Analytical Study of the Best Egyptian Heptathlon Results Against the All-time Best Scores internationally

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Introduction

From 1981, the IAAF brought in the seven-event heptathlon in place of the pentathlon, with day one containing the events 100m hurdles (H100), shot put (SP), high jump (HJ), 200m (R200) and day two, the long jump (LJ), javelin throw (JT) and 800m (R800) [1][2][8][10][16]. The achieved result is sum of the seven discipline scores that stated in IAAF Score Table. The idea of the heptathlon mainly assumes a relative balance of each discipline on the overall performance [7][20].

There are three discipline groups according to a main component analysis: A) the "Speed" type includes each of 100 m hurdles, high jump, 200 m run, and long jump, B) the "Explosive power" type (maximum strength and speed strength) comprised shotput and javelin throw, and C) the " Speed Endurance" type consisted of the 800 m run [7][9][26].

The structure of the heptathlon reflects the athletes' adaptability and generalist. Heptathletes must be able to achieve maximum performance:
• In the sprints and hurdles without the benefit of qualifying runs
• In the long jump and throws with a limited number of attempts
• In a fixed sequence of events
• Even as they become fatigued [24].

To be a top notch heptathlete a woman must according to Rovelto, "…adopt a lifestyle that allows her to develop psychologically and physically". Physically she must concurrently develop all the biomotor abilities: speed، strength, stamina, skill, and suppleness [20]. The specialists achieved an average of approximately 170 points more than the generalists and that

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specialists are found among the world's top athletes approximately 12% more often than generalists, which would explain early selection mechanisms based on good sprint-jump performances [7]. The All-time Best Scores heptathletes master an individual discipline or groups of disciplines as the main reason to achieve a high score. For Example, Jackie Joyner-Kersee is the world record holder of Heptathlon. She has the six best heptathlon marks of all time including the world record of 7291, she was also a world-class long jumper [13]. Every track coach would like to have a young Jackie Joyner-Kersee someone who is outstanding in running, jumping, and throwing. Traditionally, the heptathlon has attracted girls who excel in running or jumping events. But in other countries, heptathlon competitors are recruited from the throwing ranks [3]. For example, Dobrynska's vectory factor was in the shot put, which she launched 17.29 metres, 2 metres further than any of her near rivals [5].

Seoul Olympic 1988 Results of heptathlon were summarized by using the component analysis to see the most effective discipline on the score. The finding was that the 200m and long jump competitions receive the highest weight but the javelin result is less important [10].

Principal component analysis (PCA) has been applied in many sports field in order to quantify technique and to study whole-body movement patterns, results analysis, and even for tactics in team games [6][22][23][27]. PCA is a multivariate statistical technique used to reduce the dimensionality of a data set and to perform the analysis of the complete time series. In addition, PCA transforms the original signal into a reduced set of uncorrelated data which retains the maximum data variance [17][4]. The goal of PCA is to provide an objective tool to identify and rank differences based on amount of variance explained within a data set. This process identifies principal components, with the first component accounting for the largest possible variance and each following component descending in variance under the constraints of the preceding components [19][21][25].

The Egyptian heptathletes don't have a rank among 1155 international heptathletes until 2016 according to the IAAF records' list of heptathlons. And they have no classification as well in Africa because the limit or the minimum score of classification is 6200 Points, while the African record is 6423 points for Ghana [12] [16].The difference between the Egyptian heptathlon record and the African record exceeds 1200 points, while the difference exceeds 2100 points away from to the world record. The aim of the study is to compare the world records and the Egyptian records of heptathlon, in order to answer the following questions:

1- Are the Egyptian heptathletes master an individual event which impacts the score or they master a group of disciplines over the others?

2- Is there specific component which affect the score or it goes randomly?

Method

The best 10 records of the Egyptian heptathletes in the 2012- 2016 national championship (first class) were used in current study. The data were obtained from the Egyptian athletics federation (EAF). In addition, the best 9 All-time Best Scores records that were obtained from the International Association of Athletic Federation [12]. The scores and the discipline points were summarised by using Principal components, means, standard deviation, multivariance analysis, F-test, and the percentile of each discipline score to the maximum score in the Score Table.

