KINEMATIC ANALYSIS OF THE WOMEN'S JAVELIN THROW AT THE IAAF WORLD CHAMPIONSHIPS, DAEGU 2011

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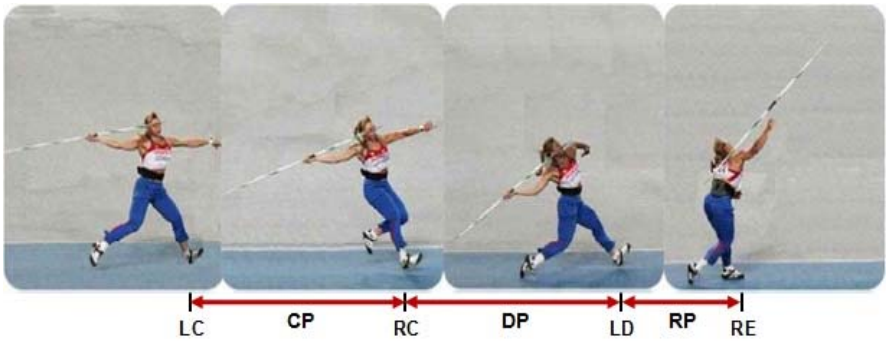
The purpose of this study was to analyze the kinematic variables for the women's javelin throw at the IAAF World Championships, Daegu 2011. Three-dimensional motion analyses of the eight players who qualified for the final round were carried out to obtain the data. The results showed that average release, attitude, and attack angles were 38.0±2.0°, 40.4±4.3°, and 3.7±1.1°, respectively. At the release, the average inclination angle of the trunk, upper arm, forearm were 60.8±8.3°, 47.3±10.1°, and 62.6±10.6°, respectively. Moreover, the release velocity and the release height results averaged 25.60±1.16 m/s and 1.86±0.05 m. The crossover phase and delivery phase had average distances of 1.88±0.31 m and 1.53±0.21 m. After release, the average distance between the landing foot and the foul line was 1.72±0.63 m.

KEY WORDS: javelin, kinematic, release angle, inclination angle, temporal parameters.

INTRODUCTION: The kinematic analyses of the javelin event have been accomplished with two major focus points. The first includes the release-factor analysis of javelin and aero dynamical-factor analysis during release (Ikegami, Miura, Matsui, & Hashimoto, 1981; Rich, Whitting, McCoy, & Gregor, 1985; Hubbard & Always, 1989; Whitting, Gregor, & Halushka, 1991). The second includes the kinematic comparative analysis for the positions of athletes before and after the release (Bosen, 1985; Komi & Mero, 1985; Mero & Komi, 1994; Barlett, Muller, Raschner, Lindinger, & Jordan, 1995). Release velocity, release angle and release height can be taken as the significant factors that are influential to the records of the javelin competition and here, the aero dynamical factors influential to the flight of javelins can be included. As the most influential factor in javelin, release velocity is determined by the speed and strength of approach and the acceleration of the physical segments. Morris et al.(1997) reported that release velocity is the most important factor for the flying distance of the javelin. They concluded that effectively relaying the energy gained from the approach and crossover step during the support landing of delivery is important in increasing the release velocity. In such ways, the kinematic studies of javelin movements for improving athletic performance are variously accomplished. However, the majority of them are kinematic analysis in practice situations and detailed analysis in actual competitions are extremely rare. Therefore, the present study has actually filmed the finals in female javelin at the IAAF World Championships Daegu 2011. The purpose of this study was to provide quantified data on the throwing skills of world-class athletes and to analyze the kinematic variables for the women's javelin throw at the IAAF World Championships Daegu 2011.

METHODS: Before starting the analyses, control objects (4m x 9m x 4m) had to be set up in order to find a control point. The control point took the movement of javelin throwers into account. Three high speed digital cameras (Casio EX-F1 Exilim, JPN, 300 frames/ sec, shutter speed 1/1000 second) were installed 45° above the athlete to capture each movement more precisely. The DLT (direct linear transformation) algorithm with Kwon3D software (Version 4.0, Visol, Korea) was used to obtain 3D coordinates for 21 body landmarks and 3 javelin landmarks. To minimize the noise due to digitizing errors, the 3D coordinates were filtered using a second order, 7 Hz low pass Butterworth filter. Four critical events and three phases were used for analysis (Figure 1). Temporal parameters, velocity

variables, release conditions, inclination angle of body segments, and distance variables were determined for each trial. The inclination angle of body segment was defined as the angle between the horizontal plane and a given line segment. The velocity parameters that were analyzed for this study were the cumulative absoulte velocity.



