KINEMATIC ANALYSIS OF THE LAST STEP AND RELEASE STAGE IN MEN'S JAVELIN THROW

Hayder Ahmed Majeed
Student Activities Department/ Basrah University
hayder.majeed@uobasrah.edu.iq

Qasim Mohammed Sayah
kenanysayah@gmail.com
Student Activities Department/ Basrah University

Abstract

The purpose of this study was to investigate the two-dimensional kinematic variables about the last step and release phase of the throwing technique of men's javelin throwers. For movement analysis, data were collected on 6 Iraqi javelin throwing athletes at the Iraq Championships in 2019. Recorded full-body video of athletes and javelin throwers during competition with a camera. High Speed (Casio Exilim EX-F1) set to 300 fps. The camera was positioned to the right and perpendicular to the runway to record the sagittal plane video. 2D coordinates were collected using (SkillSpector V1.3.2) software. The time, distance, speed, and angle around the last step and launch stage were analyzed, and the following was achieved; In order to throw the javelin effectively, subjects seem to spend more time on approach in the landing phase, and shorter delivery time in the release phase. On launch, it appears that the other items except player A1 are throwing in a state below their height. This result showed a slowdown in the speed of the project. To increase the projection velocity of the upper limb, joint in the launch event, it appears to extend the angle of the shoulder rather than increase the extension of the elbow joint. The body center of gravity angle body showed an almost incremental increase on the vertical axis in the firing event. But the anterior inclination angle of the trunk showed a small angle compared to the increase of the body by the body center of gravity angle. Therefore, in order to effectively transfer the momentum of the whole body in the javelin, the forward and backward inclination angle of the torso appears to rapidly transmit the angle displacement in the arc position or crescent state during the delivery motion of the launching stage. Therefore, Iraqi javelin throwers must practice the proper height, angle, and speed of the spear while firing. In order to achieve the effect of increasing the javelin throw distance further in the competition.

Keywords: posture, body angle, Torso tilt angle, landing.

ResearchJet Journal of Analysis and Inventions
https://reserchjet.academiascience.org

1. Need for Research

Javelin throw is one of the track and field events that has been adopted since the ancient Olympic Games and has recently been developed in Cuba, Germany, Finland, etc. It is a record game to see how far a thrower can throw using a run-up in an area with a width of 4m and a distance of 35m. In the case of Iraqis players, who are inferior in terms of physique and physical strength, facing the reality of showing a record difference of more than 20m compared to European and Western players, the most decisive factor in athletic performance is throwing posture and kinematics. is being given importance.

According to the rules, the javelin must only be carried in the designated area and the javelin must be thrown over the shoulder or upper arm. Throwing or throwing is not permitted in this competition. The rules for the javelin competition are set by the International Association of Athletics Federations (IAAF). The height of the spear, the angle of the spear, the speed of the spear (Saratlija,2013) (Morriss,1996). These factors coordinate the movements arising from the action of the muscles and joints in different parts of the body. And that achieving the farthest throwing distance requires an ideal approach speed, in which the shooter gets acceleration in the first part of it, and then obtains the optimal position of the body and the spear in the second part (the weighted step), at the end of which is the preparation process for throwing (Al-Hashimi, 1999).

Looking at preceding studies on the kinematics of javelin throw, (Hubbard ,1989) reported that the position, speed, posture, and angular velocity at the moment of release can be achieved at the optimum condition to obtain the maximum flight distance, and (Ikegami 1981) In order to increase the flight distance, the instantaneous speed of the release must be raised to the maximum by increasing the acceleration as much as possible, and (Rich ,1984) et al. It was said that speed and height differed in physique and physical condition. (Komi & Mero ,1985) and (Ikegami ,1981) reported a significant relationship between run-up speed and throwing distance. (Barrlett ,1982) and (Hay ,1985) reported the characteristics of cross-step and run-up speed. (Miller & Munro ,1983) studied the run-up step and release motion with elite players, and (Bartlett & Best ,1988) reported an increase in release speed and the maximum reachable distance when releasing. (Bosen ,1981) reported on the kinematic analysis of accelerating the speed of the supporting foot and spear at the moment of throwing a spear. (Ikegami ,1981) and (Terauds 1978) reported on the release angle and throwing distance, and (Mero ,1994) analyzed the contribution of each segment according to the release. reported to increase. (Roger & Russell 1988) reported the relationship between maximum release speed, knee flexion and performance. Based on these studies, kinematic analysis of male javelin throwers is provided as basic data for improving athletic performance. In particular, it has a very important meaning in analyzing male javelin throwers in the absence of research on male athletes in Iraq. In addition, the answer to the question of what kind of landing action should be taken to throw the spear as far as possible has not yet been clarified. Therefore, this study aims to analyze the kinematic factors that appear in the release phase according to the final run-up and delivery motions.

