CLASSIFICATION OF THE DISCUS THROW TECHNIQUE

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The purpose of this study is to classify discus throwers based on the velocity components at release and to investigate their throwing biomechanics. Forty-six male discus throwers were classified into 2 groups through cluster analysis. Twenty-two throwers were classified into a horizontal dominant group, while the remaining 24 throwers were classified into a vertical dominant group. There were no significant differences in the throwing distance and resultant release velocity between the groups. The right leg angle at release and the displacement of the centre of gravity (vertical direction) were significantly greater in vertical dominant group. These results indicated the horizontal dominant group drove their right leg forward to increase the horizontal velocity, while the vertical dominant group lifted their body upward direction to increase the vertical velocity.

KEYWORDS: release, velocity, three-dimensional analysis, delivery phase

INTRODUCTION: In the discus throw, the most important factor affecting the throwing distance is the velocity of the discus at release (Bartlett, 1992; Hay & Yu, 1995; Leigh, Gross, Li, and Yu, 2008). Among the velocity components of the discus, the horizontal (throwing direction) and vertical (upward direction) components have been shown to contribute to the discus throwing performance (Tong, Xie, Teh, and Yu, 2001). There are also different views on the strategy to achieve higher throwing performance. A study indicated that increasing the horizontal component is pivotal (Ecker, 1996), while another emphasised the importance of increasing the vertical component of the discus velocity according to the principle of the gyroscope (Miyanishi & Sakurai, 2000). Furthermore, previous study examining Asian discus throwers stated that it may be possible to classify discus throwers into two types - horizontal and vertical dominant, based on the aspects of angular momentum (Miyanishi, Sakurai, Wakayama, Togashi, and Kawamura, 1998). However, the details of the types of discus throwers and their throwing biomechanics have not been fully investigated. When considering strategies to achieve longer throwing distance for each individual thrower, it is important to understand potential factors associated with horizontal and vertical dominant types. Therefore, this study aims to classify the discus throwers based on the velocity components at release and to investigate their throwing biomechanics.

METHODS: The participants in this study were 46 male discus throwers (with throwing distance ranging from 40.88 to 59.69 m). All throwers are right-handed. The participants' performance level is from collegiate to national elite. The participants competed in official competitions held in Japan. Two or three high-speed cameras (CASIO, EX-F1, Tokyo, Japan) were used to record the throwing motion at 300 frames/s with a shutter speed of 1/1000s or 1/2000s. Cameras were placed behind and alongside the throwers. Throwing motion from each participant's best performance in the competition was used for analysis. The three-dimensional DLT method was applied to locate three-dimensional coordinate data of the endpoints of 15 body segments. The local coordinate system was expressed with a right-handed orthogonal: the z-axis was vertical and pointed in the upward direction, the y-axis was horizontal and pointed in the throwing direction, and the x-axis was perpendicular to the other two axes. The coordinate data were smoothed with a Butterworth digital filter at optimal cut-off frequencies (3.0 - 10.8Hz), determined from the residual analysis proposed by

Winter (1990). The discus's velocity, height, and angle at release were obtained mathematically from the locations of the discus at the moment of release. In addition, the hip-shoulder separation angle, the shoulder-arm separation angle, the arm elevation angle, the trunk tilt angle, the right leg angle, and the displacement of the centre of gravity (CG) were calculated. The definitions of each angle are given in Figure 1. Throwing motion is defined into five phases (Figure 2), and the variables at left-foot touchdown (L-on), release (Rel) and the changes during delivery phase (DVP) were analysed. Cluster analysis with Ward-method was used for classifying the subjects by the velocity components (x, y, and z) at release, which were standardised by using mean values and standard deviations. After classification, the differences in the variables between classified groups were obtained by Student's t-test. To investigate relationships among some variables, Pearson's product moment correlation coefficient was calculated. The significance level was set at $p < 0.05$.

