Evaluation Model for the Performance of Javelin Throw in Accordance with the Mechanical Profile for the High Level in Track and Field Competitions

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The purpose of research is to design a model for evaluating the skilled performance of throwing the javelin in track and field competitions by means of identifying some biomechanical variables most correlated to the record level of the skill under study and setting the mechanical profile in light of these variables. Three participants who were javelin throwers (elite level) in Al-Geyad and Al-Olympic Clubs were selected purposively to serve as a sample. All subjects administered descriptive survey and kinamatogeraphical analysis. Findings suggest a strong correlation between biomechanical variables (horizontal, vertical and resultant velocities, horizontal, vertical and resultant forces of the center of gravity of the body and of the joints -upper arm, forearm, thigh, leg- as well as well as angle and velocity of delivery of the javelin and height of delivery point of javelin) and the record level of throwing the javelin among athletes at elite levels. The paper recommended using an evaluation card for javelin thrower, according to biomechanical variables, in the development and modification of training process.

Key words: Evaluation, Biomechanical Analysis, measurement.

Introduction

Scientific research is directed towards resolving problems related to motor performance in order to achieve the optimum level of performance. Nowadays, the world witnesses an evolution in the realm of training and super skilled performance in various sports activities till elite levels. This evolution is an output of modern technology of the measurement systems in biomechanics which is one of the basic pillars that served sports training to move towards progress (Ala'a El-Din and Al-Sabagh, 2005).

The study of performance of motor activities of sports looks very complicated and complex due to the difficulty of controlling variables and factors affecting that performance (Abdul-Bassir, 1998).

Evaluation is the best way to develop and improve the motor performance. We recognize the points of weakness and strength and the extent of progress in the athlete's level and emphasize the methods and effectiveness of training by means of evaluation. We can rely on sports technique of high levels athletes as a standard model to evaluate the technical performance by using kinamatogeraphical analysis of the kinetic path of the skill according to kinematic variables that affect the motor performance (Abdullah, 2011).

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Careful study of mechanical characteristics improves the sporting technique through correcting and developing according to modern scientific theories of sports training (Abdul-Bassir, 1998), (Abdullah, 2011).

Track and field sports are considered to be the measure of renaissance of the developed countries as it is the foundation for all sports activities. Throwing the javelin competitions aim to throw or push the javelin to a farthest possible horizontal distance without violating the rules of this sport. It is an individual-nature sport by which the record of high level is achieved. (Darwish, and Abdul-Hafiz, 1994) suggest that javelin competitions are of combined type where the distance covered by javelin is related to the velocity and power of the thrower. These competitions require high degree of harmony, coordination of movements and accurate directed efforts during performance.

In the literature, biomechanical analysis of javelin throw skill is examined mainly by the majority of researchers in terms of describing only the performance that based on biomechanical variables, for instance Abu-Ela (2013), but not in terms of evaluating the performance level of javelin throw in spite of the importance of this sport in Olympic championships. This urged the researcher to build an evaluation model in light of the mechanical profile for javelin throw skill via identifying the most correlated biomechanical variables with the performance.

The purpose of the current study was to design a model for evaluating the skilled performance of throwing the javelin in track and field competitions by means of identifying some biomechanical variables most correlated to the record level of the skill under study and setting the mechanical profile in light of these variables.

We hypothesized the following

- Hypothesis 1: There would be biomechanical variables most correlated with the performance of javelin throw that affect the record level.
- Hypothesis 2: The mechanical profile would be possible in light of biomechanical variables most correlated to throwing the javelin.
- Hypothesis 3: It would be possible to design an evaluation card for javelin thrower.

Method

Participants

The sample was selected purposively and included three javelin throwers of the first-class in Olympy and El-Geyad Clubs. These athletes are participants in the Egyptian Federation of Track and Field who represent Egypt in many national and international competitions and take higher positions. Their training ranges between 7 to 10 years. This selection was according to their record level in the championship of Republic in 2011/2012.

Material and apparatus

Photo equipment and instruments: Video camera brand Panasonic JVC 9800 at a frequency of 120 cadre /s, Panasonic DVC video tape, tripod carrier for camera, divided bar of 2 meters height to determine the scale, indicative phosphorous marks placed on the joints of the athlete in the right side in the direction of the camera (shoulder joint – Elbow- thigh- knee- foot- wrist).

