KINESIOLOGICAL ANALYSIS OF OVERARM THROWING FOR ACCURACY WITH DOMINANT AND NON-DOMINANT ARMS

Ziheng Ning, Ana Faro[1], Doody Sue[2] and Nancy Hamilton'
Macau Polytechnic Institute, Macao
[1]University of Coimbra, Coimbra, Portugal
'University of Northern Iowa, Cedar Falls, USA

The main aim of this study was to examine differences kinematically between dominant and non-dominant overarm throws for accuracy. Fourty-nine right-handed primary school students served as the subjects who were requested to make overarm throws with dominant and non-dominant arms. A three-dimensional Motion Analysis System was used to collect all kinematic data of overarm throwing while performance errors were recorded by a video camera. Performance errors and kinematic variables of right and lefl hands were compaired with Paired t-test and the relation among performance errors and kinematic variables was evaluated with canonical correlation. It was found that significant differences in the accuracy existed between dominant and non-dominant overarm throws. The dominant hand shows much better throwing performance in terms of accuracy. Kinematic analysis also indicated that there were significant differences in velocity and acceleration even though there was a great similarity in the timing of velocity and acceleration in overarm throws for accuracy.

KEY WORDS: kinesiology, overarm throw, dominant arm, non-dominant arm

INTRODUCTION: Differences in accuracy between dominant and non-dominant overarm throwing are observed easily. Biomechanical factors have been considered widely to attribute to the difference of throwing accuracy between dominant and non-dominant arm throws. Fetz (1995) found that accuracy of the dominant hand was strongly significantly higher than that of the non-dominant hand in both sexes. Williams (1996) concluded that in the overarm throw for force, the non-dominant arm exhibited coordination patterns and performances typical of an unpracticed performer. Few studies were found where differences were examined kinematically in this type of overarm throw. Therefore, the purpose of this study was to measure differences between dominant and non-dominant overarm throws with respect to kinesiological variables and to investigate the contribution of selected biomechanical factors, which may be important factors in distinguishing from differences between dominant and non-dominant overarm throwing.

METHOD: Fourty-nine primary school students aged from twelve to fourteen year old participated the testing following informed consent. All subjects were right-hand dominant based on the subject's own assessment according to the questionnaire of handedness. Dominant and non-dominant hands then are referred to right and left hands in the study.
The task for the subjects in the test was to make a movement of standing overarm throw (Fleisig 1996) to the designated target with the same spatial accurate requirement. The subjects were required to throw a tennis ball (50-55 grams) to the centre of the target. The target with four-meter diameters was placed 8.00 meters away from the subject's standing position. The ranking order of accuracy from centre to the outside is 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10. Only the accuracy of the throwing, not the speed of the throwing was emphasized in the entire testing.
In the testing, all subjects were required to make 10 overarm throwing trials with each hand. Overall performance of ten trials was assessed by Radial Error (RE). Constant Error (CE), Variable Error (VE). RE represents the average score on the target of ten throw trials. CE indicates the signed deviation from the center of the target that represents both the amount and direction of the error. VE is a calculated score, and represents the variability, or consistency, of the subject's movement (Magill 1994). Twenty one 20-mm ball sized reflective markers were attached on both right and left sides of the body at fourteen anatomical landmarks in order to collect data for the film. The throwing movement was

filmed and tracked from the time of starting throwing until after the ball release. Four electronically synchronized 60-hertz (Hz) CCD cameras were located in separate corners of the filming area. A three-dimensional automatic digitizing system (Motion Analysis Corporation, Santa Rosa, CA) was used to quantify each throw's motion. Paired T-tests, simple correlation, and canonical correlation were employed to analyse biomechanical differences and the relationship between dominant and non-dominant overarm throwing with statistical software SPSS 8.0. The alpha level was set to 0.05.

RESULTS AND DISCUSSION: Paired t-test (two-tailed) showed significant differences among RE, CE and VE between dominant (right) and non-dominant (left) overarm throws as shown in Table 1. The results indicated that performance of the dominant hand was much better than that of the non-dominant hand. RE, CE and VE with dominant side accounted for 60.31%, 26.77% and 66.67% of those with the left side. However the results of a Pearson correlation showed that performance errors correlated with each other within each hand. The analysis showed that dominant overarm throws come out with better constant and variable radial errors. It was also shown there was strong correlation among three variables of performance errors between right and left arms in overarm throw. Correlation between radial errors of two hands is 0.47, $p<0.01$, which indicates that the radial errors between dominant and non-dominant overarm throw influenced each other positively in overarm throws for accuracy. One of the aims of this investigation was to test the hypothesis that differences in accuracy between dominant and non-dominant hands might be related to lateral differences in kinematic variables of overarm throws, especially in velocity and acceleration of arm segments. None of the correlations between performance errors and kinematic variables make explicit predictions about accuracy in overarm throws between dominant and non-dominant hands according to Pearson and canonical correlation, which leads to a conclusion that the level of velocities of different arm segments has little influence on the accuracy in overarm throw. Then it is implied that the accuracy of overarm throws is not alone a function of kinematic parameters, it also is related with motor control and motor coordination.

