A BIOMECHANICAL ANALYSIS OF COMPETITIVE AND RECREATIONAL PLAYERS IN RELATION TO THE DARTS THROWING TECHNIQUE

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The aim of this study was to clarify the difference of the darts throwing motion (technique) between competitive (CG) and recreational (RG) groups. The darts throwing motions for each group were analyzed using an automatic motion capture system and force platforms. The performance (distance) of CG was statistically superior to RG. Shoulder and elbow joint movement indexes were smaller in CG than in RG. CG threw the dart with the static position that body weight was mostly distributed to the forward leg. However, RG started from the static position that distributed two thirds of body weight on the forward leg, and subsequently threw the dart while transmitting most of the remaining body weight from backward leg to forward leg. It is concluded that CG had the less movement of body segments involved in the darts throwing motion to achieve a high level of performance.

KEY WORDS: performance, joint movement index, GRF

INTRODUCTION: The location where a thrown dart will land on the dartboard depends on the combinations of position, speed and direction of motion at the moment that it is released (Smeets, Frens & Brenner, 2002). These parameters arise directly from variations in timing of release and speed of throwing hand (Burke & Yeadon, 2009). However, movement of the throwing hand results from the movements of more proximal segments, such as forearm and upper arm of the throwing arm, and even trunk and lower limb segments. Thus, due to having the structure of a human body as a multi link-segment system, such variations should be precisely controlled or interact with all body segments in order to achieve a high level of darts performance.

Based on an observation of darts throwing motion for the skilled player, the shoulder and elbow of throwing arm stay in an almost fixed position while the forearm and hand of throwing arm moves in a circular path around them. This observation indicates that the shoulder and elbow of throwing arm is crucial as a pivot of throwing arm or trunk to rotate about, as similar as the movement of the shoulder of non-throwing arm in baseball pitching (Murata, 2001).

The purpose of the present study was to clarify the difference of the darts throwing motion between competitive and recreational players, from a practical viewpoint. We hypothesized that the competitive players would perform with less movement of the shoulder and elbow joints of throwing arm, and lower limbs (legs) in order to achieve a high level of performance.

METHODS: Nine right-handed male darts players (age 21.9±2.1 yrs, standing height 1.73±0.07 m, mass 72.6±7.7 kg) participated in this study after giving informed consent. The participants were divided into a competitive group (CG) with four subjects and a recreational group (RG) with five subjects, according to their self-reported experience with playing darts. CG had an experience as a competitor for 1.5 years, whereas RG had no experience as a competitor, and had only thrown darts a few times for a year.

All subjects threw a dart (regulation mass 20 g) 45 times aiming at the center of the dartboard, placed at the official distance (2.44 m) and height (1.73 m), with giving sufficient time to recover between 15 sets (three throws per set per subject). Two-dimensional coordinates of the location that the thrown dart landed on the board were directly measured for each subject, and the distance values (referred to as performance) from the center of board to the location were calculated. For each subject, only five throws closest to the average value of the performance of 45 throws were selected for subsequent analysis.

Three-dimensional coordinates of 45 spherical reflective markers (14 mm diameter) attached to the body and two reflective tapes attached to the dart were recorded at 250 Hz using nine MX-T20 cameras with an automatic motion capture system (VICON, Vicon Motion Systems Ltd., UK). Ground reaction force (GRF) data synchronized with the motion capture system were collected at 1,000 Hz using two force platforms (type 9287B, Kistler Instruments, Switzerland). A high-speed digital video camera (Phantom V311, Vision Research Inc., USA)

operating at 2,000 Hz, set at the lateral side of the subject, was used to determine at the moment that the dart left the throwing finger (i.e., release).
The coordinates of the reflective markers were smoothed using quintic spline functions (Woltring, 1986) with optimal cutoff frequencies (ranges: 4-25 Hz) determined by the residual analysis method (Winter, 1990). In order to calculate the body center of gravity for each subject, anthropometric segmental data for the subjects were estimated from the standing height and body mass of each subject using de Leva's (1996) adjustments of the values reported by Zatsiorsky, Seluyanov & Chugunova (1990).
To examine the differences of the throwing motion between the two groups, we calculated the shoulder and elbow joint movement (displacement) indexes (respectively, SJM and EJM indexes) of the throwing arm side based on the method reported by Murata (2001). The SJM and EJM indexes (unit less) can be expressed in the equation (1) as follows:

