MOVEMENT ANALYSIS FOR JAVELIN THROWERS IN THE QATAR 2009 CHAMPIONSHIPS

Eman Mahmud
Qatar Foundation, HSSE , Qatar , Doha

A biomechanical analysis of the javelin throw at the Qatar Athletics Championships in Doha with comparison to international throwers was carried out by the Qatar Olympic Committee in 2009. This paper presents the results of this study for male finalists. The methodology used is based on Video Photogrammetric analyses at 50Hz. The results show the characteristics of the throwers' individual model at the event, which for practical purposes can be compared with the performance of the same throwers in other competitions. In general the Qatari throwers held the javelin longer and threw at a lower. Variations in throwers' technique may result in differences in performance.

KEY WORDS: Javelin, dynamics, force,

INTRODUCTION: A description of the technique used by elite throwers gives insight into individual forms to obtain high performance. These models become references that help coaches and athletes to develop their own strategies to achieve maximum efficiency.
The pattern of motion used in the javelin throw is similar to other movements used when striking or throwing an object (Atwater, 1979; Menzel, 1987). These are characterized by the fact that the body segments act sequentially to attain the maximum speed in the most distal segment of the system at the instant when the object is struck or thrown. The present paper describes the technical models used by two Qatari finalists in the men's javelin competition at the Qatar Athletics Championships in Doha in March 2009. The aim of the study was to compare the throwers' individual models in the light of the documented data available on the biomechanical analysis of javelin throw.

METHODS: All throws in the final were filmed and the best attempts of both athletes were subsequently analyzed. The camera (SVHS Panasonic video cameras, operating at 50 fps) was aligned with the optical axis at approximately 90 degree angle to the side view. A modulated reference system (one integrated square of 2x2 m) was used for spatial calibration. The throws were analyzed using Dartfish v.5 software. The selected timing and other kinematic parameters were obtained from the digitized coordinates.
The biomechanical analysis of each athlete focused on the Preparatory and Final Delivery phases. The most important factors for javelin release occur during these decisive periods, which therefore offer the best comparison for athletes' techniques (Campos et al., 2000).
The main time points were the following:

- t1: right foot lands (support leg for right-handed thrower) on the ground (single-support) at the beginning of the Preparatory Phase
- t2: left foot lands (braking leg for right-handed throwers) on the ground (double-support or Power Position) at the end of the Preparatory Phase and at the beginning of the Final Delivery Phase
- t3: javelin is released (instant of release) at the end of the Final Delivery Phase.

The reference values from three international elite athletes were obtained, for comparison, from biomechanical analyses at the 12th World Championships in Athletics in 2009 (IAAF, 2009).

RESULTS AND DISCUSSION: ***Duration of the Preparatory Phase and Final Delivery Phase:*** The results show that the greatest differences between the athletes occur in the Preparatory Phase. Times recorded for the duration of the Preparatory Phase ranged from about 0.13 s for the international throwers up to 0.19 s for a Qatari thrower (Table 1). The international throwers had wider variation in the Final Delivery Phase, whilst the Qatari throwers had very similar times. As an average, the Qatari throwers had longer durations in both phases than the international throwers with 0.07 seconds more spent as total time for these phases.

Table 1. The results of all subjects and duration of the different phases

Athlete and nationality	Final result [m]	Preparatory phase [s]	Final Delivery Phase [s]	Total time [s]
Thorkildsen (NOR)	89.59	0.14	0.18	0.32
Martinez (CUB)	89.41	0.13	0.26	0.39
Murakami (JAP)	82.97	0.13	0.20	0.33
International Average		0.13	0.21	0.34
Ahmed (QAT)	76.98	0.12	0.26	0.38
Ibrahim (QAT)	67.99	0.19	0.25	0.44
Qatari Average		0.16	0.26	0.42
Difference between averages		0.03	0.04	0.07

Duration between maximum (peak) joint speed and the instant of release: The quality of energy transfer to the javelin is influenced by the coordinated motion of the upper limb, starting from the acceleration-deceleration of the sequences in the upper kinetic chain. These sequential motions from proximal to distal segments are one of the fundamental keys to performance in over-arm throwing (Atwater, 1979; Mero et al., 1994). Hip, shoulder, elbow, hand and javelin velocities were taken into account to analyse power transmission sequences in delivery.
The analysis of how the maximum speed timing for each marker are reached during delivery (table 2) provides a more detailed description of the timing used by the throwers to structure their individual motion models for the upper limb.

Table 2. Peak joint speed timings during delivery

	Total time	Hip time		Shoulder time		Elbow time	
Athlete and nationality	[s]	[s]	[%]	[s]	]%[	[s]	]%[
Thorkildsen (NOR)	0.32	0.12	38%	0.10	31%	0.06	19%
Martinez (CUB)	0.39	0.14	36%	0.08	21%	0.05	13%
Murakami (JAP)	0.33	0.12	36%	0.08	24%	0.06	18%
International Average		0.13	37%	0.09	25%	0.06	17%
Ahmed (QAT)	0.38	0.14	37%	0.08	21%	0.05	13%
Ibrahim (QAT)	0.44	0.14	32%	0.10	23%	0.06	14%
Qatari Average		0.14	35%	0.09	22%	0.06	14%
Difference between averages		0.01	-2%	0.00	-3%	0.00	-3%

