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Decathlon each interaction regression factors analysis based on GRA and FAM

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ABSTRACT

Decathlon has early started in our country, but it is always the backwards event in our country's athletics which still has greater disparity with the world standard. Although in recently years our country excellent athlete Qi Hai-Feng has achieved a historic breakthrough in the event, China overall level in the event appears preliminary declining tendency. This paper adopts grey relational analysis and factor analysis, researches Chinese and foreign country excellent decathlon athletes total performance and each single performance internal relations as well as athletes performance internal structure, and makes contrast analysis, finds out main gap between our country athletes and world level athletes performance, provides a certain theoretical basis for China men decathlon training plan designing, athletes scientific material selections as well as athletics events development. Applies multiple regression analysis method establishing world excellent decathlon athletes' performance prediction model and test its prediction precise.

Key words: Grey Relational Analysis, Factor Analysis Method, Multiple Regression Analysis, Men decathlon

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INTRODUCTION

Decathlon is one of the oldest events in athletics with high requests of human functions, is a comprehensive sports event that combines techniques, physical ability, intellectuals into one, whose competitive levels reflects a country athletics levels to some extent. Modern men decathlon by far has nearly 100 years history, human closely focus on its changes and development since it appeared. From world range, decathlon researches experienced events meticulous designing and combination, athletes' selection and training, grading method development and revision, different periods' cases summarizing and analysis and other stages [1-3]. From 1990s to the beginning of this century, Chinese and foreign countries scholars exploration on decathlon has arrived at peak period makes it rapidly developing and its records continuously adapting [4-6]. With Olympic Games and other huge competitions successful holding in China, our country sports has made considerable achievements, but athletics backwards levels still are the key factors that restraint our country sports competitive levels improvement, especially that competitive level of decathlon in athletics generates great gap with world athletics competitive levels, and according to data analysis though recently times it is still a long target for our country decathlon catching up with world advanced level, only we correctly find our country decathlon backwards internal causes together with improvements and learning from each other, it still can fully achieve Asian leading position in a short time [7].

Grey system theory was first proposed by our country scholar professor Deng Ju-Long in 1982.Through 20 more years' perfection and development, the theory has been widely applied in agriculture, economics, medicine, military, sports, industry control and other dozens of fields. Due to grey theory adaptation range is "small sample", "poor data information", "undefined" grey hazy set, many problems in sports system are just in the field. Therefore, it tends to be able to provide a reasonable answer for some questions that are hard to explain by traditional methods as probability statistics (such as SPSS). According to grey system theory, it can regard decathlon as a grey system project, through relevancy analysis, reveal each single item performance in decathlon training position as well as its

functions on total performance, get acknowledge of mutual relations among them. Factor analysis concept derives from the beginning of 20th century Karl Pearson and Charles Spearmen statistical analysis with regard to intellectual test. At present, factor analysis has already successfully applied in psychology, medicine, weather, address, economics and other fields, and therefore foster theory continuously enrichment and perfection. Factor analysis is premised on minimum information loss; integrate multiple original variables into few comprehensive indicators, called factors. Usually, factor analysis generated factors can finally obtain name explanatory through each way. Factor name explanation to each single item, it is impossible to achieve fully balance, system and things are composed of multiple factors. Imbalance and dynamic changes among factors also decide system and things prediction complex [3, 5].

Based on above, this paper according to Chinese and foreign 28 excellent decathlon athletes competition performance, adopts SPSS software respectively carry out factor analysis and establish each single item performance and total performance multiple linear regression prediction model ,so as to better explore decathlon internal elements structure and item laws features. Through recently years' our country decathlon athletes 'exhibition and foreign excellent athletes contrast analysis, and combining China current training, competition system, analyze China decathlon development current situations and backwards main causes from macro fields, and propose reasonable suggestions and counter measurements on China decathlon promotion.

CHINESE AND FOREIGN MEN DECATHLON TOTAL PERFORMANCE AND EACH SINGLE ITEM PERFORMANCE GREY CORRELATION ANALYSIS

Through 11th national games information, select China and world previous 14 excellent men decathlon athletes as research objects, their total scores as well as each single item scores are as following Table 1 and Table 2 shows, basically represents China and foreign men decathlon highest level.

According to grey system theory, it can regard decathlon as a grey system, make grey correlation analysis of selected research objects performance. Through correlation degree analysis, it can know each single event performance effects on total performance as well as its position in decathlon training.