And since there is a very delicate relationship between the approximate running speed and the process of launching the spear, and therefore the distance traveled by the spear depends on the speed and angle of launch. Bios Feld indicated that the mechanical characteristics of good spear throwers are the length of the last step (the push step) and the angle of the front knee at the moment of touching the ground. And the moment of the appearance of the stretched arc and finally the moment of the spear's launch, as well as the speed of the spear's launch and its angle (Tidow,1996) from this, the importance of the research was evident in the detection and analysis of the last step and its importance and impact on the completion distance, as well as the weakness of the digital level, which led the researchers to analyze the last step kinematically, as well as identifying weaknesses and diagnosing the defects from the side The mechanic to be one of the factors that helped advance the reality of this effectiveness

2. Research method

1. Subject of research

The subjects of this study were selected from the top 6 athletes who advanced to the men's general javelin throw final in the National Track and Field Championships in June 2019, and their personal characteristics are shown in (Table 1).

ResearchJet Journal of Analysis and Inventions
https://reserchjet.academiascience.org

Table 1. Characteristics of research subjects

subjects	Height(cm)	weight(kg)	best record(m)
A	165	63	66.10
B	174	77	66.81
C	166	58	70.15
D	169	70	55.10
E	170	68	74.70
F	170	58	47.20
M	172.5	72.17	63.34
SD	1.87	2.93	10.23

2. Experimental procedure

The data was captured using a high-speed camera (Casio Exilim EX-F1) set at (300) frames per second. To record a video covering the athlete's body and the javelin as it launches for the last (5 meters) of the runway. The position of the camera set to the right and perpendicular to the runway to record the sagittal plane video is shown in Fig. 1. The recordings in this study. The camera was (1m) above the ground and perpendicular to the runway for a distance of (8 m). Video was recorded as all subjects performed the javelin in the race from start to finish. Along with recording the distance traveled for each of the participants. Which was endorsed by the Jury After that, the video of each participant's longest flying distance was selected to analyze the height, angle and speed of the javelin on the computer using (SkillSpector V1.3.2). Frame calibration (2m x 2m) consisting of 9 coordinate points and placed in the location of the player's movement

