CLASSIFICATION OF THE ROTATIONAL SHOT-PUT BASED ON DURATION TIME OF MOTION PHASES

Tadahiko Kato[1], Kei Maeda[2] and Shariman Ismadi Ismail[3]

Faculty of Human Science, Kyushu Sangyo University, Fukuoka, Japan[1]
Center for Educational Development, Kyoto University of Advanced Science, Kameoka, Japan[2]
Faculty of Sports Science & Recreation, Universiti Teknologi Mara, Shah Alam, Malaysia[3]

This study aimed to investigate the relationships between throwing distance and duration times of motion phases in the rotational shot-put and attempted to classify the throw based on duration times. A total of 181 recorded trials performed by male shot-putters were obtained, and their duration time and the ratio of duration time of defined motion phases were analysed. Duration time and the ratio of duration time were not correlated with throwing distance for all motion phases. Result of a cluster analysis indicated that athletes could be classified in two groups and there were significant differences in duration time at initiation and later phases between the groups. As a result, it is suggested that the changes in duration time might not influence the throwing distance. In addition, it was identified that there are two kinds of group based on the duration times in the rotational shot-put.

KEYWORDS: cluster analysis, biomechanics for coaching, improvement

INTRODUCTION: Spatio-temporal variables are commonly used to understand sports performance. It can be easily analysed using digital video camera. For example, step frequency during sprint acceleration is one of gold standard method for understanding underlying sprinting techniques (Nagahara, Naito, Morin, & Zushi, 2014; Plamondon & Roy, 1984), was calculated by measuring the location and timing of foot contact. Some of duration times during sports performance can be also calculated with ease. Hirose et al. (2016) clarified the relationships between throwing distance and duration times of motion phases in male hammer throw. Furthermore, duration times of motion phases also influenced the throwing distance in male and female discus throw (Tauchi, Iso, Mochida, Sugita and Ae, 2007; Maeda, Ohyma-Byun, Hirose, Yamamoto, Kajitani, Nakano, Kigoshi and Ogata, 2017). Although the importance of duration times in some of throwing event of athletics is well understood, it was not fully investigated in the case of the shot-put. Thus, clarifying the importance of duration time is valuable for the shot-putters and their coaches.
On the other hand, Pagel and Pagel (2003) indicated that there are some technical differences in the rotational shot-put. Additionally, Ohyama-byun et al. (2008) calculated and revealed the two types to create mechanical momentum in the rotational shot-put. According to these knowledge, duration times of motion phases might also have some characteristic groups.
Therefore, this study aimed to investigate the relationships between throwing distance and duration times of motion phases in the male shot-put with rotational technique and attempted to classify the throw based on duration times.

METHODS: A total of 181 recorded trials of male shot-putter's throws (throwing distance: 19.34 ± 2.14 m; range: 14.15-23.10 m) were obtained from various broadcast sources on the TV program or website channels. (Hirose, Ohyama-Byun, Maeda and Ogata, 2016; Hobara, Saito, Hashizume, Namiki and Kobayashi, 2018). In this study, only one trial with the best record for each shot-putter was selected. The videos of the trials were recorded at 30-300 Hz. Throwing motion of the shot-put was defined into five phases based on the initiation of throwing, foot take-off, foot contact and release of the shot (Figure 1). Duration time for each phase was obtained by counting the number of frames from each trial using Quick time software (Apple Inc., USA). Duration times of each motion phases were also calculated as a ratio (% of total time from initiation to release for each trial).