$$JM = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_i - x_m\right)^2 + \left(y_i - y_m\right)^2 + \left(z_i - z_m\right)^2} / h \qquad (1)$$

where x_i, y_i, and z_i are each coordinate for the shoulder or elbow joints, x_m, y_m, and z_m are mean values, and h is the standing height of each subject. N represents the number of frames in the period of time for the analysis.
We calculated the movement of the forward/backward direction for the body center of gravity, and the mean pattern of the forward/backward and vertical components of the GRF, normalizing for the subject's body weight (BW). All kinematic and kinetic parameters were analyzed in the period of time from the instant of 0.7 s before the instant of release (REL) of the dart to the REL. The instant of 0.7 s means the moment that pulled the throwing forearm backward against the dartboard. Kinematic and kinetic parameters were calculated from the five throws for each subject, and these data were subsequently averaged.
Unpaired Student's t-test and Pearson product-moment correlation coefficient performed using SPSS version 20 (SPSS Inc., Chicago, IL) to assess the differences and correlations in the calculated parameters between the two groups. Significance levels were set at $p < .05$ for each test.

RESULTS: Typical examples of 45 locations that the thrown dart landed on the dartboard for each group were shown in Figure 1. Mean values of the performance for the 45 throws were significantly smaller in CG than in RG (mean±SD 28.5±6.7 mm vs. 81.3±19.4 mm, $p < .01$). Standard deviation (SD) values of the performance for the 45 throws were also significantly smaller in CG than in RG (17.2±3.0 mm vs. 48.3±12.0 mm, $p < .01$).
All SJM and EJM indexes (×10^{-3}) including x, y and z directions for each index were significantly smaller in CG than in RG as follows: CG 3.4±1.2 vs. RG 13.4±4.5 for SJM ($p < .01$), 1.2±0.6 vs. 3.2±1.3 for SJMx ($p < .05$), 2.5±1.4 vs. 12.0±4.8 for SJMy ($p < .01$), and 1.6±0.7 vs. 4.3±0.5 for SJMz ($p < .001$); 6.0±2.9 vs. 25.0±9.2 for EJM ($p < .01$), 1.7±0.7 vs. 8.1±3.9 for EJMx ($p < .05$), 1.8±1.2 vs. 15.0±6.5 for EJMy ($p < .01$), and 5.2±3.1 vs. 17.1±7.7 for EJMz ($p < .05$). Figure 2 shows that the relationships between these indexes and performance for combined group and for each group. All indexes for the combined group were significantly correlated with the performance ($p < .01$). Six indexes except SJMz, and EJMy for the CG were significantly correlated with the performance ($p < .01$, or $p < .05$). Four indexes except SJM, SJMy, SJMz, and EJMx for the RG were significantly correlated with the performance ($p < .01$, or $p < .05$).
The movement of the forward/backward direction for the body center of gravity was significantly smaller in CG than in RG (5±3 mm vs. 30±21 mm, $p < .05$). Time-history patterns of the forward/backward GRF and of the vertical GRF for each group were shown in Figure 3. All patterns and values of the CG were different from that of the RG.

DISCUSSION: Both mean and SD values of the performance for the 45 throws of the CG were significantly smaller than that of the RG. These differences indicate that the CG had

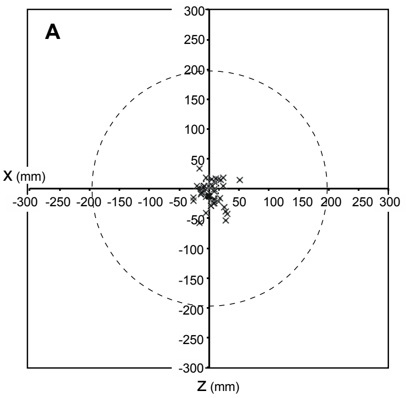

Figure 1: Typical examples of 45 locations that the thrown dart landed on the board in a competitive player (A) and a recreational player (B). Two circular dotted lines represents the outer bulls eye and double ring, respectively.