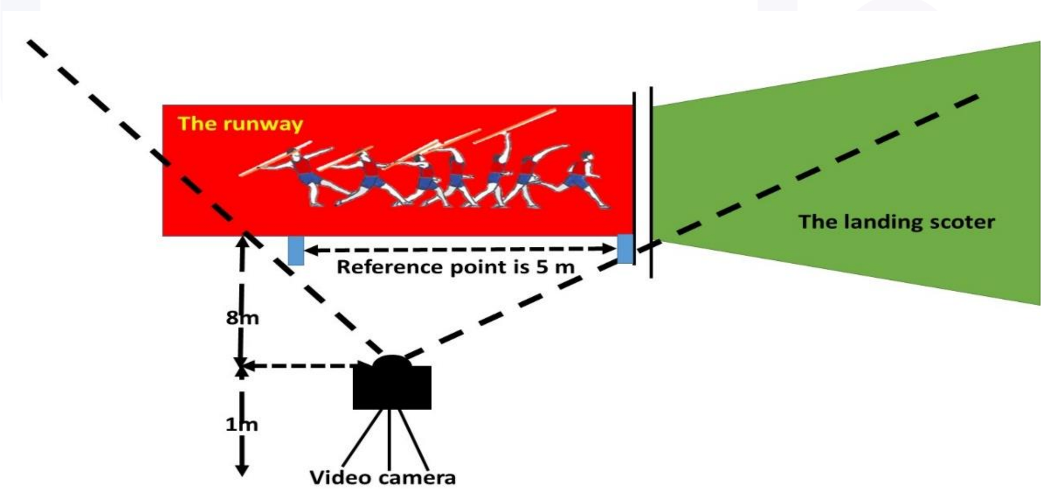

Figure 1. Location of the camera to record video.

The analysis phase of this study (Figure 1)was classified into a total of two phases and the kinematic variables for each phase were analyzed.

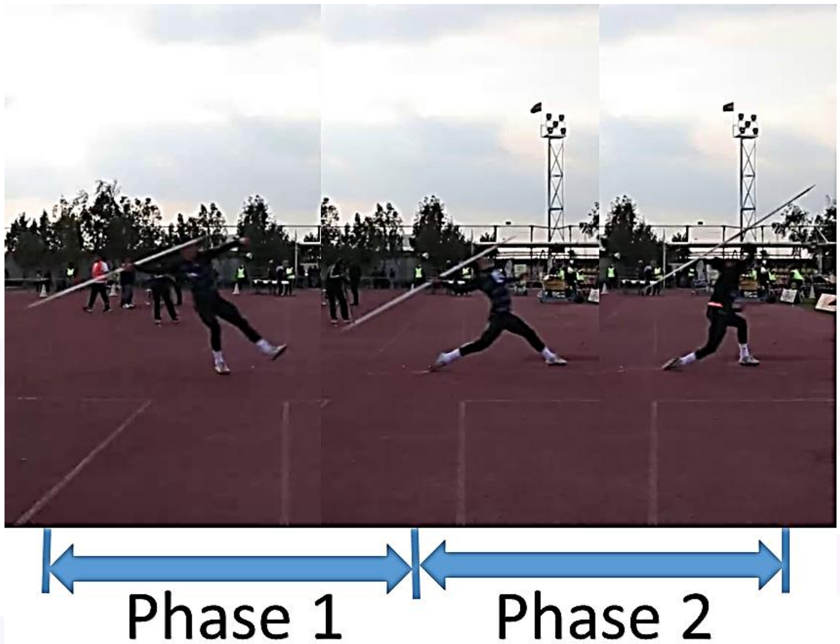

Figure 2. Analysis intervals and phases

Phase 1 (support phase): From the landing of the force foot to the moment of landing of the support foot.
Phase 1 (Release Phase): From the moment of landing with support to release.

3. Results and Discussion

1. Landing Phase

(Table 2) shows the kinematic characteristics of the landing phase. Looking at the performance time for phase 1 from the moment the strength foot lands on the ground to the moment the supporting foot lands, the average time was 0.14±0.02 sec, which was slightly faster than the 0.21 ± 0.03 sec of (Mero et al ,1994). According to (Mero et al ,1994), it was reported that if the time required from the strength foot to the landing of the support foot is long, as the stride length increases, the center of the body is lowered and the momentum transmitted to the spear is greatly transmitted. The subject who showed the longest time was A1, which was 0.17sec, and the subjects who showed the shortest time were A2, A3, and A4, which were 0.13,0.12,0.13 sec, showing some variation among subjects.

ResearchJet Journal of Analysis and Inventions
https://reserchjet.academiascience.org

Looking at the horizontal movement displacement of the midship of the body, it was 92.2±18.89cm, indicating that there was a lot of variation among subjects, and in terms of the ratio according to height, subject A6 showed the largest displacement at 112.1cm, and subject A4 showed the largest displacement at 66.9 cm The shortest displacement in cm is shown respectively.

It is thought that the large movement displacement is due to the release action while taking a rearward posture when landing on the support leg. A short movement displacement can be seen as turning the center of gravity forward. It can be seen that it is important to increase the amount of exercise while pushing the upper body to the foreground posture as much as possible while taking the upper body in the rearward posture until the movement.

