Biomechanical analysis of top pole vaulter in Egypt (Egyptian Records)

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Abstract

The purpose of the presented study is followed up the breaking of Egypt's record at the level of juniors, youth and the first level of men to identify the biomechanical specifications of the pole vault competition for the player / **Tamer Ashraf** whose ranking **1st world 2022 U-18 years** to identify the extent of the development of skill performance that led to the achievement of these sequential Records and the differences in the skill performance of this player in the achieved record levels and compare them with the best international levels. The descriptive approach based on kinematic analysis was used to suit the nature of the research, filming took place at the Olympic Center Stadium for National Teams in Maadi, Egypt, from 6/11/2021 to 27/3/2022. The research sample was the Record of (8) attempts in which the player/ Tamer Ashraf was able to achieve new Egyptian records at the level of juniors, youth and the first level of men. All trails of the subject were recorded, but a kinematical analysis was established for the phases of the trails to break Egyptian Record. one video cameras (DCR-SR68 SONY) 60 FPS were focused on the Runway and the landing bit, the analysis was performed by DARTFISH TEAM PRO 4 software program and compare results parameters between them. The misevaluates of this studies is the existence of an inverse relationship between the distance between the center of mass of the body and the point of planting the pole with the heights achieved , Increasing the time taken to bend the pole in relation to increasing the speed of tack off and reducing the distance between the center of mass of the body and the point of planting the pole at the maximum bend, Increased slot extension time in relation to the achieved record level.

Keywords: Pole vault, Biomechanics, Analysis

- Introduction:

The pole vault competition is considered one of the most complex, enjoyable and dangerous athletics competitions, due to its acrobatic movements, and this makes it fun for the viewer and the player together, as the player tries to fly his body up in the air defying gravity and attached to a flexible moving stick.

The pole vault competition depends on the performance technique, and it also requires full control over successive forms of difficult and complex performances, and the difficulty of motor performance depends on how to benefit from the jumping stick (auxiliary factor) to increase height. (11:3)

The pole vault competition is the target of many scientific studies in recent years, which relied on biomechanical analysis, especially after the emergence of pole with fiber-glass and carbon, which allows the pole to reach large degrees of curvature that help store energy inside it in the early phases of performance. (14: 1402)

By reviewing the previous studies of this competition, it became clear that there is a great scarcity of studies related to it in the Arab Republic of Egypt, in addition to the low record levels achieved in the Republic's championships at the men's level.

Egypt's record remained from 1995 to 2021 for men (5.05 m). Until the player / Tamer Ashraf, aged (17 years) broke Egypt's record under (18) years, and under (20) years six times sequentially, until he was able to break the men's Record twice, achieving (5.06 m) and then (5.07 m), and this Record ranked first in the world in this period under (18), and this player has been followed up and filmed all his attempts in successive competition every time he tries to break An Egyptian Record, whether at the junior or men's level.

This prompted the researchers to perform this study to identify the development of skill performance, which led to the achievement of these sequential Records and the differences in the skill performance of this player in the achieved record levels and compared to the best international levels.

The purpose of the presented study is followed up the breaking of Egypt's record at the level of juniors, youth, and men to identify the biomechanical variables of the pole vault competition for the player / Tamer Ashraf to identify the development of skill performance that led to the achievement of these sequential Records and the differences in the skill performance of this player and compare them with the best international levels.

- **Methods: -**

The descriptive approach based on kinematic analysis was used to suit the research, filming took place at the Olympic Center Stadium for National Teams in Maadi, Egypt, from 6/11/2021 to 27/3/2022. The research sample was **the Record of (8)** attempts in which the **player/ Tamer Ashraf** was able to achieve new Egyptian records at the level of juniors, youth, and men**.**

Table 1: subject's basic information

Name	Country	Height	Weight	Age	PB	Rank
Tamer Ashraf	Egypt	177	76	17	5.07 m	1st world 2022 U-18 years

