COMPARISON OF WORLD ELITE AND JAPANESE ELITE THROWERS IN THE DISCUS THROW

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The aim of this study is to clarify the differences between world elite and Japanese elite discus throwers by comparing their hip-shoulder and shoulder-arm separation angles. The performances of 12 male world elite discus throwers (the World group) and 12 male Japanese elite discus throwers (the National group) were analysed. The hip-shoulder and shoulder-arm separation through the throwing motion were greater in the World group than in the National group. Although the shoulder led hip in both the World and National groups, the shoulder led the arm in the National group and the arm led the shoulder in the World group at release. These results showed that the World group released the discus in front of the shoulder while utilising the kinematic-chain appropriately, while the National group released the discus with the arm still trailing behind the shoulder.

KEY WORDS : athletics, three-dimensional analysis, hip-shoulder separation, shoulder-arm separation, kinematic chain

INTRODUCTION: Japan's level of performance in the discus throw is low by global standards. Because of this, Japanese discus throwers rarely participate in international competitions. It seems that physical and technical factors are responsible for the differences in the distance thrown between world elite and Japanese throwers. Japanese elite throwers are smaller than world elite throwers (Maeda et al., 2018), which means improvements in physical strength and the development of better throwing technique are needed to compensate for their size disadvantage. To identify the technical changes needed to enhance the performance of Japanese discus throwers, the throwing motion of world elite and Japanese throwers must be compared. However, few studies have compared the throwing motion of world elite and Japanese throwers. In previous studies, discus release velocity was reported to be the most important factor contributing to long throws (Bartlett, 1992; Hay, 1985; Hay and Yu, 1995). Furthermore, hip-shoulder and shoulder-arm separation angles were also found to be related to horizontal discus release velocity (Hay, 1985; Stepanek, 1990). Therefore, this study aims to clarify the differences between world elite and Japanese elite throwers in the discus throw by comparing their hip-shoulder and shoulder-arm separations.

METHODS: The subjects of this study were 12 male world elite discus throwers (the World group) and 12 male Japanese elite discus throwers (the National group). The throwers in the World group were participants in the 11th World Championships in Athletics; the throwers in the National group participated in official competitions held in Japan. Two digital video cameras (SONY, HVR-AJ1, Tokyo, Japan) were used to record the throwing motion of the World group at 60 fields/s with a shutter speed of 1/2000s. Three high-speed cameras (CASIO, EX-F1, Tokyo, Japan) were used to record the throwing motion of the National group at 300 frames/s with a shutter speed of 1/1000s or 1/2000s. The cameras were placed

behind (coronal) and alongside (sagittal) the throwers. The throwing motion from each subject's best performance in the competition was used for analysis. The three-dimensional DLT method was applied to collect three-dimensional coordinate data of the endpoints of 15 body segments. The coordinate data were smoothed with a Butterworth digital filter. Cut-off frequencies ranging from 3.6 to 9 Hz were determined from the residual analysis method of Winter (1990). The discus's velocity, angle and height at release were obtained mathematically at the moment of release. The hip-shoulder and shoulder-arm separations were calculated as angles between virtual vectors joining the digitised hip joint centres, shoulder joint centres and a line running from the shoulder joint centre to the elbow joint centre. The definitions of the hip-shoulder and shoulder-arm separation angles are given in Figure 1. The throwing motion is divided into five phases: 1) the double support phase (DSP); 2) the first single support phase (SSP1); 3) flight phase (FP); 4) the second single support phase (SSP2) and 5) the delivery phase (DVP), consisting of six critical events: 1) maximum backswing (BS); 2) right-foot take off (R-off); 3) left-foot take off (L-off); 4) right-foot touchdown (R-on); 5) left-foot touchdown (L-on) and 6) release (Rel). Partition of normalised data was calculated based on the ratio of turn time in each phase (DSP: 40%, SSP1: 26%, FP: 7%, SSP2: 12% and DVP: 15%). Student's t-test was performed to identify the differences in the distance thrown, release velocity, release angle, and release height between the World and National groups. The significance level was set at $\alpha = 0.05$. Video data of the World group were collected by the biomechanics research group of Japan Association of Athletics Federations.

