

Structure of sports performance in women's heptathlon

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Abstract

The aim of this study was to study the athletic disciplines that predict the sports performance in women's heptathlon. The research presented the results of women's heptathlon in one of the largest samples on which specific research was carried out (535 best results in the heptathlon in history). The collected empirical material was formed by the indicators of the sport performance of the heptathlon of the best world performances according to available data from the IAAF (N = 535). Empirical material was divided into 2 groups with point scattering 5000 - 5999 points (n = 190) and 6000 - 7291 points (n = 345). The relations between the sports performance and individual disciplines in the heptathlon were calculated by the correlation, regression and step analysis methods. The hierarchy of women heptathlon disciplines in group 6000 - 7291 points: Long jump 23.07%, High jump 16.05%, Javelin throw 13.30%, Shot put 12.55%, 200 m 12.13%, 100 m hurdles 11.67% and 800m 11.23%. As the key factors predicting sports performance in women's heptathlon, these disciplines were calculated: Long jump (41.59%), Shot put (14.54%), Javelin throw (11.29%) and 800m (13.11%). Hierarchy of women heptathlon disciplines in group 5000 - 5999 points: Long jump 17.77%, Shot put 15.07%, Javelin throw 14.38%, 800m 13.97%, High jump 13.41%, 100 m hurdles 13.12% and 200 m 12.28%. As the key factors predicting sports performance in women's heptathlon, these disciplines were calculated: Long jump (24.22%), Shot put (23.31%), 800m (17.14%) and 100 m hurdles (16.84%). The heptathlon typology of athletes on historical and world level is based on versatility with emphasis on jumping and throwing disciplines.

Key Words: Track and field, Pearson correlation coefficient, stepwise analysis, prediction

Introduction

Of all the contests at the Olympic Games, it is surely the multi-event disciplines that provide the most challenging all-round tests of athletic supremacy. Multi-event competitions at the Olympic Games date to at least the eighth century BC, when the pentathlon was introduced. The original competition consisted of five events: running, standing long jump, discus, javelin and wrestling. The modern pentathlon, the brainchild of the founder of the Olympic movement, Pierre de Coubertin, stands alongside the men's decathlon and the women's heptathlon as a prominent multi-event discipline not just in the Games today (Fanshawe, 2012).

The heptathlon is a combined event within track and field athletics that includes seven disciplines performed over two days of competition (Dinnie and O'Donoghue, 2020). Women's heptathlon includes running, jumping, and throwing disciplines. It consists of 100 meters hurdles, High jump, Shot put, 200 meters, Long jump, Javelin throw, and 800 meters, which also represents seven individual athletic disciplines (Zhang and Liu, 2014).

The athletic heptathlon is a complex discipline, in which is necessary to respect the specific needs of individual sports disciplines (Koukal and Vindušková, 1987). The heptathlon, like other combined athletic disciplines, tests the speed, strength, mobility, and endurance of the athlete. The top-class heptathlon is by its specificity and structure share of individual disciplines characterized by versatility but also by unilaterality of some disciplines (Cox and Dunn, 2002; Shen and Huang, 2012; Brodání, Czaková & Dvořáčková, 2020, Brodání, Dvořáčková – Kováčová & Czaková, 2020). The majority of heptathletes perform superiorly in the sprinting and jumping disciplines in comparison to the throwing disciplines. This could be due to throwing events requiring less running and shorter explosive power efforts, and so a stronger, more powerful physique would be beneficial, as opposed to a sligher, faster anatomy for sprinting and jumping (Van Damme et al., 2002, Pavlovic et al., 2020). By heptathlon were realized research methods on the men's athletics and then they were implemented into the women's combined disciplines.

The final result of the heptathlon involves a wide range of information. The structure of successes in various heptathlon disciplines is going through changes (Majchrzak, Kamrowska-Nowak & Byzdra, 2010). Combined events are the only athletic disciplines in which the final performance is reported by points (Houtkooper et al., 2001). Performance in individual athletic disciplines is evaluated by points according to the IAAF scoring tables (Westera, 2007). The sum of points from individual disciplines is the final result of the

combined event (Čilik et al., 2020). The transformation of the performances from seconds, centimeters, and meters into points showed that the individual disciplines do not equally affect the overall competition result.

