RELATIONSHIP BETWEEN THE BALL VELOCITY AND UPPER EXTREMITY KINEMATICS DURING AN OVERARM THROWING SELF-PRACTICE PROGRAM

Gizem Ozkaya[1] Mi Sun Kim[1] Hye Ree Kim[1] Seong Jun Kim[1] Ki Kwang Lee[1]

Department of Physical Education, Kookmin University, Seoul, South Korea[1]

The purpose of this study was to investigate the relationship between the ball velocity and upper extremity kinematics in inexperienced individuals during a 5 weeks self-practice overarm throwing. Seven women participated in this study. Participants performed 15 overarm throwing 3 days in a week for 5 weeks. The relationship between the ball velocity and the first-last week overarm throwing upper extremity kinematics data (maximum angles and angular velocities) were statistically analyzed using Spearman's rho. Results showed there was weak to moderate relationship for both maximum angles and angular velocities of trunk, shoulder, and elbow. Rotational movements of upper extremities should be prioritized at the early stages of throwing skills acquisitions.

KEY WORDS: Self-practice, overarm throwing, ball velocity.

INTRODUCTION: Throwing like movements are extensively use in sports. It is a complex skill because of the involvement of multiple joints even though it can be seen as a simple task. It has been reported that learning relies highly on sensory feedback during the practices (Magill & Anderson, 2014). Other studies also showed that learning without feedback (knowledge of result or performance) were also possible and the human body has the skill to find needed corrections through the task demonstrations (Swinnen, 1996). Furthermore, feedback dependency can affect the performance poorly especially if the attention goes farther from the task itself (Kluger & DeNisi, 1996; Magill & Anderson, 2014). It was reported that the principles proposed for the simple tasks cannot be fully applicable for the complex tasks (Wulf & Shea, 2002), therefore creates a need for extensive studies for more complex skills to understand the skill acquisition.

The aim of this study was to investigate the relationship between the kinematic parameters and ball velocity during a self-practice program without any feedback. It was hypothesized that participants were able to make alterations in their technical skill even without any kind of feedback. Therefore, the relationship between the ball velocity and the kinematical parameters can give useful information about which movements should be prioritized at the early stage of overarm throwing skill acquisition.

METHODS: Seven women with no experience on any throwing activity participated in the study (Age: 25.1 ± 2.4 years, Height: 160.8 ± 3.5 cm; Weight 56.5 ± 7.8 kg). Participants were asked to refrain any kind of feedback or training throughout this study.

Participants visit the laboratory for three days with one day rest between test sessions for five weeks. Only the first and fifth week data were analyzed for this study. A ten cameras Vicon motion analysis system (T-10, T40, Oxford Metrics Ltd, UK) were used for motion capture at 200 Hz sampling rate. A 14 segment model consisted of hands, forearms, upper arms, trunk, pelvis, thighs, shanks, and feet were created for each participant (Visual3d, version 5, C-Motion, USA). However, dominant hand throws and lower extremity results were not reported in this study.

Participants performed 15 overarm throwing for the non-dominant side in every practice-test session. They were asked to throw the ball "as fast as possible" to the foam cushion approximately 4 m away from the participant. Participants performed overarm throws at their comfortable standing position. Total 45 overarm throwing were recorded for each subject and week. Ball speed also was measured 3 meters away behind the subjects and recorded for every trial. First 3 throws and trials with gimbal lock occurrences were not included for analysis.

Calculated angles were filtered by a low-pass fourth order Butterworth filter with a 13.4 Hz as suggested before by other researchers for baseball pitching (Chu, Fleisig, Simpson, &

Andrews, 2009; Escamillia et al., 2007; Fleisig, Barrentine, Zheng, Escamilla, & Andrews, 1999).
International Society of Biomechanics (ISB) recommendations were used to define all upper body segments' joint centers and local coordinate systems (Wu et al., 2005) except the wrist local coordinate system (Rao, Bontrager, Gronley, Newsam, & Perry, 1996).
Shoulder angles were described in order as the plane of elevation *(Y')*, elevation *(X)* and axial rotation *(Y'')*. Elbow angles were described as flexion – extension *(Z)*, carrying angle *(X)* and pronation-supination *(Y)*. Wrist angles were described as flexion – extension *(Z)* ulnar – radial deviation *(X)*, pronation – supination *(Y)*. Thorax angle relative to the globe coordinate system were described as lateral flexion, axial rotation, and flexion – extension.
Joint angular velocities defined according to the parent segment for each joint. All data normalized to 101 points and maximum values for each variable used for statistical analysis.
Maximum angles of trunk lateral flexion of the throwing side, trunk external rotation, trunk extension, humeral elevation, the humeral plane of elevation posteriorly, humeral external rotation, elbow flexion and wrist extension were reported for each throwing side.
Maximum angular velocities of trunk lateral flexion to the contralateral side, trunk internal rotation, trunk flexion, humeral elevation, humeral plane of elevation anteriorly, humeral internal rotation, elbow extension, and wrist extension were reported for each throwing side.
A Shapiro-Wilk test was used to investigate the normal distribution of the data set. A Spearman's rank order correlation test used to investigate the relationship between the kinematic variables and ball velocity because of the violation of normal distribution assumption.