The Sample description:

Table 1 shows a descriptive analysis of the best 9 All-time Best Scores records of the heptathlon and the disciplines. The skewness values reflect the homogeneity of the scores and disciplines among the international heptathletes. The Kurtosis values are less than 3, regardless the negative sign, for all disciplines (Platykurtic), the highest value is for SP (2.2).

Table (1)

Statistical summarization of best All-time Best Scores and the disciplines of Heptathlon (n=9)

	Minimum	Maximum	Mean	Mean of categories	Std. Deviation	Skewness	Kurtosis
Score	5926	6437	6209.8		192.5	-0.5	-1.5
H100	943	1044	1002.3	Run 932.63	38.8	-0.5	-1.5
R200	809	972	889.2		63.1	0.1	-1.7
R800	841	988	906.4		52.7	0.5	-1.1
HJ	747	1067	957.1	Jump 944.70	106	-0.9	0.4
LJ	856	1007	932.3		53.1	-0.1	-1.1
JT	545	894	744.9	Jump 761.15	103.9	-0.7	0.8
SP	700	900	777.4		57	1.2	2.2

Table (2) show a descriptive analysis of the best 10 Egyptian records of the heptathlon and the disciplines. The skewness values reflect the homogeneity of the scores and disciplines among the international heptathletes, where the values were between (-3 and +3).

Table (2)
statistical summarization of best Egyptian Scores and the disciplines of Heptathlon (n=10)

	Minimum	Maximum	Mean	Mean of categories	Std. Deviation	Skewness	Kurtosis
Score	4238	5182	4648.3		316.1	0.6	-1
H100	714	970	838.5	Run 726	81.5	0.1	-1
R200	695	841	763		42.5	0.5	0.2
R800	396	668	576.5		86	-1.1	0.8
HJ	621	916	781.6	Jump 728.1	92.2	-0.7	-0.1
LJ	551	822	674.6		94.4	0.3	-1.3
JT	247	632	489.4	Throw 635.5	137.1	-1	-0.2
SP	621	916	781.6		92.2	-0.7	-0.1

Results
1- Percentile averages

Figure 1 presents the percentile averages of each discipline to the maximum score for the two groups the All-time Best Scores and Egyptian Best Scores. Where the highest Score in the IAAF Scoring Table of seven events are 1361 points, 1498 points, 1500 points, 1342 points, 1520 points, 1500 points, and 1250 points for the disciplines H100, HJ, SP, R200, LJ, JT, and R800, respectively [16]. The figure showed that the average of percentiles of the All-time Best Scores group (73.6%, 63.9%, 51.8%, 66.3%, 61.3%, 49.7% and 74.1%) are greater than the other group (61.6%, 52.2%, 35.1%, 56.9%, 44.4%, 32.6%, and 47.1%) with differences, 12%, 11.7%, 16.7%, 9.4%, 16.9%, 17.1%, and 27%, respectively. This result shows the significant differences between the two groups in all disciplines, especially in SP, LJ, JT and 800m. It remarkable that 3 of those events are the 2nd day events.
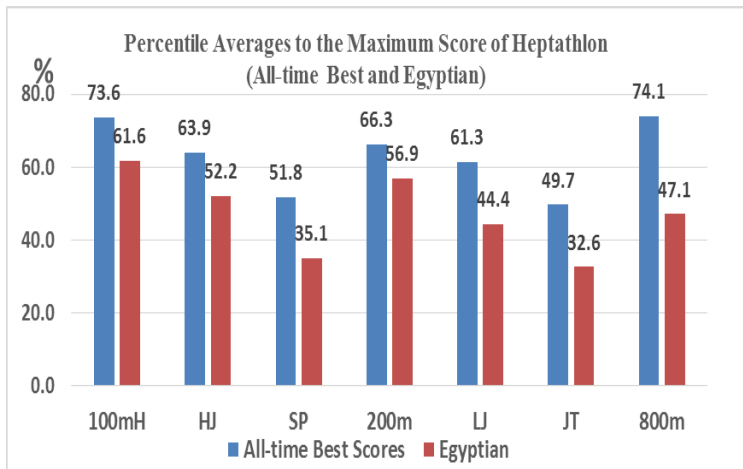

Figure 1 The percentile averages of each discipline to the maximum score of heptathlon scoring table. The data are organized according to the order of the competition days