The current conversion formula for running, jumping, and throwing disciplines favors sprint and jumping disciplines, but penalizes the athletes who are specialized in 800 meters, Javelin throw, and Shot put (Gassmann, Fröhlich & Emrich, 2016).

The complex relationships and connections in the structure of heptathlon performance indicate a different focus and content of training at different levels of sports performance (Dawkins et al., 1994). The main goal of sports performance is to reach excellent quality, which can be achieved by knowing the importance of the complexity of sports training and implicit peculiarities of psychological preparation on a heptathlon sample, which is defined by the various sports disciplines and their properties and difficulties and also by the age of an athlete (Cucui, 2017).

Material and methods

The collected empirical material consists of indicators of the best heptathlon results in 535 world athletes according to available data from the internet until December 31, 2019 (1983 - 2019). These performances were divided into two groups due to the comparison of the typology of athletes. The average sports performance of the group of 6000 to 7291 points is $M = 6433.21$ with $SD = 237.08$ points ($N = 190$). The average sports performance of the group of 5000 to 5999 points is $M = 5368.33$ points with $SD = 271.12$ points ($N = 345$) (Table 1).

Table 1: Statistical characteristics of sports performances in two groups of athletes with an average sports performance 6433.21 points ($N = 190$), and 5368.33 points ($N = 345$)

	6000 - 7291 points				5000 - 5999 points			
	M	SD	Min	Max	M	SD	Min	Max
Marks (points)	6433.21	237.08	6010.00	7291.00	5368.33	271.12	5000.00	5998.00
Day 1 (points)	3788.72	148.63	3438.00	4264.00	3211.69	170.65	2841.00	3661.00
Day 2 (points)	2644.48	139.23	2177.00	3027.00	2156.64	153.03	1732.00	2564.00
100m hurdles (s)	13.52	0.38	12.54	14.61	14.40	0.48	15.93	13.23
High jump (m)	1.81	0.06	1.60	1.98	1.67	0.07	1.50	1.87
Shot put (m)	13.89	0.95	11.72	17.31	11.52	1.22	8.33	14.47
200m (s)	24.25	0.61	22.35	25.97	25.52	0.73	27.44	23.52
Long jump (m)	6.37	0.26	5.73	7.27	5.71	0.26	5.02	6.34
Javelin throw (m)	45.27	5.10	32.18	59.32	37.28	5.48	21.08	55.20
800m (m:ss.00)	2:13.93	0:04.72	2:04.20	2:29.99	2:23.49	0:06.34	2:43.36	2:10.10
100m hurdles (points)	1048.40	56.06	894.00	1195.00	924.28	65.88	723.00	1090.00
High jump (points)	995.89	81.44	736.00	1211.00	817.14	82.40	621.00	1067.00
Shot put (points)	786.49	63.15	643.00	1016.00	629.86	80.62	421.00	825.00
200m (points)	957.94	57.77	800.00	1145.00	840.41	65.77	676.00	1027.00
Long jump (points)	966.45	82.41	768.00	1264.00	762.26	76.41	565.00	956.00
Javelin throw (points)	768.93	98.35	518.00	1041.00	615.52	104.68	309.00	961.00
800m (points)	909.11	66.71	693.00	1051.00	778.86	82.94	535.00	963.00

Statistical analysis

The final sports performance and the performance in athletic disciplines are characterized by forms of basic descriptive statistics (N - number, M - average, SD - standard deviation, Max , Min). The statistical significance of differences between disciplines is analyzed by the one-factor ANOVA. The relationships between the sports performances, days, and individual heptathlon disciplines are assessed by Pearson's correlation coefficient " r ".

The proportion $Beta \cdot r$ of individual factors is estimated by the technique of multiple correlation and regression analysis. The coefficient of multiple correlation (R), determinant (R^2), standard error of estimate (SEE), the partial regression coefficients (b), and the significance of the prediction model (F , p) are calculated. The selection of the most valid disciplines in the prediction equation is realized by the stepwise regression. The data were processed by the statistical program SPSS. We formulate findings and conclusions by the logical analysis of obtained results.

