AN ANALYSIS OF THE THROWING TECHNIQUE OF COLLEGE MALE JAVELIN THROWERS IN A COMPETITION

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The purposes of this study were to investigate the throwing technique for Japanese college male athletes in official competitions, focusing on the torso and throwing arm motions, and to obtain basic information for the improvement in their techniques. Twenty-four male college throwers were videotaped and analysed for their throwing motion using the three-dimensional DLT method and caluclated the joint angle. The throwers were divided into three groups based on their records. Comparison to the ELITE throwers, the timing of the torso rotation for college groups was delayed. Significant differences in the right shoulder horizontal abduction angle around the left foot touchdown among the three groups were found. These results imply that the right shoulder horizontal abduction may be one of the factor determining throwing distance as well as early torso rotation. The discussion suggested that the concept change from the late rotation to the early rotation of the torso for the college male javelin throwers would result in a large horizontal abduction and a quick horizontal adduction of right shoulder.

KEYWORDS: javelin throw, averaged motion, improvement of technique

INTRODUCTION: The javelin throw is one of the throwing events in athletics. The javelins used in competitions are the lightest (male, 800 g; female, 600 g) and longest (male, 2.6-2.7 m; female, 2.2-2.3 m) gear for throwing events, and this event is sensitive in aerodynamic and technical senses. Therefore, several studies on the javelin throw have examined aerodynamic relationships between release parameters and throwing distance, and have focused on throwing techniques. Hubbard et al. (1987) investigated optimal conditions for the maximum throwing distance by computer simulation. Notomo et al. (1998) created the averaged motions of elite, club and novice throwers, and revealed that there were differences in several joint angles and the torso rotation, especially the timing of the torso rotation. Ae et al. (1999) suggest that the rotation of the torso about a vertical axis should be effectively used in javelin throwing. Some javelin throw coaches for varsity clubs in Japan considered from their coaching experience that the torso would be a base of the motion of the throwing arm. Although Liu et al. (2010) reported the male and female elite javelin thrower did not follow a proximal-distal sequence, there would be no divergence of opinion about the importance of the torso motion which precedes the motion of the throwing arm in javelin throw. In other words, it can be said that differences in the torso rotation would have some effect on the motion of the throwing arm in college javelin throwers and their throwing distance as a result. To make coaching for college javelin throwers effective, it is necessary to investigate their actual throwing techniques in real competitions. However, there is very little information of technique for college throwers. Therefore, the purposes of this study were to investigate the throwing technique for Japanese college male athletes in official competitions, focusing on the torso and throwing arm motions, and to obtain basic information for the improvement in their techniques. The hypothesis of this study, which is based on the literatures cited above and coaches' experience is that the torso rotation of college throwers would be slower in timing, which could not induce sufficient motion of the throwing arm.

METHODS: Twenty-four male college throwers who participated in an official competition were videotaped with two high-speed video cameras (AX-700, SONY) which were synchronized by the event method. The camera speed was 120 frames/s and the exposure time was 1/1000 second. Their throwing motion that achieved the best record at the competition was analysed.

Twenty-three points on the body and two points on the javelin (top and rear ends of the grip) were manually digitised by an experienced digitiser with using Frame-DIAS V (DKH, Co., Japan). Three-dimensional coordinates data of the digitised points were obtained using the three-dimensional DLT method. The three-dimensional coordinate data were smoothed by a Butterworth low-pass digital filter at the optimum cut-off frequencies (from 3.6 to 9.6 Hz) determined by the residual method (Winter, 2009). The right-handed coordinate system was set with the throwing direction being the Y axis, the X axis being the right direction to the Y axis, and Z axis being the vertical direction. The mean calibration errors were 0.013 m in the X (lateral) direction, 0.012 m in the Y (throwing) direction and 0.006 m in the Z (vertical) direction. The joint angles and torso angles obtained in this study were the right elbow extension/flexion, shoulder horizontal adduction/abduction, shoulder horizontal rotation for the throwing arm and inclination and rotation angles of the torso (Kobayashi et al., 2012). Based on the records at the competition, the throwers were divided into three groups (higher, n=6, 66.59$\pm$2.43 m; middle, n=13, 58.00$\pm$2.43 m and lower, n=5, 51.55$\pm$0.27 m). The averaged motions for the three groups were created by the method of Ae et al. (2007), and that of the ELITE throwers cited from Notomo et al. (1998) was used as a reference. The coordinates data and joint angle data were normalized each to 100% from the instant of the right foot touchdown (R-on) to the left foot touchdown (L-on) as the first half of the delivery phase, and from the left foot touchdown to the javelin release (Rel) as the second half. The Kruskal-Wallis H test was performed to test differences among three groups of college throwers, followed by multiple comparisons by Mann-Whitney U test. The significance probability level for the test of the difference in the mean was set less than 5%.