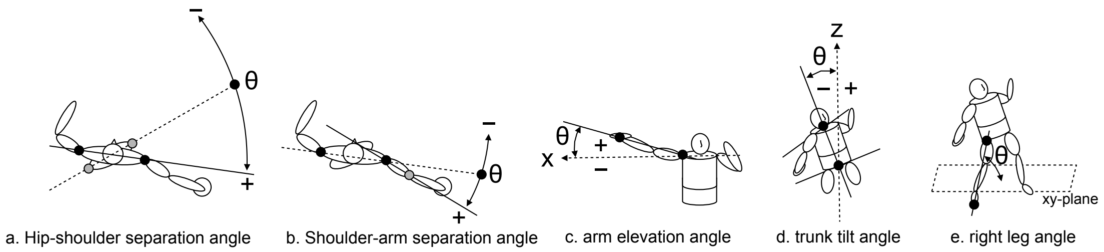

Figure 1: Definitions of each angle.

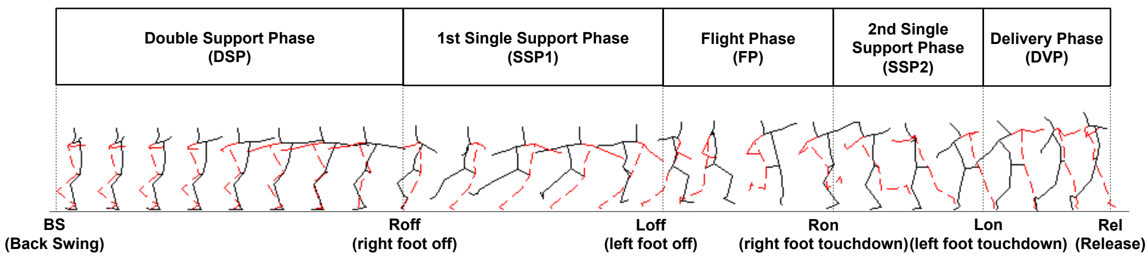

Figure 2: Definition of motion phases.

RESULTS and DISCUSSION: A result of the cluster analysis was given in Figure 3. On the basis of the cluster analysis performed using the standardised release velocity (x, y, and z), all participants in this study were classified into two groups. A total of 22 throwers were classified into a horizontal dominant group (horizontal group); all remaining of 24 throwers were classified into a vertical dominant group (vertical group).

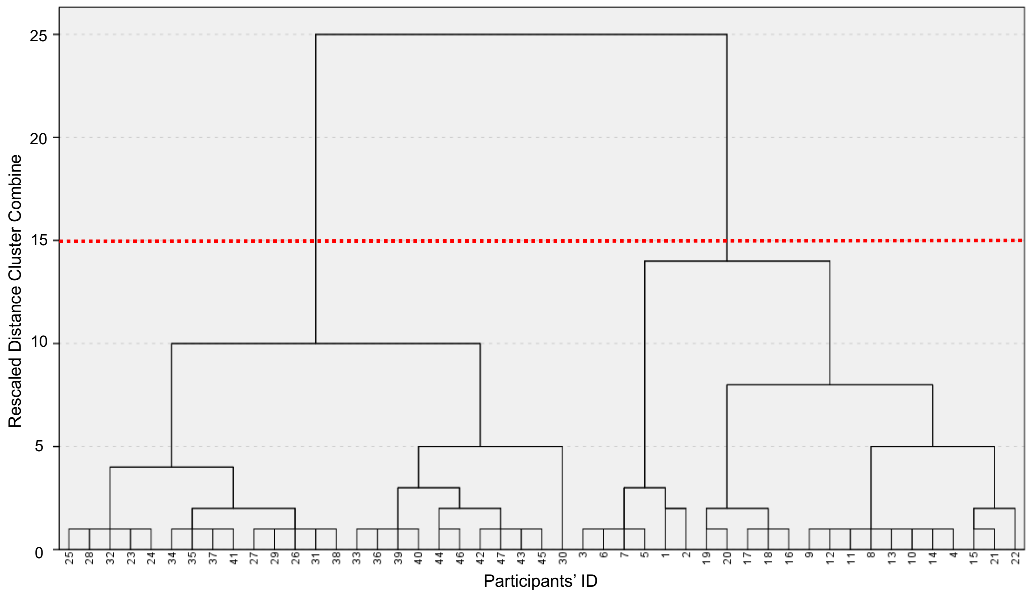

Figure 3: A result of the cluster analysis (dendrogram).

