BIOMECHANICAL ANALYSIS OF MEN'S JAVELIN THROW AT THE 19TH SOUTH EAST ASIAN GAMES

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In this paper, the javelin throwing techniques of the 19th South East Asian Games gold and silver medallists were analyzed and compared with the elite throwers of the 1995 World Championships.

KEY WORDS: biomechanical, analysis, javelin throw

INTRODUCTION: Biomechanical analysis of the javelin throw was conducted on the performance of the 1997 South East Asian (SEA) Games gold and silver medallists. The 1997 SEA Games was held in Jakarta, Indonesia. The data were obtained from the biomechanics research project of the SEA Games 97, a collaborative effort between the Singapore Sports Council and the National Olympic Committee of Indonesia. The purpose of the study is to examine the last crossover stride and release of the javelin. The throws of the gold and silver medallists were video-recorded and analyzed. Their official throwing distances were over seventy meters. The techniques of these two throwers were examined and compared with elite throwers of the 1995 World Championships reported by Morriss et al. (1997).

METHOD: A two-camera video system was used to record the performances during the finals of the men's javelin event of the 1997 SEA Games in Jakarta, Indonesia. A total of nine throws from the two throwers (Mahuse and Yazid) were recorded and analyzed. Both subjects were right-handed throwers. The cameras were placed on the right side of the throwing runway as shown in Figure 1. Cameras were gen-locked and aligned with their optical axes approximately horizontal and intersected at about 100°. In order to calibrate the performance area for the throws and obtain the necessary parameters for three-dimensional reconstruction from multiple planar images using the Direct Linear Transformation (DLT) method, a calibration frame (2.2 m x 2.2 m x 1.6 m) of 24 control points was placed on the throwing runway about 2.5m from the foul line and this calibration frame was video recorded using the two cameras. Once the calibration frame was video recorded, caution was taken to ensure that the location of the cameras remained unchanged throughout the competition.

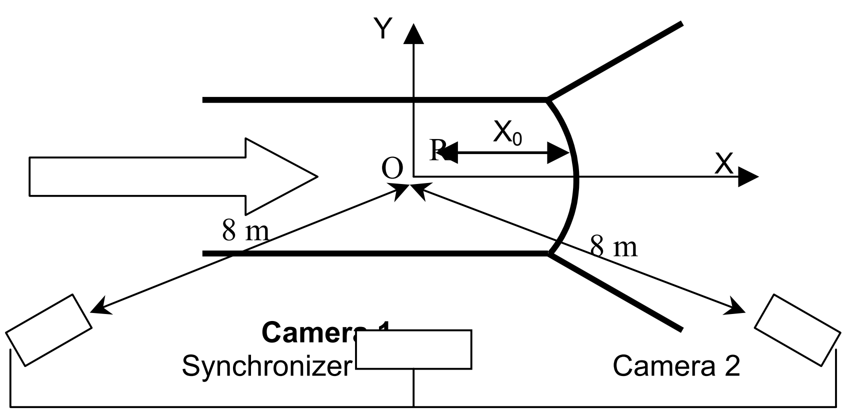

Figure 1 - Camera locations and reference coordinates.

Event synchronization was achieved by a manual trigger switch and recorded as a part of the image through an Event & Video Control Unit (EVCU, Peak Technologies Inc). The video was recorded at 50 frames per second. Twenty body landmarks of the thrower and two points on the javelin (the grip and the tip of javelin) were digitized using the Peak Motus motion analysis system. Three-dimensional coordinates were reconstructed by the DLT method. The reconstructed coordinates were smoothed using the low-pass Butterworth filter (6 Hz). The smoothed coordinates were used to calculate the locations and speeds of the mass center of throwers, the knee and elbow angles from the last cross over to the release of the javelin. The release speeds of the javelin (taken as the first derivative of the grip position at the first frame of flight) and the release angles of the javelin were also calculated. The release angle of the javelin was taken as the angle of the release velocity vector relative to the horizontal.

In order to examine if the thrower maximized the distance of throw, the distance X_0 between the tip of the javelin (when the javelin was released, indicated as R in Figure 1) and the foul line of the throwing runway was noted.