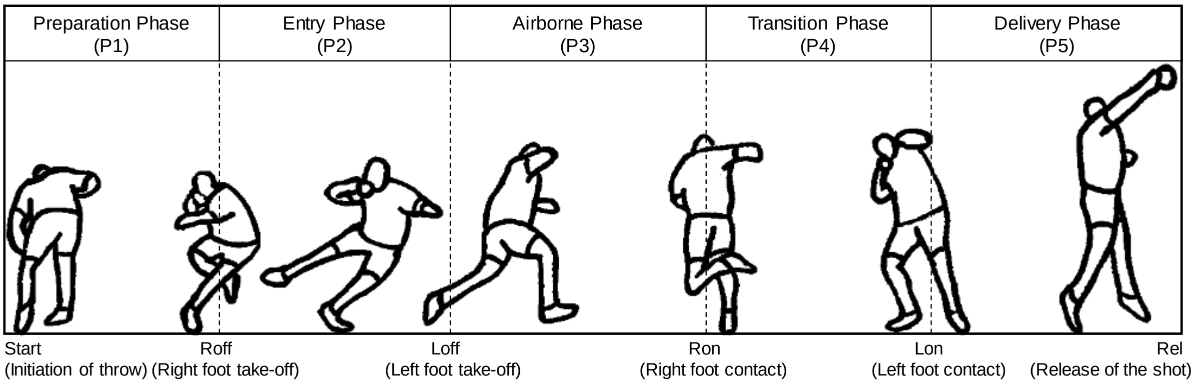

Figure1: Defined events and motion phases of rotational shot-put technique.

Intra-class correlation coefficient (ICC) were obtained to evaluate the reliability of duration times measurement in ten trials which were extracted at random when compared the results obtained by another tester. The relationships among throwing distance and variables of duration time were quantified using linear correlation techniques with Pearson's correlation coefficient (r). Cluster analysis with Ward-method was used for classifying the recorded trials based on ratio of duration time. After classification, the difference in the variables of time variables between classified groups was obtained by t-test. The significance level for statistical analysis was set at $p < 0.01$. All statistical analyses were performed using the SPSS version 24.0 (IBM Japan Ltd., Japan).

RESULTS and DISCUSSIONS: The ICCs of the counted duration times between two testers were 0.96 ($p < 0.01$) and above for all motion phases. Thus, it was concluded that the method for duration times measurement in this study has enough reliability.
Table 1 shows duration times for each motion phases, and its correlation coefficients with throwing distance. Results indicated that there was no significant correlation between throwing distance and all motion phases.

Table1: Variables of duration time and correlation coefficient among throwing distance.

Motion Phase	Duration time [s]	r	p	Ratio of duration time [%]	r	p
P1 (Start – R-off)	0.66 ± 0.17	−0.02	0.75	40.50 ± 6.03	−0.02	0.75
P2 (R-off – L-off)	0.44 ± 0.06	−0.05	0.49	27.41 ± 3.41	−0.01	0.96
P3 (L-off – R-on)	0.07 ± 0.03	0.10	0.17	4.26 ± 2.19	0.11	0.13
P4 (R-on – L-on)	0.20 ± 0.04	−0.09	0.21	12.59 ± 2.45	−0.05	0.49
P5 (L-on – Rel)	0.24 ± 0.03	−0.04	0.60	15.24 ± 2.37	0.02	0.84
Total (Start - Rel)	1.61 ± 0.19	−0.05	0.55			

r: Pearson's correlation coefficient

On the basis of the cluster analysis performed using the ratio of duration time, all trials analysed in this research were classified into two groups based on the normality of the throwing distance for each group. A total of 112 trials were classified into group A (throwing distance: 19.37 ± 2.04 m; range: 14.19-23.10 m). All remaining of 69 trials were classified into group B (throwing distance: 19.27 ± 2.30 m; range: 14.15-22.67 m). There was no significant difference for throwing distance between the groups.
Table2 shows the variables of duration time for each classified group and the results of t-test between the groups for each motion phase. Group A was characterized by a shorter duration time at P1 and total motion, while in contrast, was longer in duration time at P5 when compared with the other groups. In addition, there was no significant difference in duration time at P2, P3 and P4 between the classified groups. With respect to the ratio of duration time, group A was characterised by shorter P1 than Group B. For P2, P3, P4 and P5, group A's ratio of duration time was longer than group B. The study results indicated that group A was characterised by relatively short preparation phase (P1) due to short duration time and lower ratio of duration time, and long delivery phase (P5). In contrast, group B had longer time preparation (P1) and shorter time in delivery phase (P5).