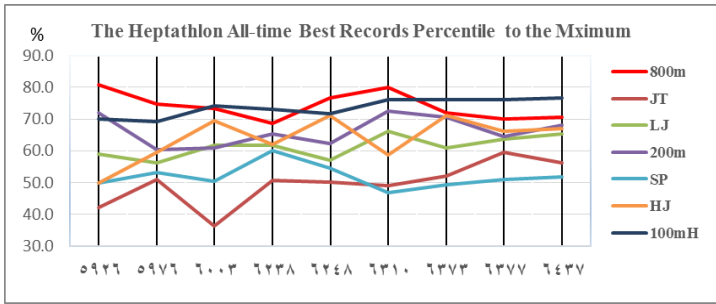The Heptathlon All-time Best Records Percentile to the Mximum

Figure 2 the heptathlon best All-time Best Records percentile averages to the Maximum score for each discipline in the score table
Figure 2 revealed that the higher the Score is, the closer the points percentile averages are. That is clear when we see, for example, the heptathlete`s score (6437) we find the averages percentiles are close to each other in a small range (51.7 to 76.7%). While the heptathlete`s score (5926) we find the averages percentiles are close to each other in a small range (42.1 to 80.7%).

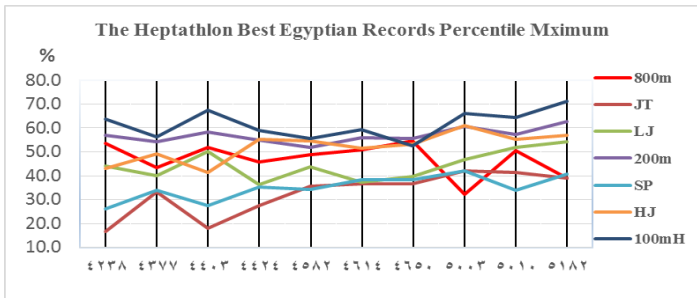The Heptathlon Best Egyptian Records Percentile Mximum

Figure 3 the heptathlon Egyptian All-time Best Scores records percentile averages to the Maximum score for each discipline in the score table
Figure 3 revealed the same point of view of figure 2. But the maximum value of percentiles are smaller than in Figure 2 (the All-time Best Scores). But it had no pattern like in Figure (2), which could be considered random pattern. For example, the heptathlete`s score (5182) we find the averages percentiles are close to each other in a small range (40.8 to 71.3%). While the heptathlete`s score (4377) we find the averages percentiles are close to each other in a small range (33.8 to 56.4%).
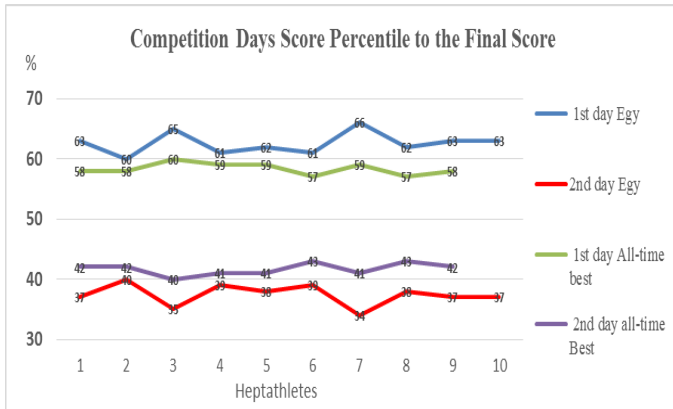
Figure 4 The contribution percentile of the first and the second days points to the Final Score

of both groups (All-time best and Egyptian)

The first day contribution percentile of the All-time best scores related to the final score were (57 – 60%) and the second day were (40-43%), with differences between (15-21%). For the Egyptian Scores, the first day contribution percentile related to the final score were (60 – 65%) and the second day were (34-40%), with differences between (20-30%).

2- analysis of variance

Table (3) refers to the significance of variance among disciplines in each group (All-time Best Scores and Egyptian) individually. The analysis of variance revealed highly significant differences among disciplines in both groups. The mean square and the coefficient of variance values of the Egyptians heptathlon best scores were greater than what is of the best All-time Best Scores heptathlon. Unlike the coefficient of determination (R^2) values, that was higher in the All-time Best Scores heptathlon group than in the Egyptian one. This result indicates the homogeneity among the disciplines of the All-time Best Scores group.