RESULTS: Mean ball velocity for the first and last week was 38.7 ± 3.8 km/h and 41.3 ± 7.2 km/h, respectively. There was a relationship between some of the kinematic variables and the ball velocity for dominant and non-dominant side (Table 1).

Table 1
Spearman's Rank Order Correlation coefficients of ball velocity vs. kinematic variables

	First Week (n = 233)		Last Week (n = 244)	
	r_s	*p*	r_s	*p*
Maximum angles				
Trunk lateral flexion[a]		NS	-.243	.000
Trunk rotation[b]	.216	.001	.318	.000
Trunk Extension	.189	.004	.493	.000
Humeral plane of elevation[c]		NS		NS
Humeral elevation[d]	.222	.001		NS
Shoulder external rotation		NS	-.180	.005
Elbow flexion		NS		NS
Wrist extension		NS		NS
Maximum angular velocities				
Trunk lateral flexion [aa]		NS	.266	.000
Trunk rotation[bb]		NS	.276	.000
Trunk flexion		NS	.341	.000
Humeral plane of elevation[cc]	-.280	.000	.169	.008
Humeral elevation[dd]		NS	.316	.000
Shoulder internal rotation	-.158	.000	.142	.027
Elbow extension	.291	.000	.470	.000
Wrist flexion	-.238	.000		NS

a: Lateral flexion to throwing side; aa: Lateral flexion to contralateral side;b: External rotation to throwing side; bb: Internal rotation to contralateral side;c: Humeral plane of elevation to posteriorly; cc: Humeral plane of elevation to anteriorly;d: Humeral elevation to posteriorly (extension); dd: Humeral elevation to anteriorly (flexion)

At the first week, maximum trunk rotation angle, shoulder elevation angle and elbow extension angular velocity showed a positive weak relationship with ball velocity while maximum trunk extension showed a very weak positive relationship with ball velocity.

Maximum angular velocities of humeral plane of elevation, wrist flexion showed statistically negative weak relationship with ball velocity. Only the shoulder internal rotation maximum angular velocity showed a negative very weak relationship with ball velocity.
Only maximum trunk lateral flexion and shoulder external rotation angle showed negative weak and very week relationship with ball velocity at the last week, respectively. Maximum angular velocities of humeral plane of elevation and shoulder internal rotation showed a very weak positive relationship with ball velocity at the last week. Maximum trunk rotation angle and maximum angular velocities of trunk lateral flexion, trunk rotation, trunk flexion, humeral elevation showed a positive weak relationship with ball velocity. Only the maximum trunk extension angle and elbow extension maximum angular velocities showed a moderate positive relationship with ball velocity at the last week.

DISCUSSION: It was expected that participants will show their sole representation of their kinesthetic information in time for faster throws and provide important information about the motor control during complex skills.
Participants showed highly similar throws with baseball pitching. Therefore, baseball studies were used for evaluating the performance of this study. There are extensive studies about baseball pitching (Chu et al., 2009; Escamilla, Fleisig, Barrentine, Andrews, & Moorman, 2002; Escamilla, Fleisig, Barrentine, Zheng, & Andrews, 1998; Werner, Suri, Guido, Meister, & Jones, 2008; Wilk, Meister, Fleisig, & Andrews, 2000).
It was reported that different pitches resulted with differences on kinematic parameters and pitchers are tend to use different patterns for better performance (Escamilla et al., 1998; Wilk et al., 2000). Fleisig et al. (1999) reported that there was no difference for angle position and temporal parameters according to different level baseball players. However, higher level pitchers throw with higher angular velocities for the torso, shoulder, and elbow (Fleisig et al., 1999). Higher level pitchers were able to produce greater joint forces and torques. Therefore, higher ball velocities were seen with the increased level (Fleisig et al., 1999).Higher body mass, maximum shoulder external rotation, and elbow extension angular velocity was reported to relate with ball velocity (Werner et al., 2008). Escamilla et al. (2002) reported that athletes used higher maximum pelvis angular velocity, maximum shoulder external rotation angle to reach higher ball velocities (Escamilla et al., 2002). Trunk is especially an important segment because of its high torque production and the transfer of this force to other segments is essential for better performance (Lin et al., 2003).
Maximum angle of trunk rotation and trunk extension showed very weak relationship at the first week which is contradicted with literature. However, participants were showed a weak to moderate relationship for trunk angles which is a sign to use the trunk in a more efficient way by using its range of motion.
In our study, participants showed negative relationships with maximum angular velocities at the first week which is contradicted with the literature. It can be explained as that the participants were not able to effectively use their segment movements‘ velocity relative to each other at the start of the study. The positive relationship between the angular velocities and ball velocity at the last weeks can be interpreted as participants were able to effectively used their segments velocity and have a positive effect on ball velocity. Furthermore, it is known that rotational movement of shoulder and trunk is important for better performance during throwing. However, sagittal movements of segments showed a moderate relationship with ball velocity while rotational movements showed weak relationships. Participants mostly relied on sagittal plane movements during throwing and were not able to effectively performed with rotational movements.