Looking at the corresponding change in the height of the center of the body, it was found that the greater the displacement of the subject, the greater the change in the height of the center of the body. According to Bosen (1981), if the stride between the support foot and the strength foot is too wide, as it is lowered, the degree of arch becomes more severe, which can increase the elastic contraction force of the muscles, but the height of the center of gravity and release decreases, and as suggested, the distance according to the height of the center of gravity decreases. It was shown that the subjects (A1, A2) who showed a height change of 20 cm and showed small changes of -7.9cm and -5.2cm showed good records.

Looking at the change in vertical position of the upper extremity joint points, the shoulder ranged from 116.68 to 109.63 or .64 cm from .06 cm, the elbow from 111.73 or .96 cm to 109.63 or .64 cm, and the wrist from 109.63 to 6.19 cm. It was found that the vertical position of the joint point was lowered with 105.77 tables.69cm. It can be seen that the high posture when landing on the strength foot lowers with the landing on the supporting foot, which can be seen as preparing for the release motion by extending the arm to the maximum while lowering the center of gravity to increase the speed of the distal segment Examining the change in velocity of the upper extremity joint, it was found that the joint speed increased faster at the moment of landing of the support leg than at the moment of landing of the power leg. Subjects A1, A3, and A6 did not show a significant change in velocity even when landing on the supporting foot, while subjects A2, A4, and A5 recorded 9.68m/s, 11.36m/s, 8.77m/s, and 9.18m/s at the wrist and elbow joints, respectively. m/s, 9.47m/s, and 9.31m/s for fast speed changes It was shown that the release motion started before the landing of the support foot, and it was found that the javelin was thrown without transmitting the momentum according to the landing of the support foot.

Table 2. Kinematic characteristics for the support phase

	Variables	Unit	Subjects A1	A2	A3	A4	A5	A6	M ± SD
1	Landing Time	sec	0.17	0.13	0.15	0.12	0.13	0.16	0.14±0.02
2	Horizontal displacement of the body's center of gravity	cm	101.3	74.2	110.3	66.9	88.4	112.1	92.2±18.89
3	Vertical displacement of the body's center of gravity	cm	-7.9	-5.2	-8	-9	-13.4	-14.3	-9.63±3.51
4	The horizontal height of the shoulder in the touchdown (foot strength)	cm	121	115.1	117.5	110.6	113.4	122.5	116.68±4.55
5	The horizontal height of the elbow when touching down (foot strength)	cm	115.2	110.1	109.4	106.4	111	118.3	111.73±4.29
6	The horizontal height of the wrist at touchdown (foot strength)	cm	117.1	108.3	101.8	107.3	109.5	118	110.33±6.19
7	Shoulder height at touchdown (foot support)	cm	118	107.1	110.2	109.2	105.8	107.5	109.63±4.39
8	elbow height at touchdown (foot support)	cm	105.2	95.1	106.3	96.5	106.4	101.5	101.83±5.02
9	wrist height at touchdown (foot support)	cm	107.2	108.3	113.5	95.8	103.1	106.7	105.77±5.93
10	Horizontal velocity in touchdown of the body's center of gravity (foot force)	m/ s	6.57	6.12	5.98	6.58	5.98	6.44	6.28±0.28
11	Horizontal velocity in touchdown of the body's center of gravity (foot support)	m/ s	5.93	5.88	5.19	5.38	5.51	5.23	5.52±0.32
12	Vertical velocity in touchdown of the body's center of gravity (foot force)	m/ s	-0.84	-0.92	-0.87	-1.1	-0.97	-0.96	-0.94±0.09
13	Vertical velocity in touchdown of the body's center of gravity (foot support)	m/ s	-0.14	-0.21	-0.33	-0.25	-0.18	-0.39	-0.25±0.09
14	velocity resultant in touchdown of the body's center of gravity (foot force)	m/ s	6.78	6.98	6.98	7.88	6.98	7.83	7.24±0.48
15	velocity resultant in touchdown of the body's center of gravity (foot force)	m/ s	6.24	6.61	6.57	6.36	5.95	7.33	6.51±0.47
16	velocity resultant in touchdown of the body's center of gravity (foot force)	m/ s	6.49	5.99	6.47	6.41	5.97	6.67	6.33±0.29
17	velocity resultant in touchdown of the body's center of gravity (foot support)	m/ s	7.4	6.87	7.27	7.68	8.23	6.89	7.39±0.51
18	velocity resultant in touchdown of the body's center of gravity (foot support)	m/ s	7.89	9.18	6.23	9.47	9.31	6.98	8.18±1.36
19	velocity resultant in touchdown of the body's center of gravity (foot support)	m/ s	7.41	9.68	6.88	11.36	8.77	7.89	8.67±1.65
20	Body angle in the force of the foot	m/ s	88.5	87.6	85.8	89.7	87.8	84.5	87.32±1.88
22	The angle of the body in support of the foot	deg	84.7	89.6	88.3	76.6	86.5	79.6	84.22±5.11
23	Torso tilt angle at foot force	deg	-16.4	-16.9	-26.4	-17.3	-7.5	-18.4	-17.15±6.01
24	Torso tilt angle at support of the foot	deg	-10.3	-15.6	-16.1	-16.7	-6.5	-9.1	-12.38±4.30
25	Elbow angle at force of the foot	deg	175.3	174.4	167.8	171.3	177.8	169.3	172.65±3.83
26	Elbow angle at support of the foot	deg	153.3	117.5	138.4	147.5	138.7	151.5	141.15±13.18
27	Shoulder angle at force of the foot	deg	101.4	98.1	102.4	105.7	94.6	110.3	102.08±5.53
28	Shoulder angle at support of the foot		114.5	131.4	128.6	117.6	104.6	115.7	118.73±9.86