Table 2: The achieved record levels

M	Tournament	Date	Record	Record Verified
1	Experiences for the Egyptian national team	06/11/2021	4.76 m	Egyptian Record under (18, 20) years **The Record was (4.75 m)**
2	Republic Championship First level (Cup)	23/12/2021	4.81 m	
3		23/12/2021	4.85 m	
4	U-18 Championship (Cup)	30/12/2021	4.86 m	
5		30/12/2021	4.90 m	
6	Republic Championship U-18 (Shield)	03/03/2022	5.00 m	
7	Republic Championship U-20 (Shield)	17/03/2022	5.06 m	Egyptian Record under (18, 20) years and first Level **The Record was (5.05 m)**
8	Republic Championship First Division (Shield)	27/03/2022	5.07 m	

- Data Collection:

All trails of the subject were recorded, but a kinematical analysis was established for the phases of the trails to breaking Egyptian Record. one video cameras (DCR-SR68 SONY) 60 FPS were focused on the Runway and the landing bit, the analysis was performed by DARTFISH TEAM PRO 4 software program and compare results parameters between them (1).

By reviewing the related studies of this competition, the most important kinematic variables were identified, through which the level of skill performance can be evaluated. (7 :44)

Table 3: The kinematics parameters to the approach, planting and tack off phases.

M	Phase	Sample	kinematics parameters	Unit
1	Approach phase, and planting phase with tack off	PSS	Average speed of the penultimate step	m/s
2		LSS	Average speed of the last step	m/s
3		SXCMTO	The horizontal velocity of CM at the tack off	m/s
4		SVCMTO	The vertical velocity of CM at the tack off	m/s
5		SRCMTO	The resultant speed of CM at the tack off	m/s
6		HDFFTO	The horizontal distance between the forefoot and the end of the box at tack off	m
7		AITPP	The angle of inclination of the trunk at planting the pole	degree
8		AIPPP	The angle of inclination of the pole at planting the pole	degree
9		TOA	Tack off angle	degree
10		DGP	The distance between grip and step up at planting	m
11		HCMTO	The height of CM at the tack off (H1)	m
12		DGFFE	Horizontal distance between grip and forefoot at tack off	m

Table 4: The kinematics parameters of Swing, Rock back, extension, bar clearance phases

M	Phase	Sample	kinematics parameters	Unit
13	Swing, Rock back, extension, bar clearance phases	DCMPP	The minimum distance between CM and the point of planting the pole	m
14		MPL	Minimum pole length	m
15		TPC	Time taken to reach maximum pole curvature	S
16		TPS	Time taken to stretch the pole	S
17		RBPP	Rotation of the body backward from the moment of planting the pole	degree
18		DCMPS	The distance between CM and the pole in the pole stretch	m
19		ATP	The angle of inclination of the trunk in departure of the pole relative to the horizontal plane	degree
20		MHCM	Maximum height of CM above the crossbar	m