Table 1 Performance Errors between Dominant and Non-dominant Overarm Throw

Parameter	Dominant throw M±SD	Non-dominant Throw M±SD	Correlation R	Paired t-test T
Radial Error (RE)	4.94± 1.49	8.19Q.07	0.47**	11.99**
Constant Error (CE)	0.83±2.75	-3.10±3.47	-0.28	-5.51**
Variable Error (VE)	4.94k1.44	7.41Q.51	0.18	6.50**

Note: $*P<0.05$, $**P<0.01$

Kinematic measures typically describe a movement's position in space, velocity, and acceleration. From Table 2, it was found that there are significant differences existing on the maximum velocities and accelerations of different arm segments between dominant and non-dominant throws. These variables of velocities and accelerations are significantly correlated with each other although Paired t-test shows very significant differences among them. To further study the relationship among velocities of each arm segment and between the velocities of different arm segments in dominant and non-dominant throws, canonical correlation was used to assess the relation between two sets of velocity variables from each arm. As shown in figure 1, the canonical correlation analysis on maximum velocities of arm segments between dominant and non-dominant hands indicated canonical correlation between the first pair of canonical variables was significant, $Rc=0.697$, $P<0.01$. Canonical correlation between two sets of maximum velocities of different arm segments of dominant and non-dominant arms indicated that significance of canonical variates is very dependent on those velocity variables with higher canonical loading coefficients, thus in the first pair of canonical variates I (CV1 and CV2), CV1 is correlated with the first set of the velocity variables in right overarm throw while CV2 associates with the second set of velocity variables in left overarm throw. It is concluded that the correlation between maximum velocities of different arm segments in right and left overarm throws is mainly the correlation between MBV of right arm and MBV of left arm. That confirmed further that release velocity of ball (MBV) of dominant overarm throw is highly correlated with that of non-dominant overarm throw, $R=0.61$, $P<0.01$.

Table 2 Kinematic comparison between dominant and non-dominant overarm throws

Parameter	Right Hand M±SD	Left Hand M±SD	Correlation R	Paired t-test T
Max. ball velocity (MBV)	12.21k1.98	10.49f1.33	0.61**	-7.67**
Max. hand velocity (MHV)	9.00k1.34	8.52k1.01	0.12	-2.15'
Max. wrist velocity (MWV)	7.86±1.47	7.18kO.96	0.32'	-3.20**
Max. elbow velocity (MEV)	5.17k0.96	4.79k0.94	0.38**	-2.51'
Max. shoulder velocity (MSV)	2.40±0.76	2.20k0.68	0.27	-1.66
Max. ball acceleration (MBA)	128.26±30.19	101.94±23.05	0.60**	-7.47**
Max, hand acceleration (MHA)	180.27±46.47	161.93k34.09	0.49**	-3.04**
Max. wrist acceleration (MWA)	151.75±41.49	123.98k30.06	0.39**	-4.79**
Max. elbow acceleration (MEA)	77.82k19.42	63.32±17.99	0.22	-4.35**
Max. shoulder acceleration (MSA)	44.65±25.10	35.52±18.07	0.04	-2.10'

Note: $^*P<0.05$, $^{**}P<0.01$

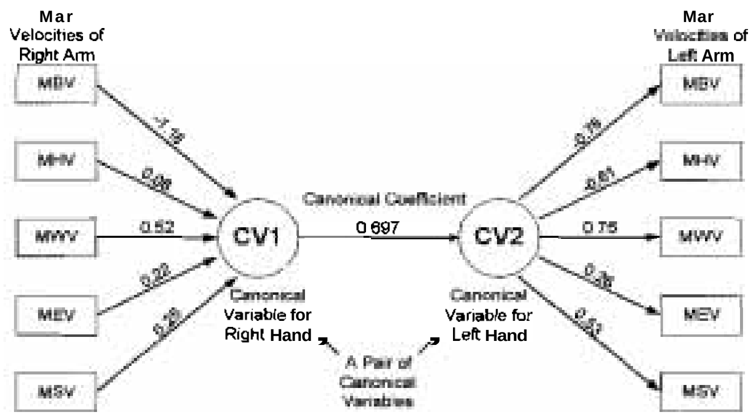
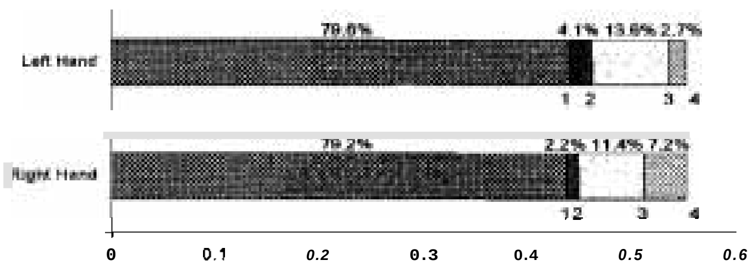