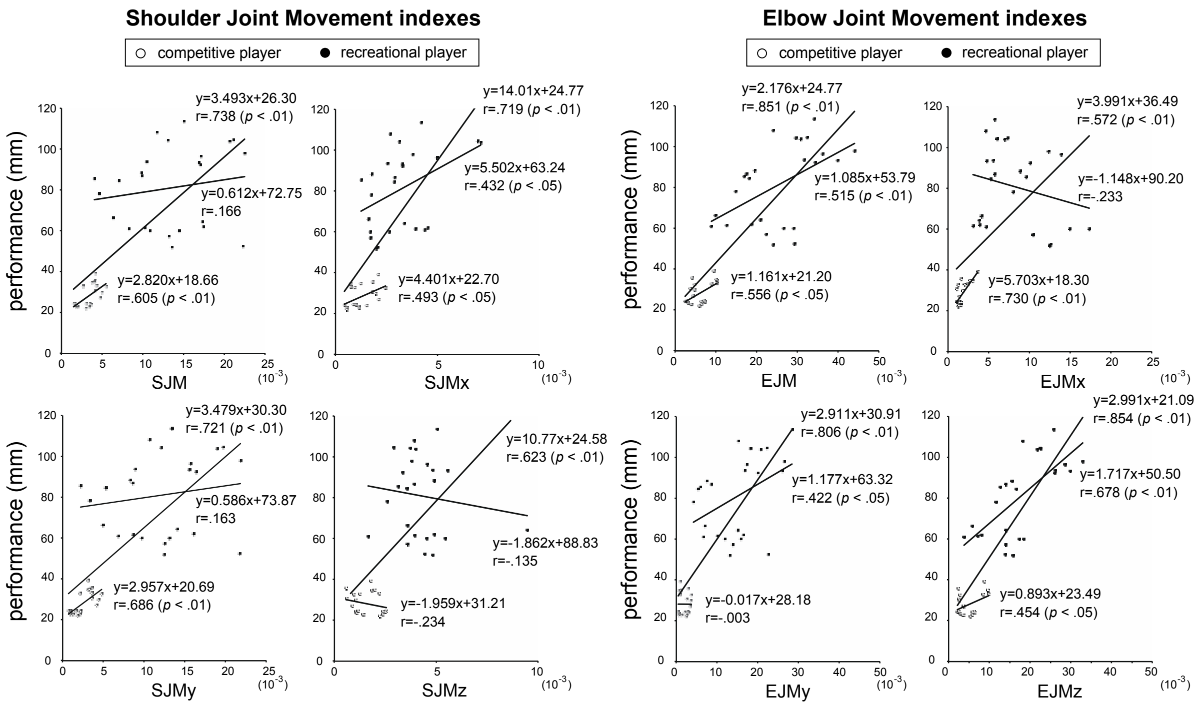

Figure 2: Relationship between SJM (left side) and EJM (right side) indexes.

attained an accuracy and reproducibility to achieve a good performance.

The data show that all SJM and EJM indexes for the CG were significantly smaller than that for the RG. Particularly, the remarkable differences were found in the indexes SJMy (CG 2.5±1.4 vs. RG 12.0±4.8, $p < .01$) and EJMy (6.0±2.9 vs. 25.0±9.2, $p < .01$) between two groups. Since the SJM and EJM indexes can be considered as an indicator of the variability of movement as shown in equation (1), the CG threw the dart with movement for the throwing shoulder and elbow joints than in the RG.