Table 1 demonstrates the throwing distance, release velocity (resultant, the x component, the y component, and the z component), release height, and release angle between the two groups. There were no significant differences in throwing distance and release velocity (resultant and x) between the horizontal and vertical groups. The y component of the release velocity was significantly greater in the horizontal group than in vertical group. By contrast, the z component of the release velocity, release height, and release angle were significantly greater in the vertical group than in horizontal group.

Table 1: Comparison of throwing distance and release parameters between the groups.

		All participants	Horizontal dominant group	Vertical dominant group	Difference (95%CIs)	t-value
Throwing Distance	(m)	48.17 ± 4.56	49.02 ± 5.44	47.42 ± 3.57	1.60 (-1.07 - 4.28)	1.21
Release Velocity (resultant)	(m/s)	20.96 ± 0.90	21.21 ± 1.01	20.75 ± 0.75	0.46 (-0.06 - 0.97)	1.76
(x)	(m/s)	2.03 ± 1.84	1.55 ± 2.03	2.45 ± 1.58	-0.90 (-1.96 - 0.16)	-1.71
(y)	(m/s)	16.77 ± 0.98	17.52 ± 0.65**	16.12 ± 0.72	1.40 (1.00 - 1.80)	7.00
(z)	(m/s)	12.23 ± 1.04	11.66 ± 1.09	12.73 ± 0.67**	-1.07 (-1.62 - -0.52)	-3.97
Release Height (m)	(m)	1.60 ± 0.12	1.56 ± 0.12	1.63 ± 0.11*	-0.07 (-0.14 - 0.00)	-2.14
Release Angle (deg.)	(deg.)	35.74 ± 2.93	33.34 ± 2.22	37.85 ± 1.49**	-4.52 (-5.65 - -3.39)	-8.09

CIs: Confidence intervals, *: p < 0.05, **: p < 0.01

These results were reflected the characteristics of each group. The horizontal group were characterised by a relatively lower release angle and higher horizontal velocity. In contrast, throwers in the vertical group were characterised by a relatively higher release angle and greater vertical velocity. These results are in line with previous research findings (Miyanishi et al., 1998). Hay (1985) argued that release height is a less influential factor to the throwing distance compared to the release velocity and release angle. This is consistent with the result of the present study, which there was no significant difference in throwing distance between the horizontal and vertical groups although release height and release was significantly greater in the vertical than in horizontal group. Release angle was significantly greater in the vertical group than in horizontal group. As earlier research showed that release angle decreased when the vertical velocity was relatively lower compare to the horizontal velocity (Bennett, Walker, and Bissas, 2018). In this study, the y and z component of release velocity is significantly correlated with release angle ($r = -0.56$, $p < 0.01$; $r = 0.86$, $p < 0.01$, respectively). The results of this study confirmed the relative relationship between release angle and co-variation of release velocity components.
Table 2 demonstrates kinematic variables for the entire sample. The right leg angle at release and the vertical displacement of the CG were significantly greater in the vertical than in horizontal group. There were no significant differences found in the other variables between the horizontal and vertical groups.

Table 2: Comparison of each kinematic variable between the groups.