To analyze the technique involved in the last cross-over step to the release of the javelin, the following key events of this action were identified to demarcate the different phases for examinations:

- Event 1: Left foot strike to the beginning of the cross-over stride (LFS)
- Event 2: Left foot take-off during the delivery stride (LFTO)
- Event 3: Right foot strike to beginning of the delivery stride (RFS)
- Event 4: Right foot take-off or dragging (RFTO)
- Event 5: Final left foot strike (FFS)
- Event 6: Release (REL)
- Phase 1: Left foot contact phase(LFC, from LFS to LFTO)
- Phase 2: Flight phase during crossover (flight, from LFTO to RFS)
- Phase 3: Right foot contact phase (RFC, from RFS to RFTO)
- Phase 4: Right foot contact to final left foot contact (from RFS to FFS)
- Phase 5: Delivery phase (from FFS to REL)

The durations of these phases were also noted (Table 2). The average time taken for the throwers to perform the crossover step and the final step is about 1 second. This would give rise to a stride frequency of 1 Hz. According to Winter (1990) for a 1 Hz stride frequency the signal power of the toe and heel trajectories were found mainly in the lower seven harmonics (below 6 Hz). Therefore, video cameras sampling at the rate of 50 Hz were quite adequate for the purpose of this study.

RESULTS AND DISCUSSION:

(1) Release conditions:

The parameters of the release for the throws analyzed are listed in Table 1. The release speed of the javelin is generally considered as the most important factor determining throwing distance. The average release speeds of Mahuse and Yazid were 25.2 m/s and 25.1 m/s respectively. These speeds were relatively slower than those performed by the elite throwers in the 1995 World Championship (28 – 30 m/s) reported by Morriss et al. (1997). The slower release speed (about 4m/s slower) performed by the SEA Games throwers may have attributed to their shorter throwing distance (up to 18 m) when compared with their counterparts in the World Championship.

Table 1 Release Conditions

(trial) Mahuse (INA)	official distance (m)	X (m)	height Z (m)	Xo (m)	release speed (m/s)	angle of release (deg)
1	69.06	0.72	1.79	-1.90	24.8	38.4
2	70.94	0.39	1.85	-2.23	25.5	34.4
3	71.62	0.79	1.78	-1.83	25.1	36.4
6	66.86	0.42	1.80	-2.20	25.3	36.4
AVE	69.62	0.58	1.81	-2.04	25.2	36.4
Yazid(MAS)						
1	67.58	-0.75	1.77	-3.37	25.4	31.6
3	64.98	0.00	1.80	-2.62	23.9	36.9
4	67.10	-0.80	1.78	-3.42	25.6	34.3
5	71.38	-0.76	1.81	-3.38	25.8	34.8
6	68.64	-0.41	1.78	-3.03	24.8	36.8
AVE	67.94	-0.54	1.79	-3.16	25.1	34.9

- X and Z are the coordinates of release points

Although the release speed of Yazid's best throw was a little higher (25.8 m/s), than Mahuse's (25.1 m/s), Yazid did not throw as far as Mahuse indicating that the throwing distance may also be determined by other factors.

The average release angle of Yazid's best throw was 34.9 ° and Mahuse's was 36.4 °. Both of their release angles were smaller than that of the World Championship athletes which averaged about 38°. For Yazid's best throw, he was noted to have released the javelin about 3.38m behind the foul line, whereas Mahuse released his javelin about 1.83 m behind the foul line. Although Yazid's release speed was a little faster than Mahuse's, his less than optimum release angle and his inability to maximize his throwing distance (his X_0 distance was over three meters) may have curtailed his throwing distance.

(2) Temporal rhythm:

The data on the duration of each of examined phases are presented in Table 2. Since Yazid released the javelin much further behind the foul line, his LFS and most of the Flight phase were out of the field of view of the camera. Therefore, most of the data on his LFS and Flight phase were not available.

Table 2 Phase Duration

Mahuse (INA)	distance (m)	LFC (s)	Flight (s)	RFC (s)	RFS-FFS (s)	FFS-RELEASE (s)
1	69.06	0.14	0.22	0.26	0.37	0.12
2	70.94	0.12	0.26	0.28	0.32	0.12
3	71.62	0.12	0.22	0.26	0.34	0.12
6	66.86	0.12	0.26	0.28	0.34	0.12
AVE	69.62	0.13	0.24	0.27	0.33	0.12
Yazid(MAS)						
1	67.58	-----	-----	0.16	0.22	0.08
3	64.98	-----	0.20	0.16	0.20	0.10
4	67.10	-----	-----	0.18	0.22	0.08
5	71.38	-----	-----	0.18	0.24	0.08
6	68.64	-----	-----	0.16	0.22	0.10
AVE	67.94	-----	0.20*	0.17	0.22	0.09

On the other hand, Mahuse's LFC, Flight and FFS-Release phases were recorded and the data were rather similar to that of elite throwers of the World Championship but his RFC and RFS-FFS phases were much longer. A long RFC or RFS-FFS phase would reduce the momentum generated in the run-up through to FFS. A longer duration spent in these phases would result in a decrease in horizontal speed of his mass center. His average mass center speed is about 4.4 m/s at FFS.
For Yazid's throw, the duration spent on in RFC and RFS-FFS phases were comparable with that of the elite athletes from the World Championship, and he attained a faster mass center speed (about 5.3 m/s at FFS) than Mahuse. But Yazid's FFS-Release phase was much shorter than Mahuse's. This may have resulted in a shorter time available to accelerate the javelin in the final delivery. A higher release speed would have been obtained with a longer FFS-Release phase.