Figure 1 - Path diagram of Canonical Correlation Analysis on maximum velocities of different arm segments between dominant and non-dominant throws

The difference between hands was not found in the timing of velocity and acceleration between the dominant and non-dominant hands. Paired T-test has shown that none of T values is statistically significant, $P>0.05$ between the dominant and non-dominant side's varibles. The duration of overarm throwing for both hands is about 0.55 seconds in this study which is much longer than that reported from Atwater (1979). It was reported that the entire upward and forward arm swing takes less than 400 msec to complete before release in his study. Time of the movement highly depends on the demands the goals of a throw either in speed or accuracy. It is expected the throw duration appears to be longer than those focusing on speed. On the other hand, it was found that kinematic difference between right and left hands lies on the significant differences both in velocity and accelerations. Similarity in velocity timing and acceleration timing does not affect the fact that significant differences existed both in performance error measures and kinematic measures. The fact that dominant overarm throw has better performance errors with higher velocities and accelerations than non-dominant overarm throw indicates that the advantage of control and coordination does indeed exist in the movement of dominant hand. Figure 2 shows another way to look at the timing of velocity between right and left hand. It is assumed that studying the timing of velocities of different arm segments is much more direct than the methods used in previous literature (Atwater 1979). The main difference of velocity timing between dominant and non-dominant overarm throw comes from the difference of time (KT) between the timing of maximum wrist velocity (SMWV) and the timing of maximum ball velocity (SMBV) in each hand. This difference of timing in right hand accounted for 7.2% of the duration of the throw while in left hand it accounts for only 2.7% of total movement time of the throw. Paired t-test was applied to the timing differences. KT of right hand was much longer that of the left hand, they were 0.035 ± 0.03 sec and 0.016 ± 0.03 sec respectively, $T=3.17$, $P<0.01$. The result of the Paired T-test indicated that there was a significant difference of KT in the velocity timing between dominant and non-dominant overarm throw. It may imply that a longer period of time (0.02 sec) in right hand than left hand for the dominant hand allowed the arm itself to be able to accelerate the ball to higher velocity with better control and coordination. There was only 0.016 sec for the left hand to accelerate itself to high level of ball release velocity. Since this period of time might be too short for the left arm to reach high ball release velocity in order to throw the ball high enough into the target, it may cause some difficulties for the left hand to throw the ball to the target with high performance.



Note : 0-1 The time from start of throwing to shoulder reaching mar velocity.
a-2 The time from start of thmwing to elbow reaching mar velocity.
0-3 Tha lime from start of throwing to wrist reaching mar velocity.
0-4 Tha lime from start of throwing to ball reaching mar velocity.

Figure 2: An illustration of the Timing Comparison of Right & Left Arms

CONCLUSION: The difference between the dominant hand and non-dominant hand was found primarily in velocities and accelerations of different arm segments in the overarm throw. The patterns in overarm throws were similar in many perspectives between dominant and non-dominant overarm throws, especially in the velocity and acceleration timing of different arm segments. There was less time for the non-dominant arm to achieve high velocity in order to throw the ball to the target which may have caused some difficulties to optimize the performance. It may be an important reason that the non-dominant overarm throw has poor performance both in accuracy and speed.

REFERENCES:

Atwater, A. E. (1979). Biomechanics of overarm throwing movements and of throwing injuries. Exercise and Sporf Science Review, 7, 43-85.

Fetz, F. & Jaeger, B. (1995) Development of throwing accuracy. Sporfonomics (Muenchen); I(1), 17-26.

Fleisig, G. S.. Barrentine, S. W., Escamilla, R. F. & Andrews, J. R. (1996). Biomechanics of overhand throwing with implications for injuries. *Sports* Medicine (Auckland, N.Z.), 21, 421-437.

Williams. K, Haywood, K. M. & Painter, M. .A. (1996). Environmental versus biological influences on gender differences in the overarm throw for force: dominant and non-dominant arm throws. Women-in-Sporf and Physical Activity Journal, 5(2), Fall 1996, 29-48.