Kinamatogeraphical analysis devices: Computer, 2-D Win analyze program. Equipment and instruments of physical measurements: Restameter to measure height (cm), measuring tape to measure length of the body's joints (cm), medical balance to measure weight (kg), sheet of recording physical measurements.

Tools of javelin throwing competitions: nine standardized javelins, guideposts for determining throwing distances of javelin, measuring tape for determining throwing distances, cones to determine the approach places, form for registering the distances covered by javelin).

Procedure

Photo-finish camera and measurements were performed in Alexandria Sports Stadium. Biomechanical analysis and data collection were conducted in the Laboratory of Faculty of Physical Education for Men – Alexandria in 2012/2013. This camera was installed perpendicular to the range of motion and against the right side of the player. The dimensions related to photo-finish camera were as follows: the distance between the photo-finish camera and the participant was 20.60 meter and the camera was positioned at 1.40 meters above the ground.

The scope of camera's lens should be taken into account to include the entire range of motion.

The divided bar was photographed before starting to determine the scale. All instructions stated in studies by (Abdul-Bassir, 1998), (Abdullah, 2011) that addressed the imaging test had to be followed. Marks were placed on the right side of athlete's joints (shoulder, elbow, wrist, thigh, knee and foot). For the purpose of testing, each athlete conducted warm-up workouts and two trials of throwing skill. Of three trials conducted by each thrower, the best two trials were determined according to the record level of the throw. The concurrence of these trials existed for the same circumstances of competitions in terms of performance standardization. The skill was divided into important phases of performance in accordance with technical performance. These phases are transition (cross over), pre-delivery stride and delivery.

The selected trials were analyzed and the biomechanical variables of each of the center of gravity of the body and of the joints (upper arm, forearm, thigh, leg and foot) were extracted. These variables included horizontal, vertical and resultant velocities, horizontal, vertical and resultant forces, as well as angle and velocity of delivery of javelin and height of delivery point of javelin. These variables were selected as they are the most important effective variables in the performance of the skill that play a major role in fulfilling the goal of this skill.

In table 1, the Descriptive Statistics for the Study are shown.

Table 1 Statistical Description of the Basic Variables of the Sample

Main Variables	Measurements Units	Mean	Std. Deviation	Median	Min. Value	Max. Value	Skewness
Total Height	Cm	183.6	2.302	184	181	187	0.606
Weight	Kg	86.4	1.517	86	85	88	0.315
Years of Training	Year	9.4	0.548	9	9	10	0.609
Record Level	Meter	52	1.581	52	50	54	0.00
Arm Length	Cm	87.4	1.140	87	86	89	0.405
Forearm Length	Cm	27.8	0.837	28	27	29	0.512
Upper Arm Length	Cm	36.6	1.140	37	35	38	0.405-
Palm Length	Cm	23.4	1.140	23	22	25	0.405
Trunk Length	Cm	41.6	1.140	42	40	43	0.405-
Thigh Length	Cm	46	0.707	46	45	47	0.00
Leg Length	Cm	51.2	1.304	51	50	53	0.546
Foot Length	Cm	107.8	1.643	107	106	110	0.518

Table 1 demonstrates the normality of height and weight data and the homogeneity of sample. The values of skewness coefficient ranged between -0.405 to 0.605, i.e., they approach zero.

Results

In table 2, the descriptive statistics for the study are shown.

Table 2: Statistical Description of Biomechanical Variables during Transition (cross-over) and Pre-delivery Stride Phases