RESULTS: Figure 1 shows the stick pictures of the averaged motion for the three groups and the ELITE group as a reference. There was a clear difference in the timing of the torso rotation between the ELITE group and the college throwers. The ELITE group rotated their torso before L-on, while the college throwers rotated after L-on.

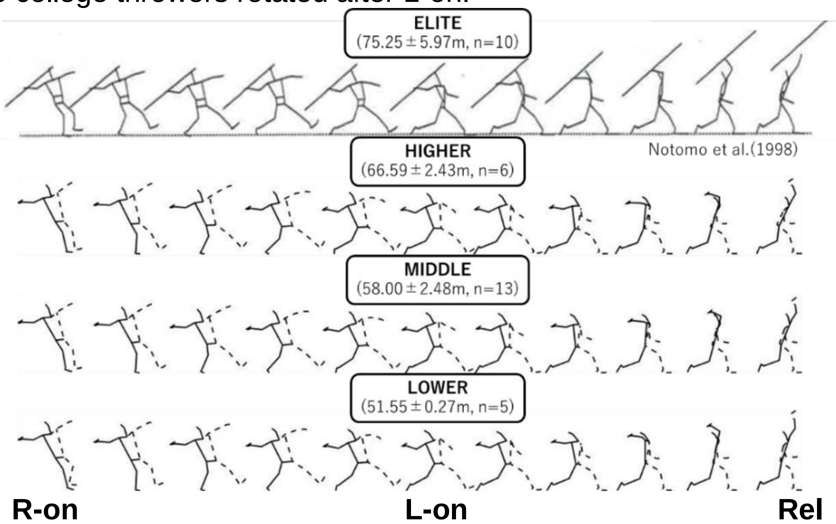

Figure 1: Stick pictures of ELITE, higher, middle and lower groups.

Figure 2 shows the change in the right shoulder horizontal adduction/abduction angle for the three groups. The figure on the left shows the first half of the delivery phase (from R-on to L-on), and the right shows the second half (from L-on to Rel). The results of the test of the differences were shown on the figure as circles, triangles and diamonds. Significant differences among three groups were confirmed at 76-100 % (p= 0.004 to 0.044) in the first half phase and 1-30 % (p= 0.004 to 0.046) in the second half phase. Although it should be noted that normalizing the phase times loses absolute time information and may cause distorsion of the timing of motion, there was still the significant difference in the right shoulder horizontal adduction/abduction angle among the three groups at L-on even in absolute time. The right shoulder horizontal abduction angle was larger as the performance level, i.e. throwing record, increased.

Figure 3 shows the angle-angle diagram of the right shoulder horizontal adduction/abduction angle and the torso rotation angle (shoulder horizontal rotation angle) for the three groups. The asterisks on lines indicate the division of the first and second halves. From the first half of the delivery phase to just after the start of the second half, the right shoulder horizontally abducted as the torso rotated to the left direction. It was likely that two angles changed in a mutually related manner. In the second half, throwers of the higher groups greatly abducted the right shoulder horizontally.

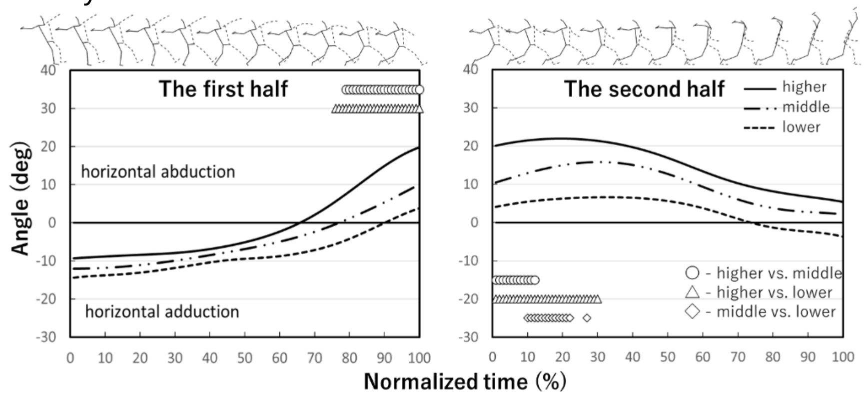

Figure 2: Changes in the right shoulder horizontal adduction/abduction angle for three groups.