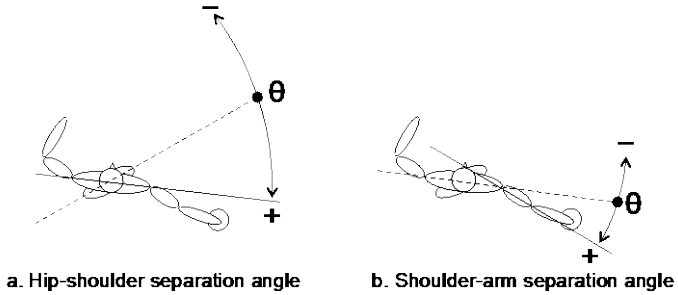

Figure 1: Definitions of the hip-shoulder and shoulder-arm separation angles.

RESULTS: Table 1 shows the mean and standard deviation of the distance thrown, release velocity, release angle, and release height. The distance thrown, release velocity, and release height were significantly greater in the World group than in the National group.
Figure 2 shows the average patterns of the hip-shoulder and shoulder-arm separations during the throwing motion. The hip-shoulder separation during SSP1 was close to 0 degrees in the National group. The hip-shoulder separation after R-on was greater in the World group than in the National group. From immediately before release to the time of release, the absolute value of the hip-shoulder separation was greater in the National group than in the World group. Only in the World group did the shoulder-arm separation reach a negative value just before release. The times of the local maximum value of hip-shoulder separation during SSP2 and the local maximum value of shoulder-arm separation in DVP differed between the World and the National groups. In the World group, hip-shoulder separation reached its local maximum in the later half of the throwing motion, hip-shoulder separation reached the local maximum in the middle of SSP2, and shoulder-arm separation reached its local maximum around L-on. In the National group, in contrast, the local maximum value of hip-shoulder separation occurred in the first half of SSP2 and that of shoulder-arm separation appeared in the middle of DVP.

Table 1: Comparison of distance thrown and release parameters in the World and National groups

	World Group (n = 12)	National Group (n = 12)	Statistical difference
Distance Thrown (m)	64.55 ± 2.17	53.18 ± 2.43	World > National***
Release Velocity (m/s)	23.66 ± 0.39	21.94 ± 0.58	World > National***
Release Angle (deg.)	35.04 ± 1.81	36.07 ± 2.54	n.s.
Release Height (m)	1.91 ± 0.10	1.62 ± 0.09	World > National***

***: $p < 0.001$

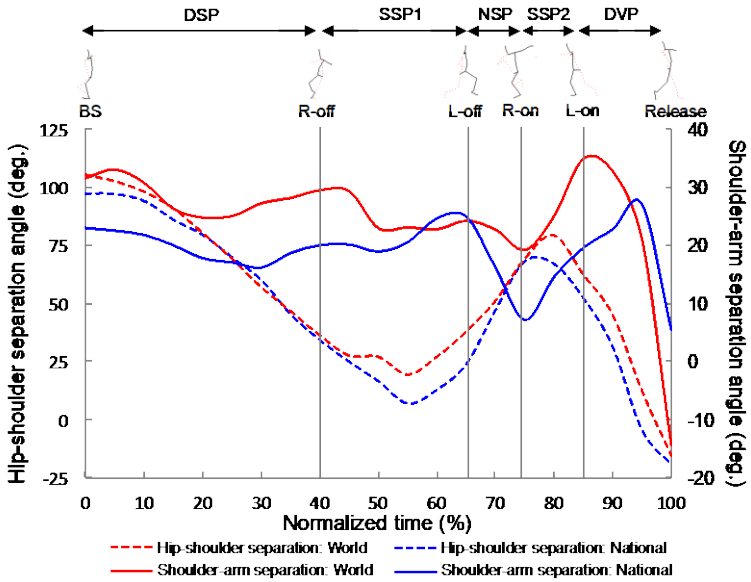

Figure 2: Average patterns of the hip-shoulder and shoulder-arm separation angles during the throwing motion

DISCUSSION: The distance thrown and release velocity were significantly greater in the World group than in the National group. Since release velocity is the most important contributor to the distance thrown (Hay, 1985; Hay and Yu, 1995), improved release velocity is needed for the National group to improve its long throws.