Table (3)
Analysis of variance among discipline of each heptathlete's group
(All-time Best Scores and Egyptian Scores)

Group	Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	R²	Coeff Var
All-time Best Scores	disciplines	6	475680.4	79280.1	15.3	<.0001	0.62	8.1
	Error	56	290929. 8	5195.2				
Egyptian Scores	disciplines	6	1971487.7	328581.3	15.8	<.0001	0.29	27.9
	Error	231	4817332.1	20854.3				

Table (4) refers to the significance of variance among the three categories (run, throw and jump) of each heptathlete's group (All-time Best Scores and Egyptian) individually. The analysis of variance revealed highly significant differences among the three categories of both groups (Pr <.0001). But the coefficient variance among the three categories of the Egyptian heptathletes group (29.67), this value is greater than the coefficient variance of the All-time Best Scores group (8.80). Unlike the coefficient of determination (R^2) values, that was higher in the All-time Best Scores heptathlon group than in the Egyptian one. This result indicates the lack of homogeneity among the three categories (running, throwing and jumping) points of the Egyptian group.

Table (4)
Analysis of variance among the three categories (run, throw and jump) in each heptathlete's group (All-time Best Scores and Egyptian)

Group	Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	R-Square	Coeff Var
All-time Best Scores	Events	2	401292.11	200646.06	32.950	<.0001	0.52	8.80
	Error	60	365318.11	6088.64				
Egyptian Scores	Events	2	1256179.58	628089.79	26.680	<.0001	0.19	29.67
	Error	235	5532640.28	23543.15				

Table (5) refers to the significance of variance between each individual discipline of both heptathlete's group (All-time Best Scores and Egyptian) and the score as well. The analysis of variance revealed highly significant

differences (Pr <.0001). But the coefficient variance show the most disciplines which present the highest variance, they are JT (29.02) and H100 (29.67). The coefficient of determination (R^2) values range are in between (0.44 and 0.72). the smallest vales in R^2 are H100 (0.44) followed by HJ (0.47). This results reveal the great variances between the athletes of the two groups in the points specially in JT and H100 disciplines. In addition, the diverge among the points in each of H100 and HJ of the Egyptians and All-time Best Scores.

Table (5)

Analysis of variance between each individual discipline and the score of the heptathlete's All-time Best Scores and Egyptian

	Source	DF	Mean Square	F Value	Pr > F	R-Square	Coeff Var
Score	Model	1	47915166.5	90.85	<.0001	0.69	17.47
	Error	41	527385.1				
100H	Model	1	1127469.2	31.82	<.0001	0.44	27.38
	Error	41	35437.2				
R200	Model	1	505810.9	41.61	<.0001	0.50	16.25
	Error	41	12155.5				
R800	Model	1	1443705.9	94.52	<.0001	0.70	22.46
	Error	41	15274.2				
HJ	Model	1	925101.7	37.09	<.0001	0.47	23.50
	Error	41	24944.9				
LJ	Model	1	1117494.1	91.95	<.0001	0.69	17.81
	Error	41	12152.8				
JT	Model	1	1016837.6	60.68	<.0001	0.60	29.02
	Error	41	16757.0				
SP	Model	1	820666.3	104.28	<.0001	0.72	17.43
	Error	41	7870.1				

3- Multiple regression

Data in Table ٦ shows the results of the multiple regression analysis in both groups. In both groups, all disciplines associated significantly as independent variables with the total scores as dependent variable. The

parameters of each discipline in the All-time Best Scores group was equal a unit and the intercept was close to zero indicating the perfect relationship between disciplines and scores. The scenario was not the same in the Egyptian group, since the parameters were less or greater than unit and the intercept (-54) was far from origin indicating the unbalance relationship between the scores and the disciplines.

Table (6)
Multiple Regression of the Best All-time Best Scores Records for each heptathlete's group (All-time Best Scores and Egyptian) scores