Looking at the change in the speed of the center of the body, in the horizontal speed, as the supporting foot landed on both subjects,

From 6.28±0.28m/s to 5.52±0.32m/s, it was found that the subject decelerated without much deviation, similar to the speed of 5.6 ± 0.3 m/s shown in the study of (Antti et al ,1994). , it was found that the vertical speed decelerated from -1.03±0.08m/s to -0.28±0.12m/s without much variation among subjects.

Looking at the characteristics of the angle factors, the angle factors looked at the body pack perception with the vector connecting the center of the left and right feet and the center of the body, the angle of the upper body front and rear angle, and the angle of the elbow and shoulder. The body angle was 87.32±1.88deg when landing on the strength foot, and 84.22±5.11deg when landing on the support foot.

Subject A1 with a small value was found to have the largest arch posture at 84.7deg, and subject A3 with 88.3deg, it was found that the support foot landing was made in a posture close to vertical. Looking at the upper body anterior-posterior angle according to the body angle, --17.15±6.01deg during the force landing, and -12.38±4.30deg during the supporting foot landing, showing many variations among the subjects. Subjects A1, A3, and A6 showed the opposite characteristics that the upper body rear angle became smaller as the supporting leg landed, whereas the upper body rear angle increased as the supporting foot landed on the subject A2, A4, and A5.

Looking at the characteristics of the shoulder and elbow angles, the elbow was found to be greatly flexed at 141.15±13.18deg in the extended state of 172.65±3.83 deg. Although it was found to be greatly flexed, the shoulder angle showed a characteristic of extending about 20 degrees, from 102.08±5.53deg to 118.73±9.86deg. It was found that the shoulder was also greatly extended.

2. Release Phase

(Table 3) shows the kinematic characteristics from the landing of the support foot to the moment of release.

Looking at the time required from the landing of the supporting foot to the release, the time was 0.16±0.02sec, and the overall execution time was 0.31±0.02sec, showing a similar time without much variation among subjects.

In particular, it was found that the subjects (A1, A3) who had a longer time in phase 1 showed a shorter performance time in phase 2. This is an important factor in the process of transferring the driving force from the lower extremities

ResearchJet Journal of Analysis and Inventions
https://reserchjet.academiascience.org

and the torso to the throwing arm with the smoothness of the motor transmission (Mohamed, 2001).