Table 2: Variables of duration time and correlation coefficient among throwing distance.

Duration time [s]				
Motion phase	Group A	Group B	t-test	p
P1	0.57 ± 0.10	0.81 ± 0.15	A < B	< 0.01
P2	0.45 ± 0.06	0.43 ± 0.06	n. s.	0.03
P3	0.07 ± 0.03	0.06 ± 0.03	n. s.	0.15
P4	0.20 ± 0.04	0.20 ± 0.04	n. s.	0.91
P5	0.25 ± 0.03	0.23 ± 0.03	A > B	< 0.01
Total	1.54 ± 0.14	1.74 ± 0.19	A < B	< 0.01
Ration of duration time [%]				
Motion phase	Group A	Group B	t-test	p
P1	36.83 ± 3.79	46.46 ± 3.83	A < B	< 0.01
P2	29.14 ± 2.68	24.61 ± 2.49	A > B	< 0.01
P3	4.61 ± 2.34	3.68 ± 1.78	A > B	< 0.01
P4	13.15 ± 2.28	11.66 ± 2.46	A > B	< 0.01
P5	16.26 ± 2.06	13.59 ± 1.85	A > B	< 0.01

n. s.: No significance

According to previous researches, it was identified that one of the main effects at preparation phase is creating source of kinetic energy for accelerating the shot at delivery phase. Ohyama-Byun et al. (2008) showed both linear momentum and angular momentum of athlete-shot system created mostly during P1 and P2. In addition, Hay (1993) indicated the theoretical model in the shot-put and it suggests that the importance of enhancing the impulse into the shot for accelerating it during delivery (P5). Moreover, Kato et al (2018) reported that linear and angular momentum of athlete-shot system before delivery (P4) influence the throwing distance as same as the impulse into the shot during delivery. Basic principles of physics defined momentum as the product of object’s mass and its velocity. And the impulse applied to an object is calculated as the product of changes in its velocity and mass. Also, as a spatio-temporal variable, the difference in duration time might influenced the velocity of the athlete and or the shot. Therefore, the results suggest the classified groups had difference approaches for acceleration of the body and the shot. Group A might create larger amount of momentum by faster velocity of their whole body when compared with group B due to their shorter duration time during P1 phase. In contrast, group B could have created bigger impulse into the shot during delivery because of their short time duration at P5.

Table 3: Correlation coefficient among throwing distance and variables of duration time for each classified group.

Motion Phase	Duration time				Ratio of duration time			
	Group A		Group B		Group A		Group B	
	r	p	r	p	r	p	r	p
P1	−0.20	0.04	0.16	0.20	−0.15	0.11	0.20	0.10
P2	−0.16	0.09	0.11	0.39	−0.05	0.58	0.02	0.88
P3	0.11	0.23	0.08	0.50	0.15	0.11	0.03	0.80
P4	−0.10	0.29	−0.08	0.49	0.01	0.97	−0.15	0.22
P5	0.04	0.72	−0.15	0.22	0.17	0.07	−0.27	0.03
Total	−0.20	0.04	0.13	0.30				

Table 3 shows correlation coefficient among throwing distance and variables of duration times for each classified group. All variables had no significant correlation with throwing distance in both groups. As indicated previously in Table 1, all variables of duration time had no influence on the throwing distance. Findings in this study also suggested that the variable of duration time might not change when the athlete improve their technique and throwing distance. However, the limitation of this study was it only investigated single trial of 181 male shot-putters respectively. Therefore, further research is warranted to clarify the influence of duration time of motion phases on shot-putter’s performance.

CONCLUSION: The results of this study suggest that there are two kinds of group based on the duration times in the rotational shot-put, and the changes in duration time might not influence the throwing distance.

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