Center of gravity	Biomechanical Variables	Measure ments Units	Mean	Std. Deviation	Median	Min. Value	Max. Value	Skewness	Correlati on factor
Center of Gravity of Body	Horizontal velocity	m/s	4.47	0.013	4.46	4.46	4.49	1.207	0.715
	Vertical Velocity	m/s	1.13	0.012	1.125	1.11	1.14	0.075-	0.612
	Resultant Velocity	m/s	4.63	0.103	4.60	4.5	4.8	0.666	0.610
	Horizontal Force	Newton	167.33-	1.751	166.50-	170-	166-	0.919-	*0.889
	Vertical Force	Newton	872.17	1.602	872	870	875	0.916	0.523
	Resultant Force	Newton	187.33	1.862	187	185	190	0.392	0.524
Center of Gravity of Upper Arm	Horizontal velocity	m/s	8.78	0.121	8.764	8.614	8.914	0.075-	0.513
	Vertical Velocity	m/s	4.41	0.010	4.41	4.39	4.42	0.666-	0.487
	Resultant Velocity	m/s	9.89	0.057	9.89	9.83	9.94	0.017-	0.482
	Horizontal Force	Newton	133.00	1.265	132.50	132	135	0.889	0.481
	Vertical Force	Newton	146.17	2.137	146	144	149	0.232	0.381
	Resultant Force	Newton	196.67	1.211	196.5	195	198	0.075-	0.295
Center of Gravity of Forearm	Horizontal velocity	m/s	10.10	0.119	10.07	10	10.24	0.329	*0.895
	Vertical Velocity	m/s	2.38	0.416	2.325	2	2.85	0.094	0.215
	Resultant Velocity	m/s	10.30	0.329	10.265	10	10.63	0.048	*0.889
	Horizontal Force	Newton	211.67	1.033	212	210	213	0.666-	0.614
	Vertical Force	Newton	119.17	1.835	119	117	122	0.513	0.612
	Resultant Force	Newton	243.67	1.366	244	242	245	0.523-	0.295
Center of Gravity of Thigh	Horizontal velocity	m/s	5.17	0.010	5.175	5.16	5.18	0.456-	0.614
	Vertical Velocity	m/s	0.73-	0.008	0.73-	0.74-	0.720-	0.313	0.315
	Resultant Velocity	m/s	5.12	0.106	5.09	5	5.24	0.320	0.516
	Horizontal Force	Newton	217.67-	0.516	218-	218-	217-	0.968	0.522
	Vertical Force	Newton	131.17-	1.169	131-	133-	130-	0.668-	0.610
	Resultant Force	Newton	254.17	2.858	254	250	259	0.521	0.612
Center of Gravity of Leg	Horizontal velocity	m/s	9.63	0.010	9.635	9.62	9.64	0.456-	0.614
	Vertical Velocity	m/s	1.93	0.008	1.93	1.92	1.94	0.313	0.618
	Resultant Velocity	m/s	9.83	0.010	9.825	9.82	9.84	0.456	0.553
	Horizontal Force	Newton	156.17	1.0119	156	150	163	0.363	0.410
	Vertical Force	Newton	225.17	3.488	225	220	231	0.428	0.612
	Resultant Force	Newton	273.17	1.329	273	272	275	0.326	0.713
Center of Gravity of Foot	Horizontal velocity	m/s	13.78	0.041	13.76	13.76	13.86	2.449	0.714
	Vertical Velocity	m/s	3.87	0.00	3.87	3.87	3.87	1.369-	0.611
	Resultant Velocity	m/s	14.30	0.00	14.30	14.30	14.3	1.369	0.629
	Horizontal Force	Newton	155.83	3.488	156	150	161	0.428-	0573
	Vertical Force	Newton	226.00	4.00	225	220	231	0.141-	0.544
	Resultant Force	Newton	274.17	0.753	274	273	275	0.313-	0.622

*** Significant (Tabulated Spearman correlation coefficient= 0.886)**

Table 2 demonstrates the normality of data concerning these variables. There is a significant correlation between some variables and throwing distance.

In table 3, the descriptive statistics for the study are shown.

Table 3: Statistical Description of Biomechanical Variables during the delivery phase