		All Subjects	Horizontal dominant group	Vertical dominant group	Difference (95%CIs)	t-value
Hip-shoulder separation at L-on	(deg.)	47.52 ± 18.30	43.42 ± 17.90	51.13 ± 18.24	-7.71 (-18.36 - 2.93)	-1.46
Hip-shoulder separation at Rel	(deg.)	-18.64 ± 12.32	-21.68 ± 11.91	-15.96 ± 12.29	-5.72 (-12.85 - 1.41)	-1.62
Change in hip-shoulder separation (DVP)	(deg.)	66.16 ± 18.40	65.09 ± 17.18	67.09 ± 19.72	-2.00 (-12.93 - 8.94)	-0.37
Shoulder-arm separation at L-on	(deg.)	23.68 ± 13.84	24.63 ± 16.43	22.84 ± 11.38	1.79 (-6.68 - 10.25)	0.43
Shoulder-arm separation at Rel	(deg.)	7.24 ± 9.08	5.09 ± 9.71	9.13 ± 8.22	-4.04 (-9.31 - 1.22)	-1.55
Change in shoulder-arm separation (DVP)	(deg.)	-16.44 ± 13.21	-19.54 ± 15.62	-13.71 ± 10.23	5.83 (-1.84 - 13.50)	1.53
Arm elevation at L-on	(deg.)	-16.90 ± 10.64	-17.38 ± 9.67	-16.48 ± 11.61	-0.90 (-7.23 - 5.43)	-0.29
Arm elevation at Rel	(deg.)	6.30 ± 10.62	6.08 ± 10.02	6.50 ± 11.32	-0.43 (-6.75 - 5.89)	-0.14
Change in arm elevation (DVP)	(deg.)	23.21 ± 14.18	23.46 ± 14.50	22.98 ± 14.18	0.47 (-7.97 - 8.91)	0.11
Trunk tilt at L-on	(deg.)	-28.92 ± 5.35	-27.99 ± 6.08	-29.74 ± 4.60	1.75 (-1.39 - 4.90)	1.12
Trunk tilt at Rel	(deg.)	-9.26 ± 4.95	-7.82 ± 5.10	-10.54 ± 4.54	2.72 (-0.11 - 5.55)	1.94
Change in trunk tilt (DVP)	(deg.)	19.66 ± 7.74	20.17 ± 9.30	19.21 ± 6.23	0.97 (-3.63 - 5.57)	0.42
Right leg at L-on	(deg.)	78.50 ± 6.23	77.55 ± 6.27	79.34 ± 6.20	-1.79 (-5.46 - 1.88)	-0.98
Right leg at Rel	(deg.)	68.91 ± 5.37	66.83 ± 4.70	70.74 ± 5.33*	-3.91 (-6.88 - -0.94)	-2.65
Change in Right leg (DVP)	(deg.)	-9.59 ± 6.27	-10.72 ± 4.89	-8.60 ± 7.22	-2.12 (-5.80 - 1.56)	-1.16
Displacement of the CG_y (DVP)	(m)	0.31 ± 0.05	0.30 ± 0.06	0.31 ± 0.04	0.00 (-0.04 - 0.03)	-0.29
Displacement of the CG_z (DVP)	(m)	0.18 ± 0.05	0.17 ± 0.05	0.20 ± 0.05*	-0.03 (-0.06 - 0.00)	-2.35

CIs: Confidence intervals, *: p < 0.05, **: p < 0.01

These results indicated that the throwers in the vertical group emphasised lifting motion: driving their right leg and body towards vertical direction rather than driving their right leg toward throwing direction compared to those in the horizontal group. Hay (1985) stated that one of the methods to increase the vertical component of the discus velocity was driving off the right leg and rotating toward and upward over the left. In contrast, Yu, Broker, and Silvester (2002) argued the importance of driving right leg forwards and rightwards during the DVP based on the analysis of ground reaction force.
The results of this study regarding the right leg angle and the vertical displacement of the CG in the vertical group supported Hay's opinion. On the other hand, the horizontal group drove their right leg towards throwing direction rather than upwards. Therefore, the horizontal group would have emphasised the throwing motion demonstrated by Yu et al. (2002). The results of this current study also indicated that there were no significant differences in other kinematic variables in trunk between the horizontal and vertical groups.
From these results, the right leg motion during the DVP would be a key variable of the throwing biomechanics when classifying discus throwers based on the velocity components at release. The mechanical relationship of how right leg motion may cause multi-segment dynamics changing CG displacement and release parameters, however, cannot be clariid by this study. Therefore, further research is warranted to investigate details of the mechanics and or kinetics in each group.

CONCLUSION: The aim of this study was to classify discus throwers based on the velocity components at release and to investigate their throwing biomechanics. The results of this study indicated that there were two types of the discus throwers based on the velocity components at release: horizontal and vertical dominant. The throwers in the horizontal dominant group increased the horizontal component of the discus velocity at release by driving their right leg forwards, while the throwers in the vertical dominant group increased the vertical component of the discus velocity at release by lifting their body upwards. The right leg motion during the delivery phase was identified as a key factor affecting release angle and release height.

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