Looking at the horizontal movement displacement of the center of the body, it was 37.3±9.73cm, which showed a lot of variation among subjects. The horizontal movement distance was 130.68±19.97 cm, which showed a lot of variation among subjects. Subjects A4 and A6 with slightly poor records showed small or large horizontal displacements, respectively, with 101.1cm and 161.9cm, respectively, while subjects A1 and A2 with excellent records showed 125.4cm and 128.3cm, respectively. If the movement displacement is small, it tends to fail to transmit the momentum to the distal segment because it is not possible to properly block the center of the body when landing on the support foot. characteristics that do not connect indicate Therefore, it is considered an important factor to take a posture suitable for each individual within the range where the center of gravity of the horizontal movement displacement from the landing of the support foot to the release is not excessively low.

Table 3. Kinematic characteristics for the release phase

	Variables		Subjects						M ± SD
		Unit	A1	A2	A3	A4	A5	A6	
1	Time	sec	0.11	0.17	0.12	0.17	0.16	0.15	0.15±0.03
2	Total Time	sec	0.29	0.3	0.28	0.28	0.29	0.32	0.29±0.02
3	Horizontal displacement of the body's center of gravity	cm	27	55.8	33.5	40.3	41.4	42.7	40.12±9.70
4	Total horizontal displacement of the center of gravity of the body	cm	125.4	128.3	140.5	101.1	126.9	161.9	130.68±19.97
5	vertical displacement of the body's center of gravity	cm	11.5	10.7	6.2	5.4	4.7	6.6	7.52±2.86
6	vertical height of the shoulder at release	cm	140.2	125.3	128.3	112.4	116.5	122.9	124.27±9.74
7	vertical height of the elbow at release	cm	163.8	1141.9	150.8	134.1	133.2	145.3	144.85±11.44
8	vertical height of the wrist at release	cm	177.8	151.7	161.6	147	148.1	159	157.53±11.52
9	Horizontal velocity of the body's center of gravity at release	m/ s	3.57	3.18	2.86	3.17	3.25	3.15	3.20±0.23
10	vertical velocity of the body's center of gravity at release	m/ s	0.96	0.91	0.78	0.55	1.21	0.95	0.89±0.22
11	velocity resultant of shoulder at release	m/ s	5.49	5.38	5.38	5.63	5.16	4.53	5.26±0.39
12	velocity resultant of elbow at release	m/ s	10.16	8.66	11.84	10.71	9.41	9.32	10.02±1.14
13	velocity resultant of wrist at release	m/ s	16.88	15.61	15.3	15.11	13.94	13.56	15.07±1.20
14	Body angle at release	deg	86.7	107.8	109.8	96.7	98.4	91.9	98.55±8.95
15	Torso tilt angle at release	deg	19.4	7.5	3.8	4.6	19.7	13.5	11.42±7.16
16	Elbow angle at release	deg	134.2	121.4	128.4	144.3	147.1	144.3	136.62±10.32
17	Shoulder angle at release	deg	147.2	145.6	143.3	147.3	133.1	139.5	142.67±5.52

ISSN: 2776-0960 Volume 3, Issue 12 Dec., 2022

Looking at the vertical change of the center of the body, it was found that the center of the body increased by an average of 7.52±2.86cm compared to phase 1, and subjects A1 and A2 showed 11.5cm and 10.7cm, and the better the record, the greater the vertical change. As suggested in the studies by Anti Mero (1994) the higher the player with the better record, the higher the height of the center of gravity at the time of release showed the same result as when the support foot landed.

Looking at the heights of the upper extremity joint points at the moment of release, it was found that players with excellent records took the release action at a higher position with 124.27±9.74cm, 144.85±11.44cm, and 157.53±11.52cm. (Miller & Munro 1983), (Gregor & Pink ,1985) and (Bartlett ,1988) reported that the height of the spear at the moment of release should be 15-30 cm higher than one's height, and according to (Hay 1978), the release height is an important factor in determining the throwing distance. As a factor, it was reported that it is advantageous to release at the highest point possible.