		Coefficients	Standard Error	t Stat	P-value
All-time Best Scores Scores	**Intercept**	-5.455E-11	**2E-12**	**1E+00**	**5E-01**
	H100	1	5E-15	2E+14	3E-15
	HJ	1	8E-16	1E+15	5E-16
	SP	1	7E-16	1E+15	4E-16
	R200	1	7E-16	2E+15	4E-16
	LJ	1	2E-15	5E+14	1E-15
	JT	1	2E-16	5E+15	1E-16
	R800	1	7E-16	1E+15	4E-16
	The predicted score = -5.455E-11+ 1*H100 + 1*HJ + 1*SP + 1*R200 + 1*LJ + 1*JT +1*R800				
Egyptian scores	Intercept	-54.0	136.0	-0.4	0.7
	H100	0.8	0.1	5.6	0.0
	HJ	1.1	0.1	10.5	0.0
	SP	1.0	0.2	5.1	0.0
	R200	1.2	0.3	4.3	0.05
	LJ	1.2	0.1	12.8	0.0
	JT	0.9	0.1	10.4	0.0
	R800	0.9	0.1	13.8	0.0
	The predicted score = - 54 + 0.8*H100 + 1.1*HJ + 1*SP + 1.2*R200 + 1.2*LJ + 0.9*JT +0.9*R800				

4- Stepwise Regression

In purpose to go deeper, the data were treated with stepwise regression. Table 7 refers to the findings, where the most effective disciplines as independent values that affected the All-time Best Scores heptathlon scores were H100 and JT according to the standardized estimate values (0.62 and 0.51) respectively. The intercept value of the All-time Best Scores group (2420.54) represents the sum of the points of the rest disciplines, where they were excluded during calculations.

Table 7 refers as well to the findings of the stepwise regression of the disciplines as independent values that affected the score of the Egyptian groups. There were no excluded disciplines during calculation. All disciplines were significantly correlated to the score with range (0.10 and 0.27). IT is remarkable that the power of the correlation for the All-time Best Scores group is greater than what is for the Egyptian group.

Table (7)
Stepwise regression of the disciplines and the scores of each group (All-time Best Scores and Egyptian)

	Variable	Parameter Estimate	Standard Error	F Value	Pr > F	R2	Standardized Estimate
All-time Best Scores Scores	Intercept	2420.54	649.40	13.89	0.010		
	100H	3.08	0.70	19.30	0.005	0.68	0.62
	JT	0.94	0.26	12.99	0.011	0.22	0.51
	Estimated Score= 2420.54 + 0.70 H100 + 0.26 JT						
Egyptian scores	Intercept	6.24	33.72	0.03	0.8547		
	H100	1.02	0.05	362.77	<.0001	0.85	0.27
	HJ	0.99	0.05	327.86	<.0001	0.01	0.21
	JT	1.07	0.06	307.32	<.0001	0.00	0.18
	R800	1.00	0.05	468.49	<.0001	0.04	0.17
	R200	1.04	0.08	153.19	<.0001	0.08	0.15
	LJ	0.97	0.09	127.09	<.0001	0.01	0.14
	SP	0.88	0.09	91.26	<.0001	0.003	0.10
	Score= 6.24 + 1.02*H100 + 1.04*R200 + 1 *R800 + 1*HJ + 1* JT + 0.88*SP						

5- Principal Component

Data in Table 8 shows the results of principle component analysis of the heptathlon of All-time Best Scores and the Egyptian scores. In case of the best All-time Best Scores, the analysis extracted two components (PC1 and PC2), they recorded high Eigenvalues 2.65 and 2.38, respectively (Figure 5). The PC1 and PC2 explained 37.95 and 34.06% of the total variation, respectively. Strong and weak correlation values were observed in relation to PC1 and PC2, respectively (Table 9). After rotation, the most two important components that affected the All-time Best Scores Best Scores accumulated 72.02% of the total variance. The PC1 explained 36.63% and included the positive disciplines **HJ, JT and H100**, while the PC2 explained 35.40% and evolved the disciplines **100H, R200 and LJ** (Figure 7). In case of the Egyptian scores, also the PCA analysis revealed two components, they recorded high Eigenvalues 3.55 and 2.42, respectively (Figure 5). The PC1 and PC2 explained 50.71 and 34.60% of the total variation, respectively. After rotation, the most two important components that affected the All-time Best Scores Best Scores accumulated 85.32% of the total variance. The PC1 explained 46.41% and included the positive disciplines **SP, HJ and JT** that correlated positively and strongly with PC1, while the PC2 explained 35.40% and evolved the disciplines **100H, R200 and LJ** that correlated positively and strongly with PC2 (Table 9) and (Figure 6).
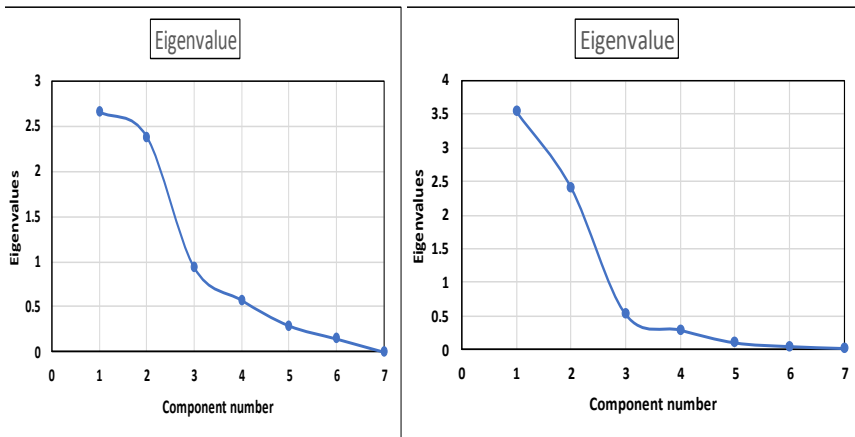
Figure 5 The Eigenvalues of the principle component analysis for the All-time best scores (left) and the Egyptian scores (wright).