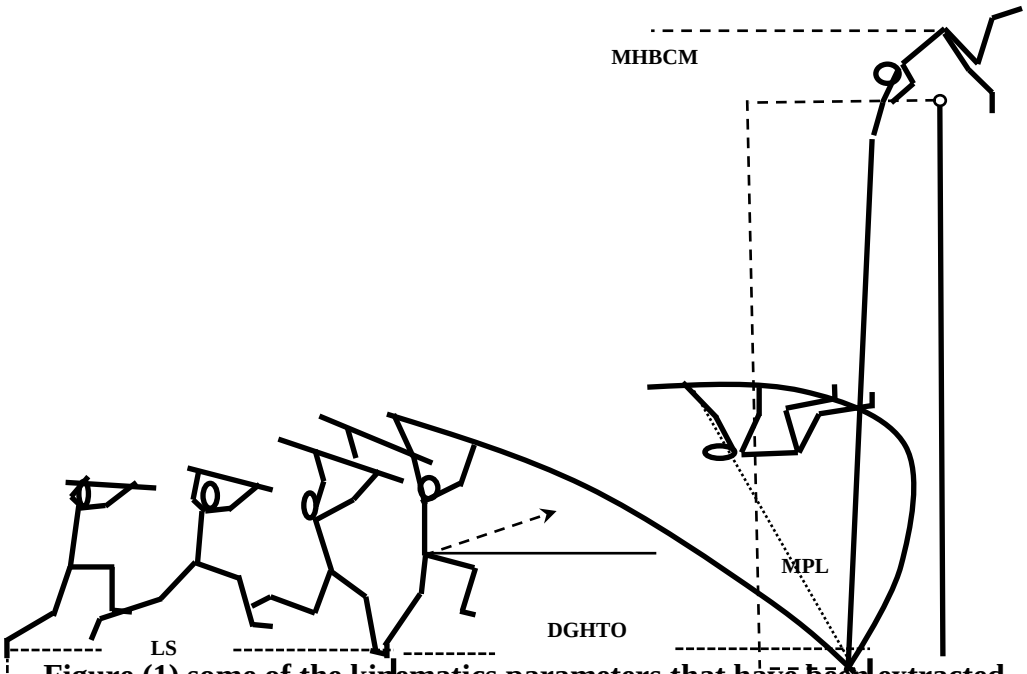
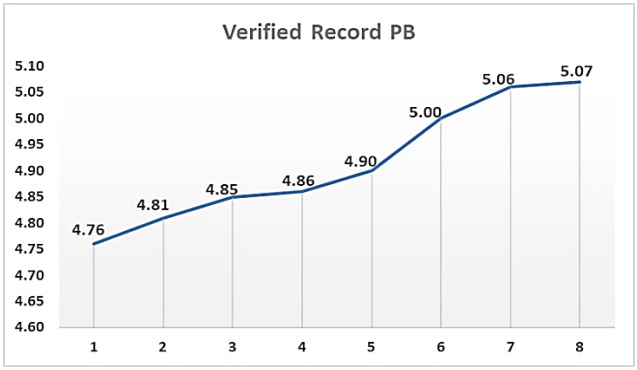


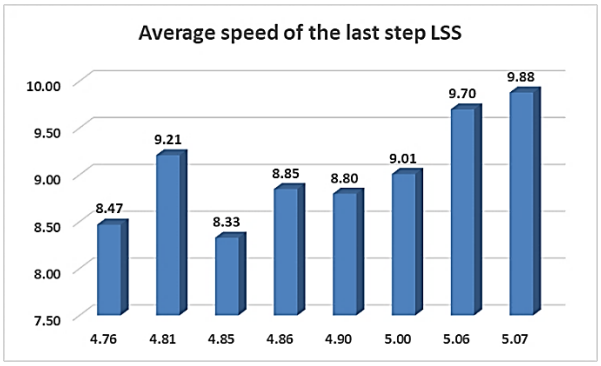
Figure (1) some of the kinematics parameters that have been extracted.

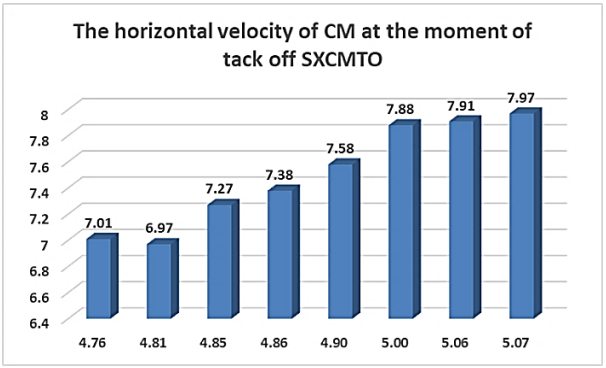
Results: -

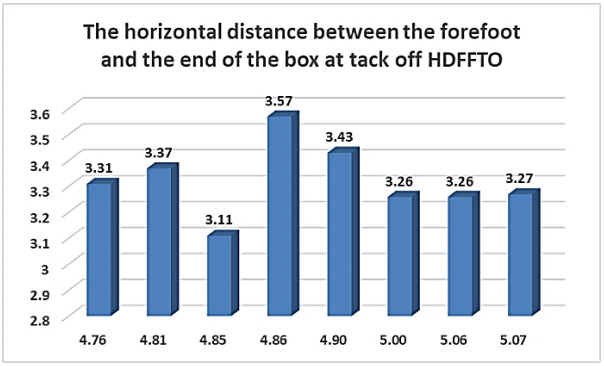
Table 5: The kinematics parameters to the approach, planting and tack off phases.