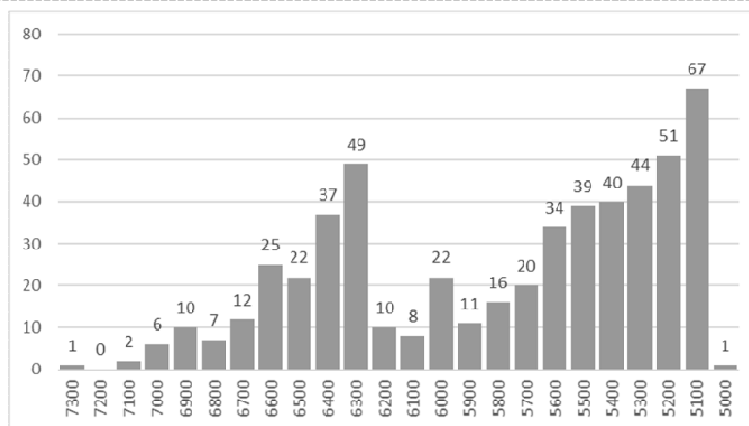


Fig. 1: Frequency of sports performances in heptathlon from 5000 to 73000 points

Results

The structure of sports performance in heptathlon 6000 – 7291 points

This group consists of 190 athletes out of 535 in total. We can describe this group as a minority but qualitatively more efficient. Heptathlon with average sports performance of $M = 6433.21$ points, with $SD = 237.08$ points ($N = 190$) has its specific structure of the single shares of individual disciplines to the whole sports performance in a race (Fig. 3). Due to the higher number of athletic disciplines on the first day, the heptathlon is characterized by a higher number of points gained on the first day. Between the athletic disciplines are statistically significant points differences see Fig. 2 ($F = 3.88, p < 0.01$).

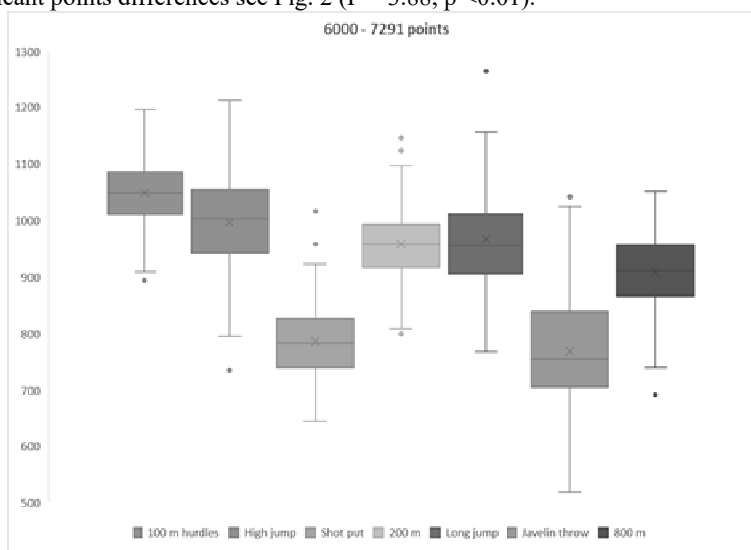


Fig. 2: Box plot of point evaluation of individual disciplines of heptathlon with the average performance $M = 6433.21$ (points)

Table 2: Correlations of athletic disciplines to overall sports performances and partial results in individual days of heptathlon with average performance $M = 6433.21$ points

	Heptathlon		Day 1		Day 2		
	r	p value	r	p value	r	p value	
Day 1	0.836	0.000					
Day 2	0.810	0.000					
6000 - 7291 points	100m hurdles	0.493	0.000	0.619	0.000		
	High jump	0.467	0.000	0.593	0.000		
	Shot put	0.471	0.000	0.521	0.000		
	200m	0.498	0.000	0.567	0.000		
	Long jump	0.664	0.000			0.578	0.000
	Javelin throw	0.321	0.000			0.597	0.000
	800m	0.399	0.000			0.493	0.000