Table (8)

Principle component analysis of the heptathlon of the Best All-time Best Scores Scores and Egyptian group

	Comp onent	Initial Eigenvalues				Rotation Sums of Squared Loadings		
		Total	% of Variance	Cumul ative %		Total	% of Variance	Cumul ative %
All-time Best Scores Scores	1	2.657	37.956	37.956		2.564	36.63	36.63
	2	2.385	34.067	72.023		2.478	35.40	72.02
	3	0.941	13.439	85.462				
	4	0.575	8.219	93.681				
	5	0.293	4.186	97.867				
	6	0.147	2.106	99.973				
	7	0.002	0.027	100				
Egyptian Scores	1	3.55	50.714	50.714		3.249	46.41	46.41
	2	2.422	34.606	85.32		2.724	38.91	85.32
	3	0.537	7.67	92.99				
	4	0.3	4.28	97.27				
	5	0.11	1.573	98.843				
	6	0.055	0.782	99.625				
	7	0.026	0.375	100				

Table (9)
Rotated Component Matrix between the disciplines and the score
of the best All-time Best Scores and Egyptian group

best All-time Best Scores			Egyptians group		
Discipline	PC1	PC2	Discipline	PC1	PC2
R800	-0.885	0.267	SP	0.964	0.021
HJ	0.741	-0.17	HJ	0.959	0.029
JT	0.635	0.124	JT	0.921	-0.03
R200	-0.241	0.825	R800	-0.699	-0.445
LJ	0.45	0.787	H100	-0.043	0.974
SP	0.298	-0.758	R200	0.249	0.9
H100	0.692	0.698	LJ	-0.017	0.874
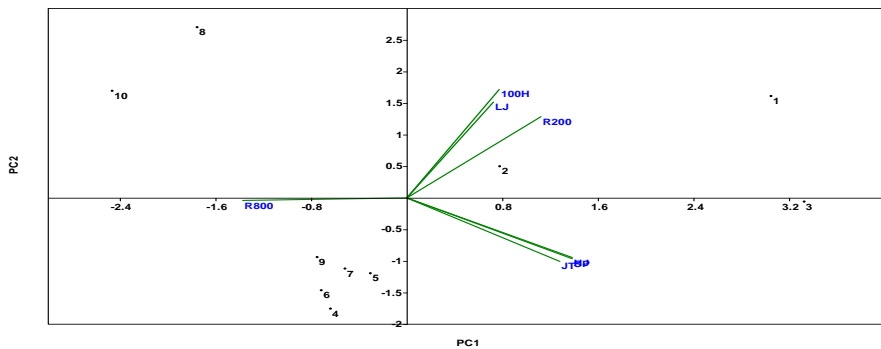
Figure 6 The biplot diagram of principle components analysis of the disciplines of Egyptian group
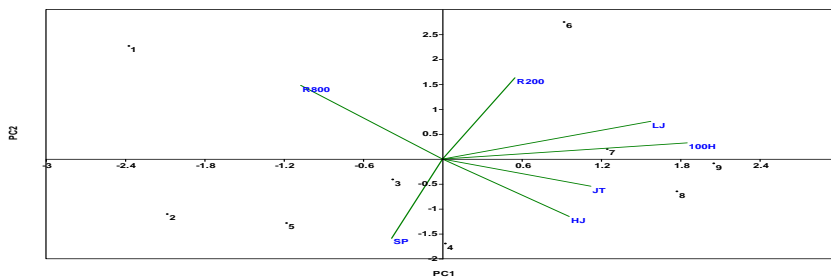