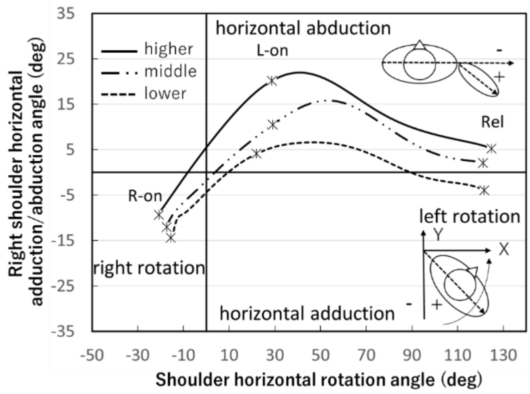

Figure 3: The angle-angle diagram on the shoulder horizontal rotation and right shoulder horizontal adduction/abduction for three groups.

DISCUSSION: Compared with the ELITE group, the timing of the torso rotation was delayed in the college throwers as they rotated their torso after L-on. This may be attributed to the difference in a concept of the javelin throwing technique between the ELITE and the college throwers. Ae et al. (2008) stated that the trunk should be rotated during the second half of the delivery phase to effectively transfer the mechanical energy generated by the joint torques, and such a rotation would be induced by the body position during the first half of the delivery phase. The ELITE throwers took advantage of the speed gained during run-up, while the college throwers could not. The college throwers may have a concept that the throwing motion should begin after L-on. The change in the concept of throwing for college throwers will be helpful to improve their performance, that is from a relatively stational and power-type throwing technique to a technique of effective use of the speed gained during run-up like the ELITE group did (Murakami et al., 2006).

The significant differences were confirmed in the right shoulder horizontal adduction/abduction angle around the L-on, and the horizontal abduction angle was larger in the higher group. Mero et al. (1994) suggested the importance of using the stretch-shortening cycle of the shoulder and arm muscle groups in the javelin throw. A greater horizontal abduction of the right shoulder may elicit a stretching-shortening cycle effect by stretching the muscle involved in the throwing motion such as the pectoralis major. Tauchi et al. (2012) pointed out the arm angle (the angle between the line connecting the right shoulder and the grip in the horizontal plane and the

horizontal lateral direction) was an important factor of the javelin throw. Therefore, this indicated that the greater horizontal abduction of the right shoulder around L-on in the javelin throwing motion was one of the factors determining the throwing distance. The fact that there were significant differences in the horizontal abduction angle of the right shoulder around the L-on could be considered as a critical feature of the college male javelin throwers and a technical point to be improved.
There seemed to be a relationship between the torso rotation and the right shoulder horizontal abduction, as shown in Figure 3. From the first half to just after the start of the second half, the right shoulder horizontal abduction occurred as the torso rotated toward the left, counter-clockwise direction. This torso rotation may induce a motion-dependent force at the right shoulder joint. The centripetal force due to the torso rotation generates a moment of horizontal adduction of the upper arm, whereas the tangential force generates a moment of horizontal abduction. The stick pictures of the ELITE group show that they began to rotate the torso greatly just before L-on. Therefore, it is inferred that the ELITE throwers had a greater angular acceleration of the torso, which may have caused a moment to horizontally abduct the right shoulder before L-on. Following this, the ELITE group may have enabled to use to adduct the right shoulder horizontally and quickly in the second half of the delivery phase. On the other hand, the college throwers of the higher group may have used a motion-dependent force to abduct the right shoulder horizontally by accelerating the torso after the L-on, making up for their lack of muscle strength of the shoulder. However, they could not adduct the right shoulder horizontally so quickly as the ELITE groups because of the delayed timing of the torso rotation, as mentioned previously.

CONCLUSION: Based on the result and discussion, it can be inferred that the concept change from the late torso rotation to the earlier timing of torso rotation would be needed for the college male javelin throwers in this study, which would result in a large horizontal abduction and a quick horizontal adduction of the right shoulder, and lead to the improvement in the technique. Further investigation on the timing of torso rotation and the motion of the throwing would be needed from both correlation analysis and mechanical viewpoints.

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