The final point values from first and second days show a high tightness with the sports performance $r(190) = 0.836$ $p < 0.01$ and $r(190) = 0.810$ $p < 0.01$ (Table 2). Statistically significant correlations $r(190) = 0.321-0.664$ $p < 0.01$ with sports performance are proven in all athletic disciplines (Table 2). We also notice the significant correlations ($p < 0.01$) within the substructure of individual days and their disciplines. By the multiple correlation and regression analysis of heptathlon disciplines, the final structure of sports performance has been constructed (Table 3). The partial shares of individual disciplines to the final sports performance is Long jump 23.07%, High jump 16.05%, Javelin throw 13.30%, Shot put 12.55%, 200 meters 12.13%, 100 meters hurdles 11.67% and 800 meters 11.23% (Fig. 3).

Table 3: Regression analysis of athletic disciplines for the prediction of sports performance at 6433.21 points in heptathlon

	Beta	r	Beta*r
100m hurdles	0.236	0.493	11.6694
High jump	0.343	0.467	16.0547
Shot put	0.266	0.471	12.5539
200m	0.244	0.498	12.1281
Long jump	0.348	0.664	23.0699
Javelin throw	0.415	0.321	13.2989
800m	0.281	0.399	11.2251

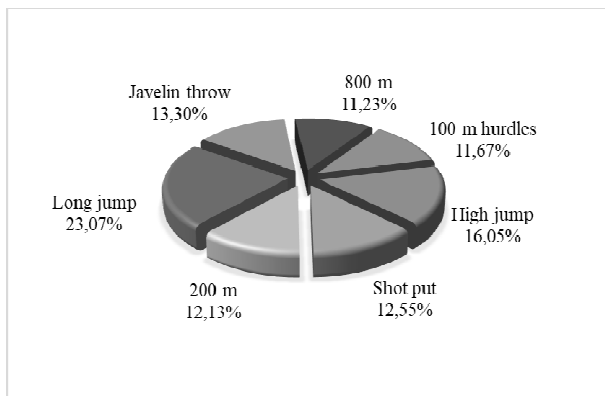


Fig. 3: Partial shares and hierarchy of the athletic disciplines for the explanation of the average sports performance at 6433.21 points

The most valid variables for the prediction of final sports performance at 6433.21 points were selected by the step regression (Table 4). The prediction equation consists of four disciplines. It contains only one discipline from the first day (Shot put) and all three disciplines from the second day (Long jump, Javelin throw, 800 meters). The equation achieves high predictive reliability ($R^2 = 0.805$, $SEE = 105.73$; $F = 191.327$; $p < 0.01$): **Prediction equation:** $Y = 2065.39 + 1.803 * \text{Long jump (m)} + 1.158 * \text{Shot put (m)} + 0.849 * \text{Javelin throw (m)} + 1.168 * \text{800 meters (m: ss. 00)}$.

Table 4: Step regression of selected athletic disciplines for the prediction of sports performance in 6433.21 points

	Beta	b	Beta*r	r	sig	t	sig
Long jump	0.6267	1.8030	41.5950	0.6637	0.0000	18.9113	0.0000
Shot put	0.3084	1.1579	14.5364	0.4713	0.0000	9.1730	0.0000
Javelin throw	0.3522	0.8490	11.2910	0.3206	0.0000	10.4496	0.0000
800m	0.3286	1.1679	13.1103	0.3989	0.0000	9.9845	0.0000
R	0.897		SEE	105.730		F	191.327
R²	0.805		bo	2065.391		sig	0.000

The structure of sports performance in heptathlon 5000 – 5999 points

This group of 345 women athletes from total 535 athletes we can describe as major but qualitatively with lower performance. Heptathlon with an average performance of $M = 5368.33$ points with $SD = 271.12$ points ($N = 345$) has its specific structure of the share of individual disciplines in sports performance (Fig. 5). Due to the higher number of disciplines on the first day, the heptathlon is characterized by a higher number of

points obtained on the first day also in this group of 5,000 - 5,999 points. The significant differences are present between the athletic disciplines ($F = 657.66, p < 0.01$), see Fig. 4.