The movement variability of the throwing shoulder and elbow joints comes from the movement of the trunk and/or lower leg segments that stay in an almost stabilized position during the throw. So, we examined the movement of the forward/backward direction for the body center of gravity that would be affected to the indexes SJMy and EJMy among the

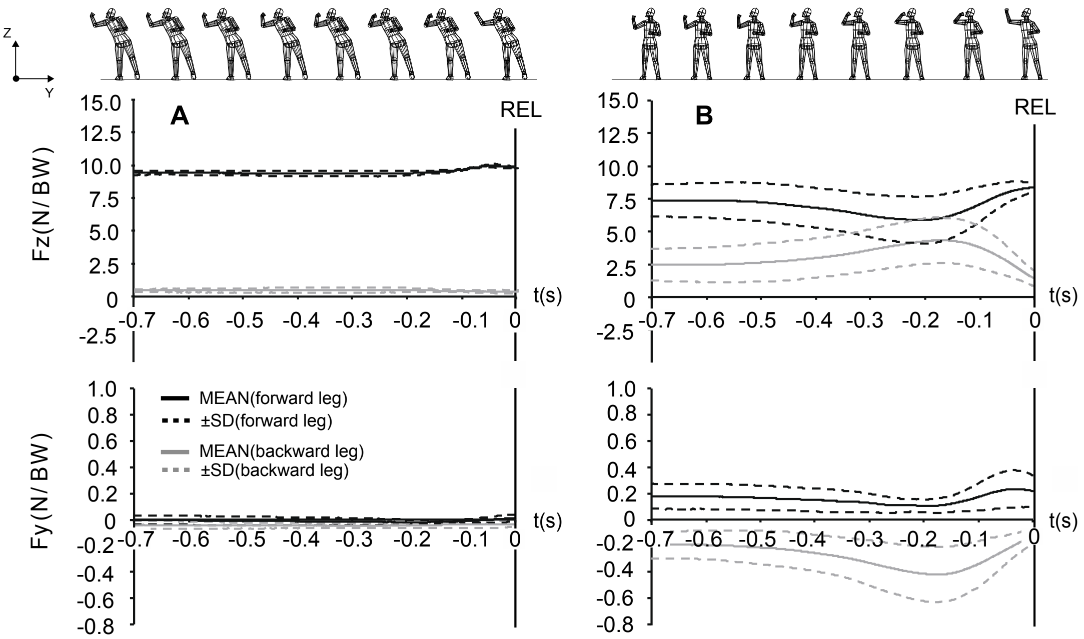

Figure 3: Time-history patterns of forward/backward GRF (Fy) and of vertical GRF (Fz) acting on each leg from the ground in the competitive group (A) and the recreational group (B). Time is expressed relative to the instant of release (REL: 0 s). The illustration in each above figure shows a typical example of dart throwing form in each group.

groups. As expected, this movement in the CG was significantly smaller than in the RG.
The movement of the forward/backward direction of the body center of gravity, on the other hand, arises from the GRF generated by pushing forward/backward against the ground with both legs. The remarkable differences were found in the time-history patterns of the forward/backward GRF and of the vertical GRF between two groups (Figure 3). These results indicate that CG threw the dart with the static position that body weight mostly distributed to the forward leg, while RG started from the static position that distributed two thirds of body weight to forward leg, and subsequently threw the dart while transmitting most of the remaining body weight from backward leg to forward leg.

From the practical viewpoint, it will be necessary to conduct a further experiment using the unskilled player in order to verify the evidence that is obtained from the present study. It will become an experiment that compares the darts throwing motions before and after the technical instruction.

CONCLUSION: The present study has clarified difference in darts throwing motion between different skill level players. It was concluded that competitive players had attained high performance by means of less movement of the throwing shoulder and elbow joints as well as the lower limb (leg) segments. From the practical viewpoint, the evidence that is obtained from the present study would be useful to improve the darts throwing performance for the unskilled player.

REFERENCES:

Burke, D. J. & Yeadon, M .R. (2009). A comparison of compensation for release timing and maximum hand speed in recreational and competitive darts player. *Proceedings of the 27th Conference of the International Society of Biomechanics in Sports,* pp.154-57.

Murata, A. (2001) Shoulder joint movement of the non-throwing arm during baseball pitch-comparison between skilled and unskilled pitchers. *Journal of Biomechanics,* 34, 1643-47.

Smeets, J.B.J., Frens, M.A. & Brenner, E. (2002) Throwing darts: timing is not the limiting factor. *Experimental Brain Research*, 144, 268-74.