Center of gravity	Biomechanical Variables	Units of measure ment	Mean	Standard Deviation	Median	Min. Value	Max. Value	Skewness	Correlation Factor
Projection Variables	Angle of delivery of javelin	degree	39.87	0.121	39.85	39.7	40	0.075-	*0.889
	Velocity of delivery of javelin	m/s	24.93	0.225	24.9	24.6	25.3	0.327	*0.891
	Height of delivery point of javelin	M	163.83	0.753	164	163	165	0.313	*0.890
Center of Gravity of Body	Horizontal velocity	m/s	1.93	0.060	1.93	1.83	2.02	0.249-	0.612
	Vertical Velocity	m/s	3.72-	0.066	3.72-	3.83-	3.62-	0.225-	0.614
	Resultant Velocity	m/s	4.19	0.066	4.19	4.08	4.29	0.225-	0.615
	Horizontal Force	Newton	265.83	6.014	266	256	275	0.249-	*0.899
	Vertical Force	Newton	289.67-	1.506	290-	291-	288-	0.215	0.801
	Resultant Force	Newton	289.17	3.488	289	284	295	0.428	0.802
Upper Arm Link	Horizontal velocity	m/s	2.10	0.007	2.096	2.086	2.108	0.428	0.755
	Vertical Velocity	m/s	2.42-	0.060	2.42-	2.51-	2.32-	0.249	0.764
	Resultant Velocity	m/s	3.20	0.073	3.20	3.07	3.3	0.609-	0.765
	Horizontal Force	Newton	398.17-	4.119	398-	450-	392-	0.363-	0.715
	Vertical Force	Newton	704.17-	2.858	704-	709-	700-	0.521-	0.714
	Resultant Force	Newton	809.17	4.750	809	802	817	0.315	0.713
Forearm Link	Horizontal velocity	m/s	9.63	0.067	9.62	9.53	9.74	0.666	*0.889
	Vertical Velocity	m/s	4.11-	0.054	4.1-	4.2-	4.03-	0.814-	*0.891
	Resultant Velocity	m/s	10.46	0.057	10.46	10.38	10.56	0.521	*0.892
	Horizontal Force	Newton	209.17	6.014	209	200	219	0.249	*0.891
	Vertical Force	Newton	107.17	1.602	107	105	110	0.916	*0.892
	Resultant Force	Newton	110.10	1.169	110	109	112	0.668	*0.915
Thigh Link	Horizontal velocity	m/s	0.86	0.060	0.86	0.76	0.95	0.249-	0.512
	Vertical Velocity	m/s	2.73-	0.073	2.72-	2.85-	2.62-	0.609-	0.514
	Resultant Velocity	m/s	2.85	0.057	2.85	2.75	2.93	0.521-	0.612
	Horizontal Force	Newton	180.83	1.329	181	179	182	0.326-	0.651
	Vertical Force	Newton	998.17-	0.983	998.5-	999-	997-	0.456	0.324
	Resultant Force	Newton	101.17	0.753	101	100	102	0.313-	0.621
Leg Link	Horizontal velocity	m/s	1.90	0.070	1.9	1.8	2.02	0.428	0.459
	Vertical Velocity	m/s	3.59-	0.057	3.59-	3.67-	3.49-	0.521	0.623
	Resultant Velocity	m/s	4.07	0.060	4.07	3.98	4.17	0.249	0.623
	Horizontal Force	Newton	145.33	1.211	145.5	144	147	0.075	0.624
	Vertical Force	Newton	341.17-	1.602	341-	343-	339-	0.041-	0.615
	Resultant Force	Newton	370.67	1.211	370.5	369	372	0.075-	0.617
Foot Link	Horizontal velocity	m/s	2.15	0.070	2.15	2.05	2.27	0.428	0.612
	Vertical Velocity	m/s	3.02-	0.054	3.01-	3.11-	2.94-	0.814-	0.616
	Resultant Velocity	m/s	3.70	0.070	3.7	3.6	3.82	0.428	0.617
	Horizontal Force	Newton	144.17	2.858	144	140	149	0.521	0.618
	Vertical Force	Newton	340.67-	5.715	341-	349-	331-	0.521	0.624
	Resultant Force	Newton	370.00	6.325	370	360	380	0.075	0.634

Table 3 demonstrates the normality of data concerning these variables. There is a significant correlation between some variables and throwing distance.

Results and Discussion

There is a positive strong correlation (0.889) between the horizontal force of the center of gravity of the body and the throwing distance demonstrated in table 2 concerning the statistical description of biomechanical variables at the end of transition (cross over) phase / the start of pre-delivery stride phase. The researcher suggests that this positive correlation between the biomechanical variables and the record level of performance in terms of mathematical relationships affecting that correlation is considered significant; that is, the horizontal force of the center of gravity of the body at the end of transition (cross over) and the start of pre-delivery stride where the rear leg drives the hips to the front, transferring the weight from rear to the front leg in the pre-delivery stride pushing to the ground. This pushing force is transferred from the ground to the two legs, trunk, right arm and finally to the javelin to launch it quickly. Results agree with the technical performance of the skill emphasized by Bartlett (2014).

Ajami (2004) suggests that pushing force on some object equals the rate of change of momentum of an object which is demonstrated by the following mathematical relationship:

$$\overset{A}{F} = \int_{t1}^{t2} \mathrm{Fdt} = \int_{v1}^{v2} mdt = (mv_2 - mv_1) = (v_2 - v_1)$$

Where: $\overset{A}{F}$: pushing force , F: Average force. t: time (mv_2-mv_1) is the rate of change of momentum (quantity of motion that is replaced by mass times velocity).