(3) Body position at Right Foot Contact (RFC):

According to Morriss et al. (1997), to generate a forceful leftward rotation of the trunk to begin the delivery action of the upper body, the leftward rotator muscles of the trunk must be stretched at the beginning the final foot strike. Morriss et al. (1997) also pointed out that in order to stretch the left trunk rotator muscle, at the RFS, the left knee should maintain an extended position, so that thrower can form a pivot at the left hip. The right knee and hip may then be extended, rotating the right hip around the left. The average left knee angle at the RFS amongst the World Championships throwers was 166°. The knee angles

Table 3 Horizontal Mass Centre Velocity and Left Knee Angle at Selected Stages

Mahuse (INA)	distance (m)	Mass centre speed (hor m/s) FFS	REL	%Loss	Left leg knee angle (deg) RFS	FFS	REL
1	69.04	4.6	2.8	39	83	167	153
2	70.94	4.2	2.8	33	78	169	158
3	71.62	4.4	3.1	30	95	162	147
6	66.86	4.3	2.1	51	90	165	-----
AVE	69.62	4.4	2.7	38	87	166	154
Yazid (MAS)							
1	67.58	5.2	3.6	31	----	168	172
3	64.98	5.1	3.4	33	138	168	169
4	67.10	5.6	3.7	34	-----	164	163
5	71.38	5.2	3.7	29	-----	168	165
6	68.64	5.3	3.9	26	151	164	162
AVE	67.94	5.3	3.7	31	145	166	166

at the RFS of the SEA Games throwers are presented in Table 3. It can be noted that at this phase Mahuse's knee was not as extended as required.

(4) Run-up speed: It is noted that elite throwers attained a forceful and high-impulse peak acceleration of the javelin at release by transferring the running speed from the body to the javelin by rapidly decelerating their mass center speed from FFS to REL. (Brown et al., 1994). Table 3 provides the horizontal velocity of the mass center at FFS and REL. The loss of the horizontal velocity of mass center from FFS to REL is also presented in Table 3 (as a percentage to the velocity at FFS). Compared with World Championship throwers the loss of horizontal velocity of Mahuse's and Yazid's mass center during their best throws were much lower. It implies that SEA Games throwers did not transfer the momentum of their approach speed to the javelin at release with necessary deceleration. Besides, the horizontal velocities of their mass centers at FFS (especially for Mahuse) were smaller than most of the World Championship throwers (who averaged at about 6 m/s).

(5) Throwing arm elbow angle:

Before the final foot strike (FFS), the javelin should be held as far from the upper body of thrower as possible to maximize the length of the acceleration path during delivery (Morriss et al., 1997). In other words, an extended throwing arm will increase the acceleration path and facilitate the generation of greater acceleration on the javelin at release. Table 4 shows the elbow angle of the throwing arm of Mahuse and Yazid at the different key moments. There was no obvious difference amongst that of Mahuse's, Yazid's and World Championship throwers (about 150° at RFS, 120° at FFS and 160° at REL).

Table 4 Throwing Arm Elbow Angles at Selected Stages

Mahuse (INA)	distance (m)	throwing arm elbow angle (deg) RFS	FFS	REL
1	69.04	146	142	156
2	70.94	137	111	169
3	71.62	142	122	155
6	66.86	143	146	165
AVE	69.62	142	130	161
Yazid (MAS)				
1	67.58	-----	128	143
3	64.98	65	145	159
4	67.10	-----	136	137
5	71.38	-----	134	150
6	68.64	145	138	134
AVE	67.94	105	136	145

CONCLUSION: Compared with World Championship throwers, the release speeds of Mahuse and Yazid were much slower and their release angles were also smaller. To improve in their throw, the speeds of their mass centers should be increased especially at FFS and effectively transferred to the javelin at the delivery (by more rapid deceleration of their mass center velocities at release). Notably, Yazid should try to move his release point forward (closer to the foul line) to reduce the initial distance lost. It is hoped that the findings of this study will assist these SEA Games throwers in their quest for improved performance.

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