However, according to (Terauds ,1978) and (Rich et al ,1985), there was no significant relationship between throw distance and release height.

Pointed out that at the moment of release, it was thrown straight over the head, and the release motion should be performed with the upper body tilted backward. However, in this study, all subjects except for subject A1 appeared to perform the release action at a position lower than their height, so it can be seen that the window was projected without transmitting the momentum of the upper limb segment during the delivery motion. Looking at the characteristics of the horizontal and vertical speeds of the center of the body, it was found that they decreased significantly more than at the moment of landing on the support foot, from 6.28±0.28m/s at the moment of landing on the support foot to 3.20±0.23m/s at the moment of release, about 2 m/s. or more, and the vertical speed increased by about 1 m/s or more, from --0.25±0.09m/s to 0.89±0.22m/s. In particular, there is a lot of variation among subjects in vertical velocity rather than horizontal velocity. In order to increase the projection distance by transferring effective momentum to the distal segment, it was found that the horizontal velocity should be converted to vertical velocity as much as possible at the moment of release.

The release speed is directly related to the throw distance (Komi & Mero, 1985; Miller & Munro, 1983; Terauds, 1978). Looking at the composite speed for the upper extremity joints, the shoulder, elbow, and wrist were 5.26±0.39m/s,

ResearchJet Journal of Analysis and Inventions
https://reserchjet.academiascience.org

respectively, 10.02±1.14m/s and 15.07±1.20m/s, respectively, showed that the deviation between subjects increased as it progressed toward the distal segment? Which (Barlonietz) considered one of the main variables that affect the throwing distance (Hassan, 2011).

Looking at the body angle at the moment of release, subjects A1 and A6 showed 86.7deg and 91.9deg and projected the window in a posture smaller than vertical, and subjects A2, A3, and E exhibited a release motion in a forward tilted posture. Has been shown to take as shown in the anterior-rear angle of the upper body, the postures of all subjects are in the foreground posture. Subjects A1 and A5 showed a large foreground posture, while subjects A3 and A4 performed the release motion in a state close to vertical. Appear. The researchers attribute this to the fact that the kinematic movement of the elbow during the approaching phase influences the speed of the throwing movement and the force of the javelin's launch. Accordingly, by returning the arm aimed backwards to the farthest extent, the angle of the elbow increases and, in turn, the angle of the torso increases in the forward support (Shaker, 2010). Throwing is carried out while leading the spear, and as reported that the upper body should be slightly tilted forward in accordance with the direction of the spear in order to increase the speed by applying more force to the spear, all subjects showed that the upper body tilted forward during the release motion. However, it showed a lot of variation among subjects.

In particular, in order to increase the throwing speed, the change in the upper body anterior-posterior angle should be large, and the angular displacement of about 22 degrees from the landing -12.38±4.30deg) to the release (11.42±7.16deg) of the supporting foot was shown, and the number of subjects with excellent records It was found that the rock angular displacement appeared large. The shoulder and elbow angles at the moment of release showed 136.62±10.32deg and 142.67±5.52deg, respectively. The better the record, the smaller the elbow angle, but the larger the shoulder angle. The angle is large and the shoulder angle is small. However, according to Kami & Mero (1985), the elbow angle was 92.0±0.19deg, indicating that the spear should be projected with the shoulder fully extended rather than fully extended at the moment of release.

4. Conclusion

As a result of factor analysis, distance factors, speed factors and angle factors, the following conclusions were obtained.

ResearchJet Journal of Analysis and Inventions
https://reserchjet.academiascience.org

It is found that the time required for the landing phase from the forceful foot landing to the supporting foot landing should be longer, and the launching procedure should be carried out with a shorter time in the launching phase. At the moment of release, most people were shown with their hands lower than their height, and the resulting projection speed was found to be small. It was found that the shoulder angle should be greatly extended at the moment of release rather than fully extending the elbow by increasing the elbow angle. At the moment of release, the angle of the body, which is the angle between the supporting foot and the center of the body, increased near the vertical axis, but the angle of inclination of the upper part of the body appeared smaller than the increase in the angle of the body. It is found that the angular displacement of the anterior and posterior angle of the upper body should quickly shift in position.