CONCLUSION: Participants were able to use their segments more effectively at the end of the five weeks' self-practice program. Participants mostly rely on sagittal movements. Therefore, coaches should emphasize rotational movements at the early stages of skill acquisition because it is hard to improve their role with only kinaesthetic information without any feedback. Also, coordination studies should be conducted for a full approach to the skill acquisition while performing throwing movements.

REFERENCES:

Chu, Y., Fleisig, G. S., Simpson, K. J., & Andrews, J. R. (2009). Biomechanical comparison between elite female and male baseball pitchers. *Journal of Applied Biomechanics*, *25*(1), 22–31.

Escamilla, R. F., Fleisig, G., Barrentine, S., Andrews, J., & Moorman, C. (2002). Kinematic and Kinetic Comparisons between American and Korean Professional Baseball Pitchers. *Sports Biomechanics*, *1*(2), 213–228.

Escamilla, R. F., Fleisig, G. S., Barrentine, S. W., Zheng, N., & Andrews, J. R. (1998). Kinematic comparisons of throwing different types of baseball pitches. *Journal of Applied Biomechanics*, *14*(1), 1–23.

Escamillia, R., Barentinne, S., Fieisig, G., Naiquan, Z., Takada, Y., Kingsiey, D., & Andrews, J. (2007). Pitching biomechanics as a pitchers approaches muscular fatigue during a simulated baseball game. *American Journal of Sports Medicine*, *35*(1), P. 22-33.

Fleisig, G. S., Barrentine, S. W., Zheng, N., Escamilla, R. F., & Andrews, J. R. (1999). Kinematic and kinetic comparison of baseball pitching among various levels of development. *Journal of Biomechanics*, *32*(12), 1371–1375.

Kluger, A. N., & DeNisi, A. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin*, *119*(2), 254–284.

Lin, H., Su, F., Nakamura, M., Chao, E. Y. S., Lin, H.-T., Su, F.-C., … Su, F. C. (2003). Complex chain of momentum transfer of body segments in the baseball pitching motion. *Journal of the Chinese Institute of Engineers*, *26*(6), 861–868.

Magill, R. A., & Anderson, D. (2014). *Motor learning and control: Concepts and applications* (10th editi). New York: McGraw-Hill.

Rao, S. S., Bontrager, E. L., Gronley, J. K., Newsam, C. J., & Perry, J. (1996). Three-dimensional kinematics of wheelchair propulsion. *IEEE Transactions on Rehabilitation Engineering*, *4*(3), 152–160.

Swinnen, S. (1996). Information Feedback for Motor Skill Learning: A Review. In H. Zelaznik (Ed.), *Advances in Motor Learning and Control* (pp. 37–66). Champaign, IL: Human Kinetics.

Werner, S. L., Suri, M., Guido, J. A., Meister, K., & Jones, D. G. (2008). Relationships between ball velocity and throwing mechanics in collegiate baseball pitchers. *Journal of Shoulder and Elbow Surgery*, *17*(6), 905–908.

Wilk, K., Meister, K., Fleisig, G., & Andrews, J. R. (2000). Biomechanics of the overhead throwing motion. *Sports Medicine and Arthroscopy Review*, *8*(2), 124–134.

Wu, G., Van Der Helm, F. C. T., Veeger, H. E. J., Makhsous, M., Van Roy, P., Anglin, C., … Buchholz, B. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion - Part II: Shoulder, elbow, wrist and hand. *Journal of Biomechanics*, *38*(5), 981–992.

Wulf, G., & Shea, C. H. (2002). Principles derived from the study of simple skills do not generalize to complex skill learning. *Psychonomic Bulletin & Review*, *9*(2), 185–211.

Acknowledgement

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2013S1A5A2A03045819).