Table 2 shows the data of time duration from maximum hip, shoulder and elbow speed to release, with average times of 0.13 s for the time from maximum hip speed to release, 0.09 s from maximum shoulder speed to release and 0.06 s from maximum elbow speed to release for the International throwers. The two Qatari throwers showed similar timings. The differences between the International and Qatari throwers were in relative timings. The Qatari throwers displayed maximum hip speed 2% later, and both shoulder and elbow speed 3% later than the international throwers. These differences in starting hip motion confirm findings by Best et al. (1993) that this parameter depends on individual technique and its effect on performance should be considered in relative terms.
Release conditions (release height; release angle and angle of attack): Release height is a measure of ballistic efficiency and depends on the thrower's height, lateral bending of the trunk and front leg knee angle at the instant of release (Mahmud, 2007). Throwers should aim to release the javelin from as high as their height allows while maintaining foot contact on the

ground. The results show release heights that range from 1.80 m to 2.14 m. The parameters relative to the position of the javelin at release should include javelin position angle (also called attitude angle), release angle and, as a consequence of these, angle of attack. (Mahmud, 2007).Attitude angle is the angle between the position of the javelin and the horizontal, the release angle is formed by the velocity vector and the horizontal, and the angle of attack is the difference between attitude angle and release angle. Theoretical references suggest that the release angle should be 32° - 37° and the angle of attack not over + 8° for an effective throw. (Morris et al., 2001).

Knee Angle of the braking leg (Final Delivery Phase t2 - t3): The bracing and blocking action of the braking leg must also be taken into account in order to reach maximum release velocity, as it greatly reduces the horizontal velocity of the thrower-plus-javelin system (Morris et al., 2001).The knee angle of the braking leg is an indicator of the athlete's ability to transfer kinetic energy to the javelin. This blocking action favors kinetic energy transfer from the upper part of the body to the javelin. It seems evident that this action is decisive, considering that in elite throwers 60% of the javelin's kinetic energy is generated in the last 50 ms before release (Morriss & Bartlett, 1995). Results from the international throwers showed an average knee angle of 162° at t3, but the Qatari average was found to be considerably less at 151° (table 3). The Qatari throwers do not seem to be able to hold the knee angle of the braking leg as stable as the international throwers.

Table 3. Braking leg knee angle values at t1, t2& t3

Athlete and nationality	t1	t2	t3
Thorkildsen (NOR)	170	162	169
Martinez(CUB)	171	152	153
Murakami (JAP)	178	163	166
International Average	173	159	162
Ahmed(QAT)	175	141	147
Ibrahim(QAT)	173	145	155
Qatari Average	174	143	151

All the finalists showed increasing extension of the braking leg knee angle in the Final Delivery Phase. Therefore, braking leg knee extension at release was higher than for the whole of the Final Delivery Phase. The main difference between the International throwers and Qatari throwers were that the Qatari throwers knee angle was very flexed at t2, i.e. already at the instant of left foot landing. Thus, although both International and Qatari throwers extended their knee from this point onwards, due to already more extended knee at the start of the final delivery phase, the international throwers ended up having better support (equal to a more extended knee) at the time of release (t3). This allows a higher release point and higher release velocity.

Hip and Shoulder axis rotation on the sagittal plane: Rotation of the hip and shoulder axis in the sagittal plane are two important measures that show the thrower's ability to make a wide and continuous movement in the Final Delivery Phase and help throw the javelin further. With regard to shoulder motion, both International and Qatari averages were 175° at the start of the preparation phase (table 4). During this phase, the international throwers rotated the shoulder more than Qatari athletes and ended up with an angle of 133° at the start of double-support (t2), which is in line with a study by (Morris & Bartlett 1996) on elite throwers. In addition, there was greater variability in the difference between shoulder and hip axes angles at t1 than at t2. The Qatari athletes' hip angles were considerably smaller than the international athletes' hip angle at t1, but then larger at t2. Similarly to hip, the shoulder rotation undergone by the Qatari athletes was less than for the international athletes showing that the Qatari athletes should get a better body position at t1 and then have stronger rotation in the preparation phase.

Table 4. Measurements recorded for each athlete during t1 and t2.

	Hip		Shoulder		Hip-Shoulder difference	
Athlete with nation	t1	t2	t1	t2	t1	t2
Thorkildsen (NOR)	141	107	165	133	24	26
Martinez(CUB)	182	114	180	135	-2	21
Murakami (JAP)	170	114	181	132	11	18
International Average	164	111	175	133	11	21
Ahmed(QAT)	124	124	188	154	64	32
Ibrahim(QAT)	135	111	162	143	27	32
Qatari Average	129	117	175	149	46	32

CONCLUSIONS: In agreement with previous studies it was observed that each thrower maintained an individual throwing pattern in relation to timing and the values obtained in the different kinematic parameters under study. Nevertheless, these individual patterns are related to what could be called efficiency filters. These are the minimum requirements needed to throw the javelin a long distance which affect the position of the kinetic chain in the Final Delivery Phase as well as the coordination of the body segments for ballistic movement. The Qatari athletes showed weak individual patterns on the body position in the final delivery.

The aspects that distinguished Thorkildsen from the rest of the throwers was that his movements were more rectilinear in the final phases and he throws from a higher position, with a longer acceleration path and more favorable release conditions. However, It is felt that the information presented herein will be useful for javelin throw coaches and throwers and that it will contribute to the understanding of this sport and improve their achievement.

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