The previous relation shows the integration of force function with respect to time. Therefore, it is clear that the change in the velocity of female athlete depends not only on her exerted force but also on how long the force is exerted (Grimshaw et al., 2007),

The pushing position where both feet are placed firmly on the ground helps to increase the distance of acceleration and the reaction with respect to the horizontal motion of the center of gravity of the body which finally forms the resultant force that push the implement in a constant streamline manner (El-Sokkary and Hasan, 1997)

There is also a positive correlation between the horizontal velocity and the resultant velocity of the center of gravity of forearm, and the throwing distance. The values of correlation coefficients were 0.895, 0.889 respectively (El-Sokkary and Hasan, 1997); (Husam El-Din, 1993); (Guthrie, 2003)

The previous table demonstrated that there is a positive correlation between the angle and velocity of delivery of javelin and the height of delivery point, and the throwing distance. The values of correlation coefficient were 0.889, 0.891, and 0.890 respectively. The researcher believes that these biomechanical variables possess an effect on the throwing distance where there is a typical angle for each height and velocity of delivery (Husam El-Din, 1993).

Darwish and Abdul-Hafiz (1994) report that the best angle of delivery for a proper javelin path ranges between 35 to 40 degrees.

Throwing the javelin takes the projectile path known as Parabola which is a pattern of curves having similar peaks. The inclination of the peak of parabola depends on the measure of delivery angle; the larger the angle of delivery, the larger the inclination of parabola will be. There is a positive correlation between the horizontal force of the center of gravity of the body and the throwing distance rated 0.899, where the center of gravity of the body is located above the front part of the foot while maintaining the direction of delivery angle. The rear leg (right) pushes the ground strongly in the direction of throwing starting to get the terminal velocity in the javelin through the stance of the thrower which is called the stretched bow. Also, the force transfers from the two legs to the trunk, shoulder, forearm, wrist, and finally to the fingers to press firmly on the javelin, thus the javelin acquire a explosive force from a natural spin motion at delivery which increase the efficiency of motor performance and achieve the best record level.

There is a positive correlation between the horizontal and vertical velocity and the resultant velocity and the horizontal and vertical force and the resultant force of the center of gravity of the forearm, and the throwing distance. The values of the correlation coefficients were 0.889, 0.891, 0.892, 0.891, 0.892, and 0.915 respectively. At the stance of throwing, the forearm moves strongly and quickly in the direction of throwing to achieve the largest horizontal distance. The correct movement of the arm and head leads to an elevated flying path and acceleration of the javelin in a straight line (Al-Sokkary and Hasan, 1997).

The earlier the extended arm and palm to get an increase in the velocity, the longer the time to exert force. This provides a chance of increasing the benefit of the mechanical force of the arm to launch the javelin to achieve maximum possible distance according to this equation: $F = ma$, where F: force, m: mass, a: acceleration. This means that the acceleration of the arm is directly proportional to the affected force and in the same direction (Husam El-Din, 1993).

Based on the above results, the effect of the previous mechanical variables and their correlation with the throwing distance (record level) are clear. These variables are considered to be a good indicator for achieving the motor task required for this skill. Based on these variables; the researcher concluded a mechanical profile of these biomechanical variables most correlated to the technical performance under study (Figure 1).

The mechanical profile during the performance of throwing the javelin is illustrated in figure 1.