References

1. Al-Hashemi, Samir (1990): *Biomechanics*. Basra: Dar Al-Hikma Press. 94-101.
2. Shaker, Iman (2010): a comparative study. for a stage. The release of the spear. Between the heroes of Qatar. and some of the world champions participating in. Berlin. 2009, 1-17.
3. Bartlett, R. M., & Best, R. J. (1988). The biomechanics of javelin throwing: a review. Journal of Sports Science 6, 1-38.
4. Bartlett, R. M., Muller, E., Raschner, C., Lindinger, S., Jordan, C. (1995). Pressure distributions on the plantar surface of the foot during the javelin throw. Journal of Applied Biomechanics 11, 163-176.
5. Best, R. J., Bartlett, R. M., & Morriss, C. J. (1993). A three-dimensional analysis of javelin throwing technique. Journal of Sports Science 11, 315-328.
6. Hassan, Essam El-Din Shaaban Ali (2011): Movement chemistry of spear elites, published research, Umm Al-Quqi University, Saudi Arabia.6-15.
7. Hubbard, M. (1984). Optimal javelin trajectories. Journal of Biomechanics Vol. 17, 777-787.
8. Hubbard, M., & Always, L.W. (1984). Optimum release conditions for the new rules javelin.8-16.
9. Hubbard, M., & Always, L.W. (1989). Rapid and accurate estimation of release conditions in the javelin throw. Journal of Biomechanics Vol. 22, 583-595.
10. Hubbard, M., & Rust, H. J. (1984). Simulation of javelin flight using experimental aerodynamic data. Journal of Biomechanics Vol. 17, 769-776.

11. Hubbard, M., Bergman, C. D (1989). Effect of vibrations on javelin lift and drag. International Journal of Sport Biomechanics, 5-16.
12. Ikegarni, Y., Miura, M., Matsui, H., & Hashimoto, I. (1981). Biomechanical analysis of the javelin throws. Biomechanics VII-B,123-135.
13. Komi, P. V., & Mero, M. (1985). Biomechanical analysis of Olympic javelin throwers, International Journal of Sport Biomechanics, 139-150.
14. Mero, A, Korni, P.V., Kotjus, T., Navarro, E., & Gregor, R. G. (1994). Body segment contributions to javelin throwing during final thrust phases. Journal of Applied Biomechanics 10, 166-179.
15. Miller, D. I. & Munro, C. F. (1983). Javelin position and velocity patterns during final foot plant preceding release. Journal of Human Movement Studies, 0, 1-20.
16. Morriss C, Bartlett R. Biomechanical Factors Critical for Performance in the Men's Javelin Throw. Sports Med. 1996;21(6):438-446.
17. Morriss, C., & Bartlett, R. (1996). Biomechanical factors critical for performance in the men's javelin throw. Sports Medicine Jun 21, 438-446.
18. Muhammad, Muhammad Jassim (2001): A proposed training curriculum according to the most important chemical variables in the completion of the javelin throw, unpublished master's degree, Faculty of Mathematical Degradation, University of Babylon.17-25.
19. Plagenhoef, S. (1983). Anatomical data for analyzing human motion. Research Quarterly for Exercise and Sports, 54(2). 169-178.
20. Saratlija P, Zagorac N, Babic V. Influence of kinematic parameters on result efficiency in javelin throw. Collegium antropologicum. 2013;37 Suppl 2:31-36.
21. Terauds, J. (1978). Javelin release characteristics of USA and USSR thrower-1974. Track and Field Quarterly Review 78, 42.
22. Vaughan, C. L. (1989). Biomechanics of sport. CRC Press Inc, 227-236.
23. Whitting, W. C., Gregor, R. J., & Halushka, M. (1991). Body segment and Release Parameter contributions to new- rules javelin throwing. International Journal of Sport Biomechanics 7, 111-124.