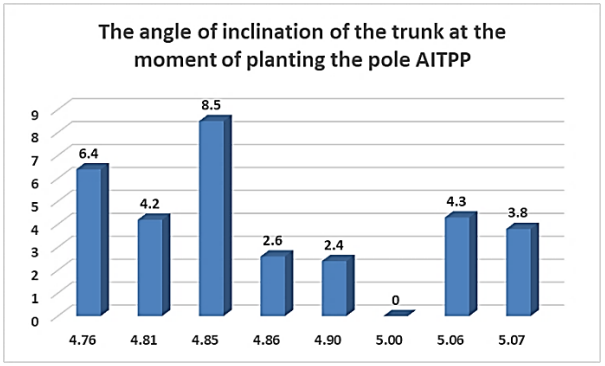
Phase	Parameters	Abb	Unit	1	2	3	4	5	6	7	8
approach, planting and tack off phases	Verified Record	PB	m	4.76	4.81	4.85	4.86	4.90	5.00	5.06	5.07
	Average speed of the penultimate step	PSS	m/s	8.23	8.19	8.06	7.48	8.15	9.46	8.35	7.56
	Average speed of the last step	LSS	m/s	8.47	9.21	8.33	8.85	8.80	9.01	9.70	9.88
	The horizontal velocity of CM at the tack off	SXCMTO	m/s	7.01	6.97	7.27	7.38	7.58	7.88	7.91	7.97
	The vertical velocity of CM at the tack off	SVCMTO	m/s	1.64	1.82	0.91	2.23	2.34	2.73	2.12	2.78
	The resultant speed of CM at the tack off	SRCMTO	m/s	7.20	7.20	7.33	7.77	8.05	8.34	8.16	8.34
	The horizontal distance between the forefoot and the end of the box at tack off	HDFFTO	m	3.31	3.37	3.11	3.57	3.43	3.26	3.31	3.29
	The angle of inclination of the trunk at planting the pole	AITPP	degree	6.40	4.20	8.50	2.60	2.40	0.00	4.30	3.80
	The angle of inclination of the pole at planting the pole	AIPPP	degree	31.00	31.80	31.30	28.10	28.40	31.40	30.40	29.60
	Tack off angle	TOA	degree	67.90	73.00	80.60	71.30	71.80	62.80	73.90	72.30
	The distance between grip and step up at planting	DGP	cm	41.00	30.00	47.00	51.00	40.00	62.00	31.00	38.00
	The height of CM at the tack off (H1)	HCMTO	cm	1.15	1.11	1.02	1.16	1.08	1.04	1.01	1.04
	Horizontal distance between grip and forefoot in tack off	DGFFE	cm	7.00	4.00	13.00	7.00	3.00	42.00	5.00	18.00