End of Cross-over phase and start of pre-delivery stride phase						Throwing Moment																			
Center of Gravity of Body		Forearm joint										Center of Gravity of Body		Forearm joint											
Horizontal Force		Horizontal Velocity		Resultant Velocity		Angle of delivery		Velocity of delivery		Height of delivery point		Horizontal Force		Horizontal Velocity		Vertical Velocity		Resultant Velocity		Horizontal Force		Vertical Force		Resultant Force	
-	162	-	8	-	8	-	20	-	20	-	120	-	200	-	8	-	2	-	8	-	200	-	90	-	90
-	162.5	-	10	-	10	-	25	-	25	-	130	-	210	-	10	-	4	-	10	-	210	-	95	-	95
-	163	-	12	-	12	-	30	-	30	-	140	-	220	-	12	-	6	-	12	-	220	-	100	-	100
-	163.5	-	14	-	14	-	35	-	35	-	150	-	230	-	14	-	8	-	14	-	230	-	105	-	105
-	164	-	16	-	16	-	40	-	40	-	160	-	240	-	16	-	10	-	16	-	240	-	110	-	110
-	164.5	-	18	-	18	-	45	-	45	-	170	-	250	-	18	-	12	-	18	-	250	-	115	-	115
-	165	-	20	-	20	-	50	-	50	-	180	-	260	-	20	-	14	-	20	-	260	-	120	-	120
-	165.5	-		-		-		-		-	190	-	270	-		-		-		-	270	-	125	-	125
-	166	-		-		-		-		-		-	280	-		-		-		-	280	-	130	-	130
-	166.5	-		-		-		-		-		-		-		-		-		-		-	140	-	140
-	167	-		-		-		-		-		-		-		-		-		-		-		-	
-	167.5	-		-		-		-		-		-		-		-		-		-		-		-	
-	168	-		-		-		-		-		-		-		-		-		-		-		-	
-	168.5	-		-		-		-		-		-		-		-		-		-		-		-	
-	169	-		-		-		-		-		-		-		-		-		-		-		-	
-	169.5	-		-		-		-		-		-		-		-		-		-		-		-	
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-	170.5	-		-		-		-		-		-		-		-		-		-		-		-	
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Figure 1. Mechanical profile during the performance of throwing the javelin

Figure 1 represents a simple and useful board for visual comparison. It facilitates the evaluation process and compares the athlete's level for each defined variable. The essence of evaluation is based on the comparisons with various techniques. This is provided by the profile technique which is built on determining the arithmetic means of the biomechanical characteristics of highest effect on the performance of throwing the javelin.

The researcher designed an evaluation card as illustrated in figure 2. This card depends primarily on the median as the middle of three-score standard. The card was designed as follows:

- Identifying the most effective biomechanical variables with respect to throwing the javelin.
- Conducting statistical treatments to find the median of these biomechanical variables.
- Registering the value of median, as it is the middle of three-score standard, in order to separate between levels. Two points are scored for the median, a point for the value lower than median and three points for the value upper than median. This registration is done in accordance with the variable; if the decrease in variable is an indicator for the effectiveness of performance (as in velocity when the time is decreased), this will score higher. The lesser the time in recovery phase the better the pushing will be.

For each player, points are placed in front of each variable and by connecting these points we get the specific form of the athlete's level. This card is attached to the graph to the profile concerning these characteristics, thus we get a simple model to evaluate the level of performance.

- Judging on the athlete's level of performance.
- Identifying strength and weakness points in the athlete's level according to the biomechanical variables which enable the modification of training process to increase its effectiveness.

The evaluation card of throwing the javelin is illustrated in figure 2.

Participant Name: Age: No. of Training Years:

	Biomechanical Variables	Lower	Median	Upper	Median Value	Evaluation
Cross-over and Pre-delivery stride	Horizontal force of center of gravity of body (Newton) Horizontal velocity of center of gravity of forearm (m/s) Resultant velocity of center of gravity of forearm (m/s) Angle of delivery of javelin (degree) Velocity of delivery of javelin (m/s) Height of of delivery point of javelin (m)					
Delivery (Throwing)	Horizontal force of center of gravity of body (Newton) Horizontal velocity of center of gravity of body m/s Vertical velocity of center of gravity of forearm m/s Resultant velocity of center of gravity of forearm m/s Horizontal force of center of gravity of forearm (Newton) Vertical force of center of gravity of forearm (Newton) Resultant force of center of gravity of forearm (Newton)					
	Evaluation Points	1	1	3		sum

Figure 2. Evaluation card of throwing the javelin

There are thirteen biomechanical variables. Considering 3 point for each variable as maximum, therefore, the sum of these points is 39. The level is estimated to be 33-39: excellent, 27-32: very good, 22-26: good, 18-21: accepted, less 18: weak.

The evaluation card of throwing the javelin is illustrated in figure 3.