Events	Phases
. **LC : Left foot of Cross step** . **RC : Right foot Contact** . **LD : Left foot in Delivery** . **RE : Release**	. **CP : Crossover stride Phase** . **DP : Delivery Phase** . **RP : Release Phase**

Figure 1: Critical instants and phases of the javelin throw.

RESULTS: The women's final event analytical results were as follows (Table 1); average angle of release 38.0±2.0°, angle of attitude 40.4±4.3°, and angle of attack 3.7±1.1°. At the release, the average inclination angle of the body segments were as follows; angle of the trunk 60.8±8.3°, angle of the upper arm 47.3±10.1°, and angle of the forearm 62.6±10.6°. Moreover, the release velocity and the release height results averaged 25.60±1.16 m/s and 1.86±0.05 m, respectively. Additionally, three phases, the crossover phase (CP), delivery phase (DP), and release phase (RP), had an averages durations of 0.350±0.066 sec, 0.198±0.039 sec, and 0.138±0.013 sec.

Table 1: Kinematic data of woman's javelin throw finals.

Rank		1	2	3	4	5	6	7	8	M	SD
Result (m)		71.99	71.58	68.38	65.24	64.32	61.96	61.65	59.27	65.55	4.71
release velocity (m/s)		25.11	26.17	24.42	26.48	26.09	25.10	27.49	23.96	25.60	1.16
release height (m)		1.85	1.96	1.84	1.88	1.78	1.83	1.87	1.86	1.86	0.05
CM velocity at release (m/s)		0.85	0.87	0.80	0.80	0.63	0.66	0.69	0.67	0.75	0.09
Angle at release (deg)	Attitude	43.8	42.2	43.0	35.2	41.3	43.9	32.3	41.7	40.4	4.3
	Release	39.4	38.2	39.3	33.2	38.8	38.9	37.3	38.6	38.0	2.0
	Attack	4.4	4.0	3.7	2.0	2.5	5.0	5.0	3.1	3.7	1.1
Inclination angle (deg)	Trunk	61.2	52.8	46.7	65.1	58.8	62.5	73.5	66.0	60.8	8.3
	Upperarm	43.7	47.5	62.8	29.6	47.1	40.6	56.8	50.5	47.3	10.1
	Forearm	47.6	67.8	68.6	62.7	51.8	80.6	65.9	56.0	62.6	10.6
Distance (m)	Crossover stride	1.87	1.61	1.59	2.01	1.91	1.81	2.51	1.66	1.88	0.31
	Delivery stride	1.74	1.60	1.41	1.66	1.51	1.74	1.51	1.10	1.53	0.21
	Foul line	2.36	2.54	1.66	1.20	0.57	1.91	1.64	1.85	1.72	0.63
Duration (ms)	Crossover stride	313	313	310	370	433	350	450	257	350	066
	Delivery stride	194	190	167	173	203	203	164	287	198	039
	Release	140	147	113	143	154	130	133	143	138	013

The CP and DP had average distances of 1.88±0.31 m and 1.53±0.21 m accordingly, while after release, the distance difference between the landing foot and the foul line averaged 1.72±0.63 m. Gold medalist M. Abakumova achieved the season's best throw when she beat

her 2009 season's best throw from the qualifying rounds of the Berlin Competition by 3.07 m. The defending champion, and second place finisher B. Spotakova(CZE), who had not been performing well recently, also improved from her previous Berlin Competition score by 5.16 m, making it her personal best throw for the whole season. However, she was not able to beat her all-time personal best throw and World Record of 72.28 m. South African third place finisher S. Viljoen(RSA) did not qualify for the finals at the Berlin Competition. However, she was able to achieve her season's best throw and set the record for furthest throw by an African. Every athlete, excluding the top three winners, underperformed by an average of 2.52 m compared to their season's best throws. In particular, C. Obergfoll(GER) underperformed with a fourth place finish 3.14 m behind the bronze medalist. She also fell short of her throw at the Berlin Competition by 5.57 m. During the qualifying records C. Obergfoll's first and only throw was her best throw of the season. And during both the qualifying and final rounds she consistently threw further than third place finisher S. Viljoen (RSA). However, Viljoen shot ahead of Obergfoll with her second to last throw of 68.38 m, and Obergfoll took fourth place with a throw of 65.24 m.

DISCUSSION: Looking at the kinematic variables of the top three finalists for the women's javelin throw at the 2011 IAAF World Championships, Daegu, reveals that gold medalist M. Abakumova's release velocity was lower than her velocity at the Berlin Competition by 0.01 m/s. Nonetheless, she was still able to throw the javelin 5.93 m further. Even though the travel distance of the javelin is highly correlated to the release velocity, she was able to achieve a higher distance with lower velocity. This is because the angle of release and release height(103.4 %height) led to a positive outcome.