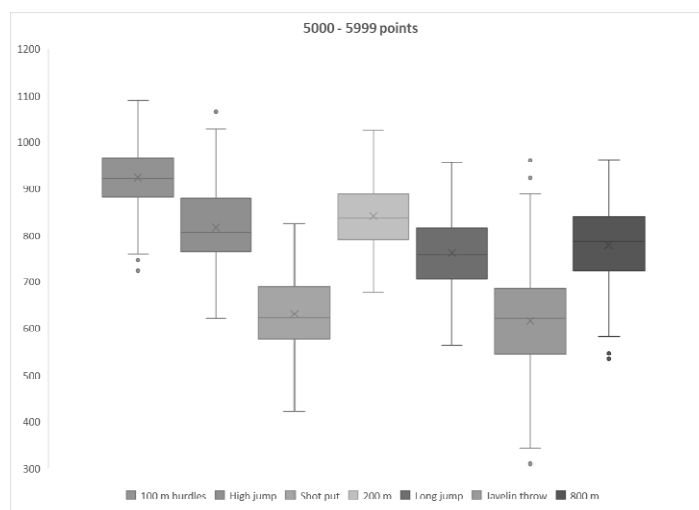


Fig. 4: Box plot of point evaluation of individual disciplines of heptathlon with the average performance $M = 5368.33$ (points)

The final point values from the first and second day show a high tightness with sports performance $r(345) = 0.856, p < 0.01$ and $r(345) = 0.817, p < 0.01$ (Table 5). Statistically significant correlations $r(345) = 0.372 - 0.631, p < 0.01$ with sports performance are demonstrated by all athletic disciplines (Table 5). The significant correlations ($p < 0.01$) within the substructure of individual days and their disciplines are founded. By the multiple correlation and regression analysis of women's heptathlon disciplines, the final structure of sports performance has been constructed (Table 6). The disciplines from the first and second day contribute to the overall sports performance of the heptathlon, but their mutual differences in the impact on the final sports performance in heptathlon are much tighter in the group 5000 - 5999 points than in the group over 6000 points, as follows: Long jump 17.77%, Shot put 15.07%, Javelin throw 14.38%, 800 meters 13.97%, High jump 13.41%, 100 meters hurdles 13.12% and 200 meters 12.28% (Fig. 5).

Table 5: Correlations of athletic disciplines to overall sports performances and partial results in individual days of heptathlon with average performance $M = 5368.33$ points

Day 1	0.856	0.000				
Day 2	0.817	0.000				
5000 - 5999 points	100m hurdles	0.540	0.000	0.669	0.000	
	High jump	0.441	0.000	0.565	0.000	
	Shot put	0.507	0.000	0.514	0.000	
	200m	0.506	0.000	0.587	0.000	
	Long jump	0.631	0.000		0.535	0.000
	Javelin throw	0.372	0.000		0.622	0.000
	800m	0.457	0.000		0.568	0.000

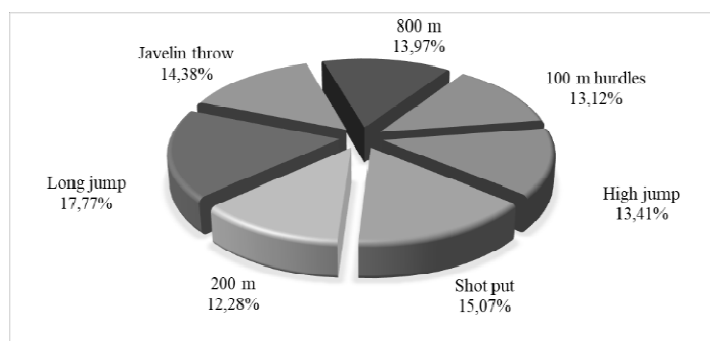


Fig. 5: Partial shares and hierarchy of the athletic disciplines for the explanation of the average sports performance at 5368.33 points

Table 6: Regression analysis of athletic disciplines for the prediction of sports performance at 5368,33 points in heptathlon

