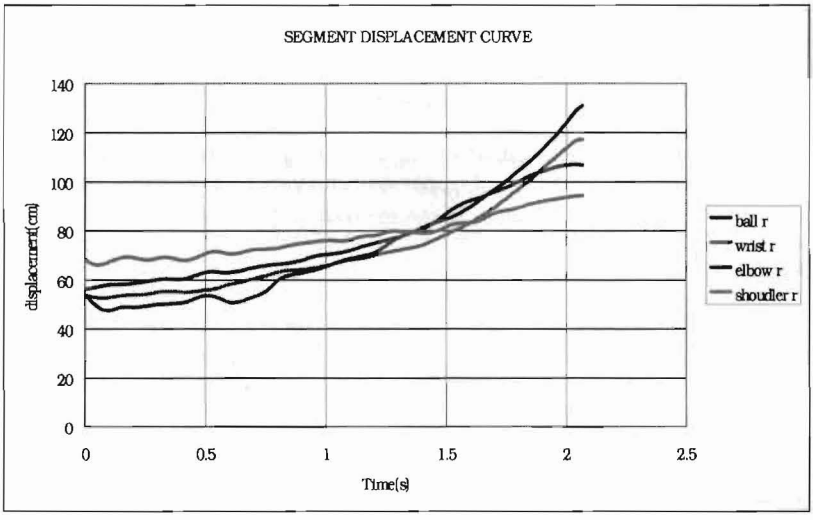

Figure 2 The average displacements of the ball, wrist, elbow and shoulder.

It was also showed that the velocities of the ball, wrist, elbow and shoulder all approximated to cubic curves in Figure 3 and which maximum velocity were about 25.386, 20.092, 19.732 and 23.846 m/s respectively. The maximum velocity of the ball and wrist were taken place after 1.5 second, and the velocity derivations of the elbow and shoulder were opposite to negative derivations. The duration from the maximum velocity changes taken place were 0.5 second.

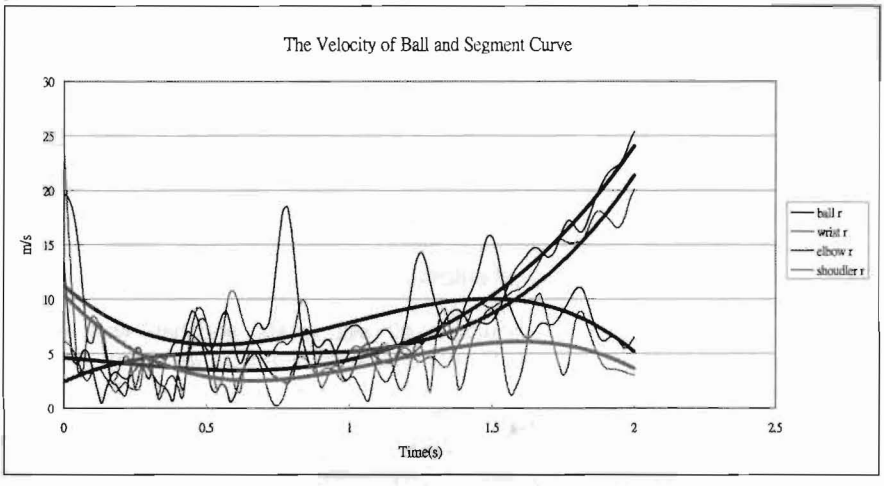

Figure 3 The velocities of the ball, wrist, elbow and shoulder, solid lines mean average value.

The Figure 4 showed that the accelerations of the ball, wrist, elbow and shoulder approximate to six order curves and which maximum accelerations were about 505.082, 545.526, 401.82 and 568.26 m/s^2 respectively. Note that the maximum acceleration changes were taken place after 1.8 second and which duration were only 0.2 second.