Out of all of the medalists, M. Abakumova (Figure 2) had the highest vertical body angle at release. When release occurs closest to a vertical body angle, the javelin can travel more smoothly. Moreover, she had the fastest delivery velocity, called the power stride. A power stride is possible when the delivery stride secures a wide base, efficiently sending power from the ground to the javelin. Most of all, even though her angle of release decreased by 3.2° compared to the Berlin Competition, with the right combination of javelin balance and movement direction, she was able to effectively release the javelin, enabling her to secure the gold medal.

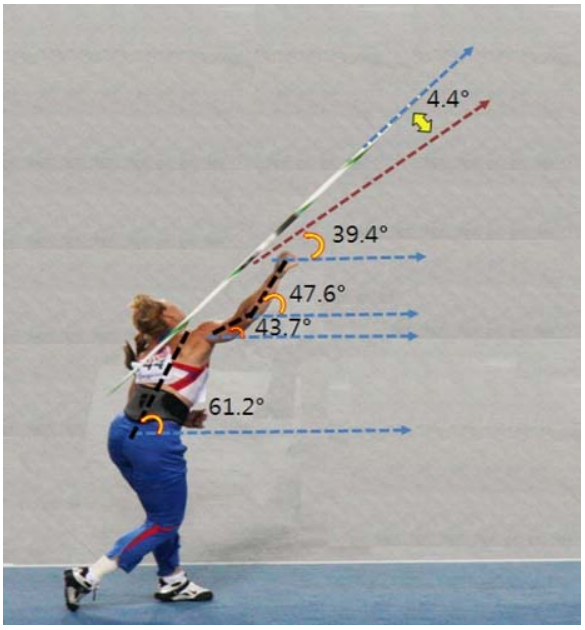


Figure 2: Gold medalist M. Abakumova (RUS)

The number one ranked thrower in the world, B. Spotakova missed the gold medal by just 0.41 m. In terms of kinematic analysis, it can be concluded that she had a more favorable position by achieving a release velocity of 26.17 m/s and an angle of attack of 4.0°. However, the distance between her landing foot and the foul line was 2.54 m, 1.06 m more than the other athletes. Furthermore, compared to the gold medalist, her CP and DP phase speeds were 2.56 m/s and 0.19 m/s lower respectively. In order for her to win the gold medal, she would need to improve her step distance, maintaining a continuous rhythmical run-up, and taking her steps into account from cross step until the moment of release. Additionally, she would need to work on her release position so that the distance between the foul line and her landing foot decreases.

S. Viljoen, who won bronze, achieved the lowest score for release velocity compared to the other competitors, which has the most direct influence on distance in the javelin throw. She had a trunk angle of 46.7° which was too low for the throw to be at top efficiency. Moreover,

her CM velodity was the slowest out of the three medalists; this had a negative effect on the release velocity. This type of outcome shows that if the CM velocity of the body is too slow it will cause a negative effect on the horizontal flight distance.
Comparing the kinematic parameters of the female medalists to those of male athletes at the 2011 IAAF World Championships, Daegu, reveals that the women had a higher average angle of release and angle of attitude. Gold medalist M. Abakumova, silver medalist B. Spotakova, and bronze medalist S. Viljoen achieved angles of 39.4°, 38.2°, and 39.3°, respectively. It can be seen that all the medalists had an angle of release close to 40°.
In the 2009 Berlin Competition, the best throw was 68.92 m, set by M. Abakumova in the qualification round. In the finals, B. Spotakova won the silver medal. Both athletes exceeded the male athletes with angles of release of 38.7°, and 38.8°. This can be interpreted to show that even a slight difference in the weight of the javelin or in the release velocity may change the outcome. This study, demonstrated that a medalist's average angle of velocity was 39.0±0.7°, while the other athletes got 37.4±2.4°. Both top male and female athletes attained higher angles of release compared to other finalists.

CONCLUSION: This study analyzed the kinematic variables of the women's javelin throw at the IAAF World Championships Daegu 2011. Results provide directions of technical training for enhancing competitive performance. The amount of time taken in the delivery phase may be a critical factor to enhance javelin performance. Thererfore, a javelin thrower would need to carry out the right amount of step distance, having a continuous rhythmical run-up, and take it into account from cross step until the moment of release. Since the trunk position at relase plays a greater role in determining release height and release velocity, a javelin thrower should not rely on the upper extremity to achieve the release velocity as high as possible. As a result of the study, converting to stable positions prior to release and maintenance of ideal angle of physical segmentation are interpreted to have positive effects for competitions.

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