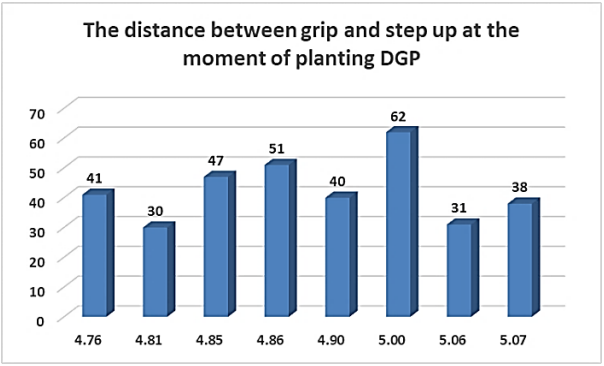












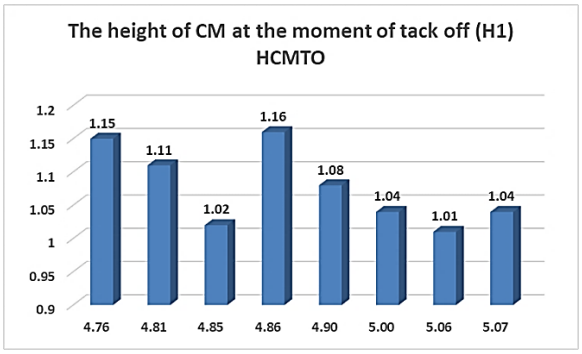
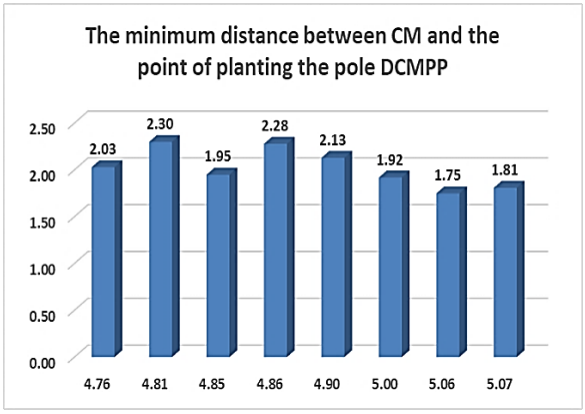
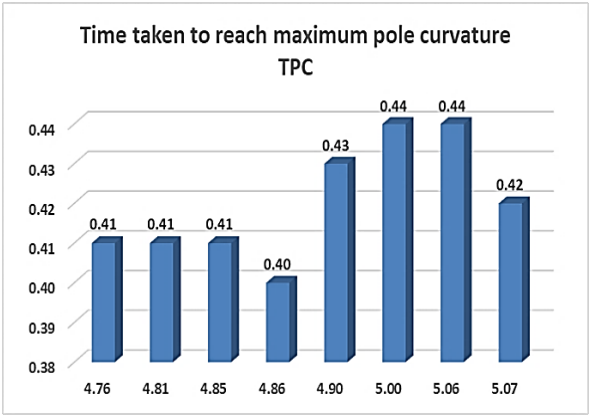


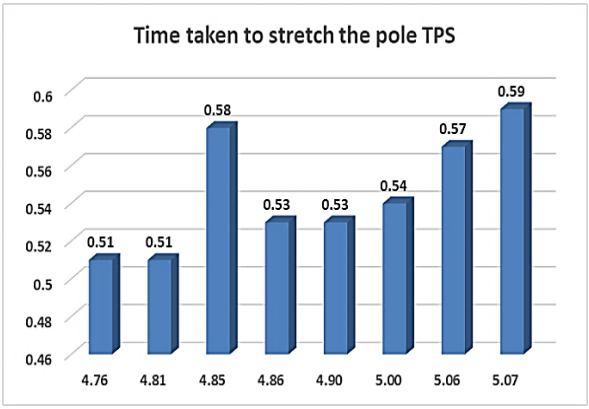
Figure (2) some of the kinematics parameters to the approach, planting and tack off phases.

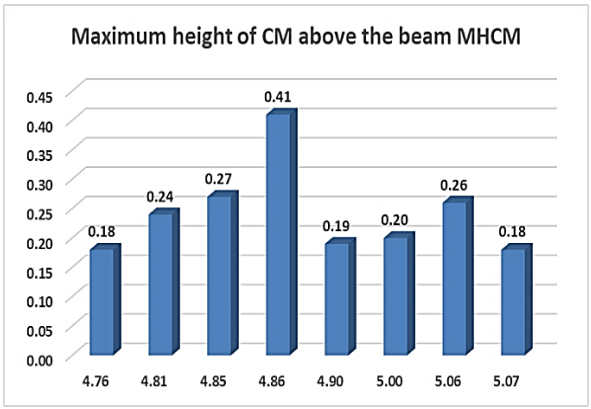
Table (6): The kinematics parameters of swing, rock back, extension, bar clearance phases