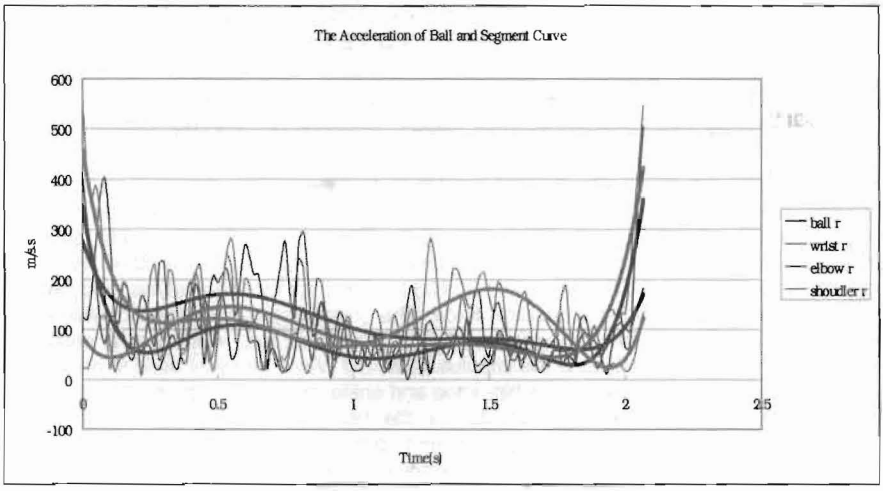

Figure 4 The accelerations for the ball, wrist, elbow and shoulder, solid lines mean average value.

CONCLUSION: In this study the conclusions were as follows:first, the displacement of arm movement (i.e. polo ball, wrist, elbow, and shoulder) was quadratic polynomial at a frequency of 0.6 second with maximum distance of 130.97 cm for ball, 117.17 cm for wrist, 107.04 cm for elbow, and 94.22 cm for shoulder. Second, the velocity of arm movement was a cubic curve with maximum speed of 25.368 m/s for ball, 20.092 m/s for wrist, 19.732 m/s for elbow, and 23.846 m/s for shoulder. Moreover, the change of maximum velocity of ball and wrist occurred after 1.5 seconds, while the velocity of elbow and shoulder both decreased for 0.5 seconds. Third, the acceleration of arm movement showed a 6^{th} order polynomial at a frequency of 0.2 second with maximum acceleration of 505.082 m/s^2 for ball, 545.526 m/s^2 for wrist, 401.82 m/s^2 for elbow, and 568.26 m/s^2 for shoulder.

REFERENCES:

Adrian, M.J., & Cooper, J.M. (1995). *Biomechanics of Human Movement* (2^{nd} ed.). Madison, Wisconsin: Brown & Benchmark.

Cochrane, D., Hemsley, S., & Farrance, J. (1996).*Level one canoe polo coaching manual.* Australian: Australian Canoeing Ine.

Elliott, B.C., & Armour, J. (1988).The penalty throw in water polo: a cinematographic analysis. *Journal of Sports Sciences,* 6, 103-114.

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.

Luttgens, K., & Hamilton, N. (1997).*Kinesiology: Scientific basis of human motion* (7^{th} ed.). Boston:WCB/McGraw Hill.

Sakurai, S. (2000). Motion analysis of overhand throwing: past, present, and future. In Y. Hong, & D. P. Johns (Eds.), *Proceedings of the XVIII International Symposium on Biomehanics in Sports* (pp. 13-19).Hong Kong:Chinese University of Hong Kong.

Whiting, W. C., Puffer, J. C., Finerman, G. A., Gregor, R. J., & Maletis, G. B. (1985). Three-dimensional cinematographic analysis of water polo throwing in the elite performers. *The American Journal of Sports Medicine,* 13 (2), 95-98.

Zatsiorsky, J. E., Steiner, L. A., & Petruska, A. J. (1995). Overhead throwing and other related motions. In M. J. Kelley, & W. A. Clark (Eds.), *Orthopedic Therapy of the Shoulder* (pp.371-406). New York: Lippincott Williams & Wilkins.