The hip-shoulder and shoulder-arm separations are related to horizontal discus release velocity (Hay, 1985; Stepanek, 1990). It is important for throwers to apply the force to the discus for the longest time possible because release velocity is increased throughout the throwing motion by the force throwers apply to it (Hay, 1985). A longer path means force is applied to the discus for a longer time (Bartlett, 1992; Hay, 1985), and a longer horizontal path can be achieved with greater hip-shoulder and shoulder-arm separations (Leigh and Yu, 2007). In our findings, the hip-shoulder and shoulder-arm separation angles were greater in the World group than in the National group approximately throughout the throwing motion. These results showed that the World group could apply force to the discus for a longer time than the National group. Therefore, release velocity and the distance thrown were larger in the World group than in the National group. The results of the times of the local maximum value of hip-shoulder and shoulder-arm separations indicated that throwers in the World group swung their throwing arm immediately after untwisting their trunk and the throwing arm was posterior to the shoulder after untwisting the trunk, while throwers in the National group swung the throwing arm from the middle of DVP. From these findings, we can conclude that throwers in the World group seemed to utilize the kinematic chain more appropriately than those in the National group. In addition, while the shoulder led the hip in both groups, the shoulder led the arm at release in the National group while the arm led the shoulder in the

World group. Although the optimum hip-shoulder and shoulder-arm separations have been identified as 0 degrees (Knicker, 1990), the results of the present study do not support this recommendation, and we will argue that the optimum hip-shoulder and shoulder-arm separations at release are not always 0 degrees. However, release of the discus when the throwing arm has travelled past parallel may reflect both flawed technique and overreliance on arm strength (Knicker, 1990). From this, we can conclude that the throwing arm was posterior to the shoulder in the National group because the timing of the onset of arm swing was late. This problem seems to be a persistent technical habit in the National group.

CONCLUSION: The aim of this study was to clarify the differences between world elite and Japanese elite throwers in the discus throw by comparing hip-shoulder and shoulder-arm separations. The hip-shoulder and shoulder-arm separations were greater in the World group than in the National group throughout the throwing motion. Hip-shoulder separation reached its local maximum in the middle of SSP2, and the shoulder-arm separation reached its local maximum around L- for the World group. In contrast, in the National group, the local maximum of the hip-shoulder separation occurred in the first half of SSP2 and that of the shoulder-arm separation angle appeared in the middle of DVP. While the shoulder led the hip in both groups, the shoulder led the arm at release in the National group, while the arm led the shoulder in the World group. These results indicated that throwers in the National group failed to utilise the kinematic chain and released the discus with the throwing arm still posterior to the shoulder, while throwers in the World group employed the kinematic chain appropriately in the last half of the throwing motion.

REFERENCES

Bartlett, R.M. (1992). The biomechanics of the discus throw: A review. *Journal of Sports Science*, 10, 467-510.

Hay, J.G. (1985). The Biomechanics of Sports Techniques (Third Edition). Prentice Hall: New Jersey, pp. 487-502.

Hay, J.G. and Yu, B. (1995). Critical characteristics of technique in throwing the discus. *Journal of Sports Sciences*, 13, 125-140.

Knicker, A.J. (1990). Determining factors in discus throwing of top level athletes. In G. P. Brüggemann and J.K. Rühl (Eds.), Proceedings of the First International Conference on Techniques in Athletics, Vol. 2 (pp. 670-677). Köln: Deutsche Sporthochschule (cited in Bartlett, 1992).

Leigh, S. and Yu, B. (2007). The associations of selected technical parameters with discus throwing performance: A cross-sectional study. *Sports Biomechanics*, 6 (Suppl.3), 269-284.

Maeda, K., Ohyama, B.K., Hirose, K., and Ogata, M. (2018) Relationships between throwing distance and parameters about morphology and physical strength in male discus throw: Estimating physical strength requirement corresponding to throwing distance. *The Japan Journal of Coaching Studies*, 31 (Suppl. 2), 175-184. (in Japanese).

Stepanek, J. (1990). Findings of the IAAF biomechanical research concerning shot put. In G. -P. Brüggemann and J.K. Rühl (Eds.), Techniques in athletics (pp. 625-628). Cologne: Deutsche Sporthochschule (cited in Bartlett, 1992).

Winter, D.A. (1990) Biomechanics and motor control of human movement, (pp. 41-43) New York: John Wiley and Sons.

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