Phase	Parameters	ABB	Unit	1	2	3	4	5	6	7	8
Swing, Rock back, extension, bar clearance phases	Verified Record	PB	m	4.76	4.81	4.85	4.86	4.90	5.00	5.06	5.07
	The minimum distance between CM and the point of planting the pole	DCMPP	m	2.03	2.30	1.95	2.28	2.13	1.92	1.75	1.81
	Minimum pole length	MPL	m	2.91	2.98	2.81	3.06	3.09	2.93	2.59	2.91
	Time taken to reach maximum pole curvature	TPC	s	0.41	0.41	0.41	0.40	0.43	0.44	0.44	0.42
	Time taken to stretch the pole	TPS	s	0.51	0.51	0.58	0.53	0.53	0.54	0.57	0.59
	Rotation of the body backward from the moment of planting the pole	RBPP	degree	130.00	154.10	140.00	160.20	153.40	152.00	140.60	153.10
	The distance between CM and the pole in of the pole stretch	DCMPS	cm	29.00	4.00	4.00	2.00	2.00	1.00	1.00	1.00
	The angle of inclination of the trunk in departure of the pole relative to the horizontal plane	ATP	degree	90.00	121.10	131.50	109.90	126.40	117.80	130.20	116.70
	Maximum height of CM above the crossbar	MHCM	m	0.18	0.24	0.27	0.41	0.19	0.20	0.26	0.18









the kinematics parameters to swing, rock back, extension, bar Figure (3) some of clearance phases.

Discussion: -

It is clear from Table (5) and Figure (2) that the improvement of the speed levels of the last step **LSS** is related to the development of the achieved record level, where the speed levels were (8.47 m/s) when achieving a height of (4.76 m) while the speed levels reached (9.88 m/s) at a height of (5.07 m), which confirms the importance of the approach speed to increase the curvature of the pole during the following phases of technical performance.

The references indicate a positive relationship between the average horizontal speed of approach in general and the achieved record level. (1 :429)

The references also confirm that players achieving record levels ranging between (4.70: 4.90 m), their approach speed is between (8.88: 9.43 m/s) (5: 33), (9:44)

This was followed by the improvement of the speed levels produced during the tack off, as it was associated with the levels of speed gained from approaching and then the achieved record level, where the speed of the body's center of gravity for the moment of tack off **SXCMTO** was (7.01 m / s) when achieving a height of (4.76 m) while the speed of the center of mass of the body at the moment of tack off was (7.97 m / s) when the height was (5.07 m), which confirms the relationship between increasing the ability to achieve high tack off speeds when increasing Approach speed and how this relates to the achieved record levels

The references emphasize that higher record levels can be achieved by increasing the horizontal speed at the moment of tack off. (6: 440) , (13 : 3195) , (10 : 2264)

As can be seen from Table (5) and Figure (2) the difference in the distance between the forefoot and the end of box at tack off **HDFFTO** during the records achieved, which indicates the placement of the body under the pressure because he can't make free tack off and the inability to affect the pole, which is confirmed by the variable angle of inclination of the trunk back for the moment of planting the pole, where **HDFFTO** was at a height

of (4.86 m) with a value of (3.57 m), which is the highest value in all attempts met The angle of inclination of the trunk backward **AITPP** by (2.6 degrees) only, while the lowest value of the **HDFFTO** variable was (3.11 m) in height (4.85 m) offset by the angle of tilt of the trunk backward by (8.5 degrees), which was the highest value in all attempts under analysis.

Which confirms that the player's body was not in the correct position at the moment of tack off, as there was a tendency of the body back at the moment of tack off, which loses the ability to carry out a free tack off that increases the amount of movement produced and affecting the pole in the following phases of jumping.

This is also confirmed by the achievement of (5.00 m) **HDFFTO** value (3.26 m) offset by the inclination of the rear trunk by (zero degrees), which is the largest record jump for the player by (10 cm) from the previous height.