	Beta	r	Beta*r
100m hurdles	0.243		
High jump	0.304	0.540	13.1221
Shot put	0.297	0.507	15.0658
200m	0.243	0.506	12.2807
Long jump	0.282	0.631	17.7710
Javelin throw	0.386		
800m	0.306	0.372	14.3772
		0.457	13.9723

The most valid variables for the prediction of final sports performance at 5368.33 points were selected by the step regression (Table 7). The prediction equation consists of four disciplines. Unlike the first group over 6000 points in the second group 5000 - 5999 points, the equation contains two disciplines from the first day (Shot put and 100 meters hurdles), and two disciplines from the second day (Long jump and 800 meters). The equation has high predictive reliability ($R^2 = 0.815$, $SEE = 117.25$; $F = 374.869$; $p < 0.01$).

Prediction equation: $Y = 1213.028 + 1.363 * \text{Long jump (m)} + 1.548 * \text{Shot put (m)} + 1.227 * \text{800 meters (m:ss.00)} + 1.283 * \text{100 meters hurdles}$.

Table 7: Step regression of selected athletic disciplines for the prediction of sports performance in 5368.33 points

	Beta	b	Beta*r	r	sig	t	sig
Long jump	0.3841	1.3628	24.2187	0.6305	0.0000	14.7435	0.0000
Shot put	0.4601	1.5475	23.3149	0.5067	0.0000	19.4973	0.0000
800m	0.3754	1.2270	17.1437	0.4567	0.0000	15.8384	0.0000
100m hurdles	0.3118	1.2833	16.8391	0.5401	0.0000	12.0712	0.0000
R	0.903		SEE	117.250		F	374.869
R²	0.815		bo	1213.028		sig	0.000

Discussion

This research presents the results of women's heptathlon in one of the largest samples on which specific research was carried out (535 best results in the heptathlon in history). Both groups of divided athletes (group 6000 - 7291 points, $N = 190$, and group 5000 - 5999 points, $N = 345$) presents athletes as mostly jumping and throwing types of athletes (group over 6000 points: Long jump 23.07%, High jump 16.05%, Javelin throw 13.30%, Shot put 12.55%, and group 5000 - 5999 points: Long jump 17.77%, Shot put 15.07%, Javelin throw 14.38%, 800 meters 13.97%).

With chronologically arranged researches: [Heazlewood, 2011; Sukhanov, 2013; Gassmann, Fröhlich & Emrich, 2016; Sakr, 2016; Brodání, Czaková & Kováčová, 2020; Dinnie & O'Donoghue, 2020; Nemstev et al., 2020), the results achieved by this research of sports performance and the selected disciplines differ in content and quality. There are also some similarities and mutual confirmations of the summaries.

By Heazlewood's factor analysis of the 173 best athletes from the year 2010 divided the disciplines involved in the sports performance into three factors according to their influence on the sports performance and recommended follow this procedure in the training process (Heazlewood, 2011). The first factor is represented by running disciplines (100 meters hurdles and 200 meters) and jumping disciplines (Long jump and High jump). The second factor is about the throwing disciplines, and the third factor with the smallest influence on the performance is assigned to 800 meters. Our research agrees with the above results only in the field of jumping disciplines and denies the inclusion of throwing disciplines and 800 meters to the less important category (Jayal et al., 2018). Sukhanov (2013), determined the structure of the heptathlon performance on the largest share of the disciplines of the Long jump, High jump, 100 meters hurdles, Shot put, and Javelin throw, which is confirmed by this research. The partial agreement can be found in the researches of Gassmann, Fröhlich & Emrich (2016), who determined that the biggest impact on the 10 best women's performances from the World Championships in the years 1987 - 2012 had a Long jump (Panoutsakopoulos et al., 2017), 200 meters, 100 meters hurdles (Kaisidou et al., 2021) and High jump with a share of 48% to 21% from the total sports performance. In these types of researches in the models of regression analysis, the running and jumping disciplines were the most important (100 meters hurdles, High jump, 200 meters, Long jump), the second was the endurance discipline (800 meters) and the last were throwing disciplines (Shot put, Javelin throw). In comparison with these results, our findings agree with the first positions only in jumping (as most influential) disciplines (with the first group

agreement with two disciplines, with the second group agreement in one discipline). In our regression model, there are similarities with the 800 meters, which in the above research is in 5th place and in our research in 4th place in the group over 6000 points, and in 3rd place in the group 5000 - 5999 points. We confirm the phenomenon of a gradual increase in the impact of 800 meters running to the final sports performance in women's heptathlon.