Name: **Age:** **No. of Training Years:**

	Biomechanical Variables	**Lower**	**Median**	**Upper**	**Median Value**	**Evaluation**
Cross-over and Pre-delivery stride	Horizontal force of center of gravity of body (Newton)			×	166.5	3
	Horizontal velocity of center of gravity of forearm (m/s)			×	10.07	3
	Resultant velocity of center of gravity of forearm (m/s)			×	10.265	3
Delivery (Throwing)	Angle of delivery of javelin (degree)		×		39.85	2
	Velocity of delivery of javelin (m/s)			×	24.90	3
	Height of delivery point of javelin (m)		×		164	2
	Horizontal force of center of gravity of body (Newton)	×			226	1
	Horizontal velocity of center of gravity of body m/s		×		9.62	2
	Vertical velocity of center of gravity of forearm m/s			×	4.1	3
	Resultant velocity of center of gravity of forearm m/s		×		10.46	2
	Horizontal force of center of gravity of forearm (Newton)			×	209	3
	Vertical force of center of gravity of forearm (Newton)			×	107	3
	Resultant force of center of gravity of forearm (Newton)			×	110	3
	Evaluation Points	1	1	3		Sum=33

Figure 3. Evaluation card of throwing the javelin

Figure 3 demonstrated an evaluation model of throwing the javelin, for an athlete who is good at throwing the javelin, using the card. This participant got 33 points representing 84.615%, hence his level is very good. It also shows that each phase of performance can get a point to reveal the effectiveness degree of each phase and to detect the weakness and strength points in his level aiming to treat these weakness points and improve and develop his performance. For instance, we find that the participant got 9 points out of 9 during the cross-over and pre-delivery stride phases while he got 24 points out of 30 during the delivery phase. The deficiency in the horizontal force of the center of gravity of the body weight is revealed during the delivery phase.

The analysis of these results using the previous method enables the coach to detect the strength and weakness points, and hence improve and develop the level of the participant to ensure a record level that let her achieve the highest level. The final report represents the excellent one rated 84.62%

Conclusions and applications

- Identifying the biomechanical variables most correlated with the record level of throwing the javelin among high level athletes during cross-over and pre-delivery stride phases. These variables are horizontal and vertical velocities and the resultant velocity, horizontal and vertical forces, and the resultant force of the center of gravity of the body and the joints (upper arm, forearm, thigh, leg and foot) as well as angle and velocity of delivery of javelin and the height of delivery point.

- In light of biomechanical variables most correlated with the record level of throwing the javelin, the biomechanical profile of performance has been concluded.
- Designing an evaluation card for the performance of throwing the javelin in accordance with biomechanical variables most correlated with the record level of throwing the javelin skill.

Recommendations for future researches

- Using the side-pattern (profile) as a guide to identify the level of athletes.
- Guiding with the evaluation card in developing and modifying the process of training.

References

Abdul-Bassir, A. (1998). Biomechanics and integration between theory and practice. Cairo: Book Center for Publishing. pp133, 167 -169.

Mohamed, E.M. (2013). Some motor indicators and their effect on the outcome of javelin throwers with different record levels. Unpublished PhD thesis, Faculty of Physical Education for Girls, Alexandria University.

Abdullah, E.M. (2011). Motor science and Biomechanics: Theory and Practice. First edition, Alexandria: Dar –El-Wafa'a. pp.18, 184-185.

Ala'a El-Din, G. and Al-Sabagh, N.A. (2005). Motor Science. Eighth edition, Alexandria: El Kholy for Printing, 282.

Grimshaw, et.at. (2007). Sport & Exercise Biomechanics. Bio Instant Notes cries, UK: Taylor & Francis. 137.

El Sokkary, K.I. & Hasan, S.A (1997). Guide of training and learning in throwing the javelin, Alexandria: Dar El-Ma'aref. pp. 152, 159.

Mark, G. (2003). Coaching Track & Field successfully. U.S.A: Human Kinetics, pp. 177, 178.

Omar, M.S. (2002). Scientific directions in biological and physical variables in light of modern technology and information era. Faculty of Physical Education for Men, Alexandria University. 8.

Ajami, O.I. (2004). Current evolution in biomechanical technology. PhD thesis, High Council of Universities.

Roger, B. (2014). Introduction to sports biomechanics: Analyzing human movement partners, third Routidge, London and New York: Taylor & Francis Group, .220

Tantawy, S.S. (2012). Building a mechanical profile for a specific skill in Gymnastics, PhD thesis. Faculty of Physical Education, Alexandria University.

Husam El-Din, T. (1993). Biomechanics, theoretical and practical applications. First edition, Cairo: Dar El-Fekr Al-Araby, pp. 9, 74, 75, 272, 310, 311.

Darwesh, Z.M. And Abdul- Hafez, A.M. (1994). Athletics encyclopedia, Alexandria: Dar El-Ma'arf, pp. 27, 46, 47.