Studies and references have confirmed the importance of working with the upper limbs during the first half of the jump to change the position of the body on the pole, which contributes significantly to the impact on the pole, making it reach the maximum flexion. (9: 213) ،(4 : 1467)

References indicate that high-level players have a trunk tilt backward that does not exceed (2:3 º) only at the moment of planting the pole (2:1629).

As can be seen from Table (6) and Figure (3) the larger curvature of the pole, the greater the target height, as the minimum distance between the center of mass of the body and the point of planting the pole **DCMPP** to lower distances the greater the height where it was in height (4.90 m) by (2.13 m), while in height (5.00 m) was by (1.92 m), and in height (5.06 m). It was (1.75 m)

The references indicate that the players who achieve record levels between (4.70: 4.90 m) be the distance (1.94 m) and for the higher levels achieved for record levels between (4.90: 5.30 m) the distance was (1.86 m) and from the above, it is clear that there is an inverse relationship between the distance between the center of mass of the body and the point of planting the pole and the height achieved. (5: 33), (9:44)

This is also confirmed by the increasing time taken to curvature the pole **TPC** at higher heights, where it was at a height of (4.86 m) by (0.40 seconds), while at a height of (4.90 m) it reached (0.43 seconds), while in heights (5.00 m, 5.06 m) it was by (0.44 seconds), which is the result of increasing the speed of the player's body during the approach and the moment of tack off, which increases the effect of the player's body strength on the Pole and increasing its curvature in the penetration and rock back phases.

The references indicate that the phases of penetration and rock back all work to transfer the force from the player's body to the pole to reach the maximum curvature, then the pole begins to extend to transfer the force from the pole to the player's body again, heading it upwards. (3: 1265)

The references confirmed the importance of mastering and implementing the first phase of work on bending the pole because it is the most important and related to the level of record and added that if there is some short coming in the phase of extension of pole, it may not significantly affect the level achieved. (8: 151)

Studies also indicated the importance of the jumper's attempt to increase the rotation around the transverse axis of the body (rock back phase) to increase the angle of entry of the pole under the crossbar, which contributes to ensuring that it extends in the direction of the crossbar and not outside. (12: 385)

This resulted in an increase in the time taken to stretch the pole **TPS** in relation to the achieved record level, where the time was (0.53 seconds) in heights (4.86 m, 4.90 m), while in the height of (5.00 m) it was (0.54 seconds), and in the height of (5.06 m) it was (0.57 seconds) and in the height (5.07 m) it was (0.59 seconds).

The greater the effect of gaining speed in the early phases of performance on increasing the bending time of the pole and thus increasing the time of the extension of the pole, this is associated with the player's body reaching higher heights, which leads to an improvement in the achieved record levels.

Conclusions: -

1. Improvement of speed levels for the last step of approach and also the speed of the body's center of mass for the moment of tack off and its correlation with the achieved record levels
2. The improvement of the achieved record levels is related to the proper body position of the moment of tack off in terms of the necessity of not having a tilt of the trunk back at the moment of planting the pole and the moment of tack off to the ability to make the necessary effect on the pole during the tack off process.
3. The existence of an inverse relationship between the distance between the center of mass of the body and the point of planting the pole with the heights achieved.
4. Increasing the time taken to bend the pole in relation to increasing the speed of tack off and reducing the distance between the center of mass of the body and the point of planting the pole at the maximum bend.
5. Increased slot extension time in relation to the achieved record level

Recommendations: -

1. Work on developing the speed levels gained during the approach and tack off phases to increase the bending time of the pole and increase the energy storage during the early phases of the technical performance.
2. Work to improve the position of the vertical trunk at the moment of tack off to make the most benefit of the tack off phase to increase pole bending then do quick extension in the final phases of performance.