Sakr (2016) in a sample of the top 10 Egyptian athletes emphasized the greatest influence of the 100 meters hurdles, High jump, and Javelin throw, while our research coincides with the disciplines in 2nd and 3rd place in the elite group and in 3rd place (Javelin throw) in the group of 5000 - 5999 points. BrodĀni, Czaková, KováčovĀ (2020) in their research of heptathlon sports performance describes the group of 172 best athletes as mostly jumping and running types of athletes, while the most influential are the disciplines of Long jump (23.52%), High jump (15.89%), 200 meters (14.31%) and 100 meters hurdles (12.61%). Our research confirms the jumping dominance and thus corresponds to this research.

Contrary to our research findings, the results of the work of Dinnie & O'Donoghue (2020), who did their research in a smaller group of world athletes (409) with their performance ranging from 4048 to 7032 points, showed that throwing disciplines in the final sports performance in women's heptathlon take a lower percentage significance as a running and jumping disciplines.

Nemstev, Bguashev, Nemtseva, Gunazhokov (2020) selected in his research the 100 best athletes in history and divided them into two groups according to points (from 1st to 32nd place and from 33rd to 100th place) and found that with a very small variance from 16, 0% to 12.1% (1st group) and from 16.2% to 11.9% (2nd group) the disciplines participate in the sports performance in the following order: 100 meters hurdles, High jump, Long jump, 200 meters, 800 meters, Shot put and Javelin throw. This result confirms the dominance of jumping disciplines but our research excludes the placement of throwing disciplines at the end of the hierarchy of final sports performance in heptathlon. By the majority of works and researches, in the structure of final sports performance in heptathlon the dominance of running and jumping disciplines has been confirmed. This research confirms the predicted and actual trend, which also creates a prediction for the future, that athletes who compete in heptathlon will be successful at the international level only when they are versatile with a predominance of jumping types, but with great emphasis on throwing disciplines and last but not least, on running disciplines.

Conclusion

It has been confirmed that women's heptathlon with sports performances at the level of $M = 6433.21$ points (group 6000 - 7291 points) and $M = 5368.33$ points (group 5000 - 5999 points) is a complex athletic discipline of combined events.

Women's heptathlon has its specific structure composed of individual athletic disciplines, which are divided into first and second day disciplines, which significantly affects the overall sports performance.

The highest average points in the group of 6000 - 7291 points are achieved by athletes in the disciplines of 100 meters hurdles, High jump, Long jump and 200 meters.

The highest average values in the group of 5000 - 5999 points are achieved by athletes in the disciplines of 100 meters hurdles, 200 meters, High jump and 800 meters.

The hierarchy and share of disciplines in women's heptathlon in the group of 6000 - 7291 points is: Long jump 23.07%, High jump 16.05%, Javelin throw 13.30%, Shot put 12.55%, 200 meters 12.13%, running 100 meters hurdles 11.67% and 800 meters 11.23%.

Hierarchy of disciplines in women's heptathlon in the group of 5000 - 5999 points is: Long jump 17.77%, Shot put 15.07%, Javelin throw 14.38%, 800 meters 13.97%, High jump 13.41%, 100 meters hurdles 13.12% and 200 meters 12.28%.

The prediction equations of both selected groups, consisting of four disciplines, are fully sufficient to predict the structure of sports performance in women's heptathlon.

The large performance differences of all athletes confirmed the fact that even at top world level, there is no athlete with a balanced score in all disciplines.

It was confirmed that only the historically best athletes were able to compete with the best athletes in the individual disciplines, even in running and jumping disciplines.

Typology of heptathlon athlete at the historical and world level is based on versatility with an emphasis on jumping and throwing disciplines.

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