Figure 7 The biplot diagram of principle components analysis of the disciplines of All-time Best Scores group

Discussion

The current study analyzed the best Egyptian senior heptathlon scores comparing with the All-time Best Scores that listed in the IAAF records list of Heptathlon [12]. The purpose was to answer couple of questions, and try to determine the critical steps that have to be carried on in order to enhance the Egyptian heptathlon's records and push the heptathletes to cash the international record list or, at least, in African area record list.

In general, the differences between the two groups in the Scores are big. Which is the result of the internal differences in each discipline, where the percentile averages were between (9% - 27%), and the greatest averages were in SP, LJ, JT and 800m, ascendingly (Figure 1). These disciplines represent the three main components of the heptathlon: speed, strength and endurance. It is remarkable that 3 of those events are the 2nd day events. The Second day contribution percentiles of the final Score were close in case of all-time best records (15-21%), but it was (20-30%) in case of the Egyptian heptathletes scores. The unfavorable result is that the higher the score is, the bigger the difference is (Figure 4). Which is referring to the unbalance in training and performance. That disagree with the idea of the heptathlon which assumes the relative balance of each discipline on the overall performance [7], what is realized in all-time Best Scores percentiles (Figure 2, 4). Therefore, the training for the Egyptian heptathletes should be directed to achieve the best possible performance of maximum performance possibility. The basic task is to adapt the techniques and tactics required for the individual disciplines to the combined events context [24].

There are clearly high variances among the disciplines each other affecting the score that is 3 times the variance in the All-time Best Records (Table 3). The same is the variance among the three categories (run, jump, throw) disciplines, which also exceeds 3 times the variance in the All-time Best Records (Table 4). As well as the variances between the two groups points

in each discipline individually. The higher variances were in H100, HJ, and JT (Table 5). These are speed disciplines and two of them are in the heptathlon's first day. We have to notice here that the best Egyptian heptathletes are mainly 100m hurdles and 400m Hurdles athletes [11] [14] [15]. All disciplines are correlated to the Score in the Egyptian scores but weakly. H100 on the head of the list but with (0.27), which is the same of the All-time best Scores but H100 is correlated with (0.62) (Table 7).

That insures the necessity of developing the performance in hurdles and integrating the training in other events.

The principal component points to that each of **SP, HJ and JT** correlated positively and strongly with PC1, two out of them (SP and JT) had a wide percentile averages from the All-time Best Scores group. While each of **100H, R200 and LJ** that correlated positively and strongly with PC2 (Table 9) and (Figure 6). All of these disciplines belongs to speed category. R800 was excluded. This result agrees with two of

PC1 related disciplines of the All-time Best Scores, which are **HJ and JT** (Table 9)**.** This results disagree with any of other studies that used the principle components. Where they found that "runnerjumpers" heptathletes have advantage in scores [5], and disciplines of 100 m hurdles, high jump, and 200 m run and Long jump are the key of mastering the heptathlon. [7]. the most effective discipline on the score of Seoul Olympic 1988 Results of heptathlon were the 200m and long jump competitions receive the highest but the javelin result is less important [10]. Heptathletes should put more effort in R200m, then HJ then H100 to ensure additional points to the score [18].

Conclusion

Therefore, the results of the Egyptian heptathletes reflect the random training and selection, in spite of following the same international point of view of selecting the specialists not the generalists. That reflected the unintegrated training of the disciplines of the Heptathletes, which is probably focusing on the strengths of the athletes and neglecting the weaknesses.

that the specialists achieved an average of approximately 170 points more than the generalists and that specialists are found among the world's top athletes approximately 12% more often than generalists, which would explain early selection mechanisms based on good sprint-jump performances [7]

the results here verify that Are the Egyptian heptathletes were selected as specialists of an individual event, but they don't master it, and the competition or the training goes randomly where there is no specific trend of mastering events or distributing the effort on two days to perform with the required balance to collect the maximum of possible points of all disciplines.

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