References: -

1- **Fagaras Pia Simonaa and Graur Cristiana** : Study Regarding the Speed Analysis on Approach at Junior III, Pole Vault Salt. 7th World Conference on Educational Sciences, (WCES-2015), 05-07 February 2015, Novotel Athens Convention Center, Athens, Greece, Procedia - Social and Behavioral Sciences 197 (2015) 426 – 429

2- **Falk Schade a and Adamantios Arampatzis** : Influence of pole plant time on the performance of a special jump and plant exercise in the pole vault. Journal of Biomechanics 45 (2012) 1625–1631

3- **Falk Schade, Adamantios Arampatzis and Gert-Peter BruKggemann** : Infuence of different approaches for calculating the athlete's mechanical energy on energetic parameters in the pole vault. Journal of Biomechanics 33 (2000) 1263_ 1268

4- **Falk Schade, Adamantios Arampatzis and Gert-Peter BruKggemann** : Reproducibility of energy parameters in the pole vault. Journal of Biomechanics 39 (2006) 1464–1471

5- **Falk Schade, et, al.** : Biomechanical analysis of the pole vault at the 2005 IAAF world championships in Athletics , New Studies in Athletics .29-45. no,2/2007.

6- **Guangyu Liu, Sing-KiongNguang and YanxinZhang** : Pole vault performance for anthropometric variability via a dynamical optimal control model. Journal of Biomechanics 44 (2011) 436–441

7- **Ines Gudelej et, al.** : Differences in Some Kinematic Parameters between Two Qualitatively Different Groups of Pole Vault , Coll Antropol.39 (2015) Suppl. 1: 41-46 Original scientific paper.

8- **Julien Frère et, al.** : Catapult effect in pole vaulting: Is muscle coordination determinant?. Journal of Electromyography and Kinesiology 22 (2012) 145–152

9- **Julien Frère et, al.** : Effect of the upper limbs muscles activity on the mechanical energy gain in pole vaulting. Journal of Electromyography and Kinesiology 22 (2012) 207–214

10- **Julien Morlier, Michel Mesnard** : Influence of the moment exerted by the athlete on the pole in pole-vaulting performance. Journal of Biomechanics 40 (2007) 2261–2267

11- **Michael Doerflein** : PHYSICAL CHARACTERISTICS USED TO PREDICT POLE VAULT PERFORMANCE, MASTER OF SCIENCE IN EXERCISE SCIENCE faculty of Arkansas State University, August 2015

12- **Michel Mesnard, Julien Morlier and Mariano Cid** : An essential performance factor in pole-vaulting. C. R. Mecanique 335 (2007) 382–387

13- **Shigemichi Ohshima, Yuuki Nashida and Atsumi Ohtsuki** : Optimization of pole characteristic in pole vaulting using three-dimensional vaulter model. 8th Conference of the International Sports Engineering Association (ISEA), Procedia Engineering 2 (2010) 3191–3196

14- **Vaslin, P, Cid, -M.** : Three Dimesional Dynamic Analysis of the pole vault International Society of Biomechanic Congress , Paris, France, 1993.

Research Summary

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Search Procedures:

The descriptive approach based on kinematic analysis was used to suit the research, filming took place at the Olympic Center Stadium for National Teams in Maadi, Egypt, from 6/11/2021 to 27/3/2022. The research sample was **the Record of (8)** attempts in which the **player/ Tamer Ashraf** was able to achieve new Egyptian records, all trails of the subject were recorded, but a kinematical analysis was established for the phases of the trails to breaking Egyptian Record. one video cameras (DCR-SR68 SONY) 60 FPS were focused on the Runway and the landing bit, the analysis was performed by DARTFISH TEAM PRO 4 software program and compare results parameters between them.

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Results:

1. Improvement of speed levels for the last step of approach and also the speed of the body's center of mass for the moment of tack off and its correlation with the achieved record levels.
2. The improvement of the achieved record levels is related to the proper body position of the moment of tack off in terms of the necessity of not having a tilt of the trunk back at the moment of planting the pole and the moment of tack off to the ability to make the necessary effect on the pole during the tack off process.
3. The existence of an inverse relationship between the distance between the center of mass of the body and the point of planting the pole with the heights achieved.
4. Increasing the time taken to bend the pole in relation to increasing the speed of tack off and reducing the distance between the center of mass of the body and the point of planting the pole at the maximum bend.
5. Increased slot extension time in relation to the achieved record level.

the effect of spatial ability training on Some other skill variables.