Table 1: Chinese 14 excellent men decathlon athletes each single event performance and total performance

Rank	Athlete	1500m	Javelin	Pole vault	110mHurdle	100m	400m	Shot	High jump	Long jump	Discus	Total performance
1	Qi Hai-Feng	643	752	761	872	893	849	699	804	906	769	7946
2	Yu Bin	594	772	674	888	895	813	744	723	942	754	7798
3	Zhu Heng-Jun	601	705	761	944	929	874	711	697	855	636	7712
4	Liu Hai-Bo	640	669	618	832	785	779	673	916	809	713	7433
5	Hao Ming	605	546	820	844	800	747	720	832	772	692	7376
6	Wang Jian-Bo	522	743	731	836	755	709	724	697	835	800	7351
7	Zhao De-Ning	601	680	703	843	835	816	626	645	840	679	7266
8	Lu Huan-Yong	629	658	646	794	800	691	695	887	838	623	7260
9	Guo Wei -Zhao	616	671	703	850	837	823	659	723	795	556	7233
10	Li Xian-Gui	591	585	674	871	806	794	660	723	847	560	7111
11	Lin Qing-Quan	520	799	618	726	811	753	696	697	734	664	7017
12	Yang Wen-Liang	640	702	790	728	768	726	620	645	700	695	7014
13	Tang Jun	561	551	618	934	832	739	539	777	730	485	6766
14	Zhou Bin	590	300	703	807	783	755	484	671	779	456	6327

Table 2: World 14 excellent men decathlon athletes each single event performance and total performance

Rank	Athlete	Country	1500m	Javelin	Pole vault	110m hurdle	100m	400m	Shot	High jump	Long jump	Discus	Total performance
1	Ashton Eaton	America	721	767	972	1032	1011	963	769	850	1068	716	8869
2	Terre Hardy	America	674	838	849	1035	994	904	807	794	942	834	8671
3	Lionel Suarez	Cuba	744	996	819	917	801	859	759	906	940	782	8523
4	Hans Van Alphen	Belgium	795	763	849	863	850	853	819	850	970	835	8447
5	Warner	Canada	746	780	819	926	980	899	712	850	945	785	8442
6	Rico Freimuth	Germany	695	698	880	989	940	906	782	714	864	852	8320
7	Oleksiy Kasyanov	Ukraine	721	661	790	963	961	888	756	794	947	802	8283
8	SergeySviridov	Russia	702	865	790	799	910	866	754	794	922	817	8219
9	Kerzen	South Africa	768	810	760	955	841	882	715	850	854	738	8173
10	Pascal Behrenbruch	Germany	696	810	819	932	847	813	831	767	850	761	8126
11	Elko	Holland	737	720	1004	920	894	868	739	740	903	509	8034
12	Newdic	New Zealand	692	735	819	847	838	804	795	767	900	791	7988
13	Barroilhet	Chile	629	697	1035	959	821	766	758	850	767	690	7972
14	Garcia	Cuba	689	736	790	944	906	873	758	794	755	711	7956

Through Table 1、Table 2 observation, it is known that athletes each single event performance and total performance have the same dimension and so no need to take dimensionless treatment on data.

Select each athletes total performance $x_0(k)$ as reference series:

$$x_0 = \{x_0(k) \mid k = 1,2,\ldots,n\} = \{x_0(1), x_0(2), \ldots, x_0(n)\}$$ (From which k represents the k athlete)

Select each athlete each single event performance $x_i(k)$ as contrast series:

$$x_i = \{x_i(k) \mid k = 1,2,\ldots,n\} = \{x_i(1), x_i(2), \ldots, x_i(n)\}$$ (From which i represents the i single event)

It can be concluded that the k athlete contrasts series x_i correlation coefficient to reference series x_0:

$$\xi_i(k) = \frac{\min\limits_s \min\limits_t \left|x_0(t) - x_s(t)\right| + \rho \max\limits_s \max\limits_t \left|x_0(t) - x_s(t)\right|}{\left|x_0(k) - x_i(k)\right| + \rho \max\limits_s \max\limits_t \left|x_0(t) - x_s(t)\right|} \tag{1}$$

Among them, $\rho \in [0,1]$ is resolution coefficient? It is called in formula(1) $\min\limits_s \min\limits_t \left|x_0(t) - x_s(t)\right|$ is two-level minimum difference, $\max\limits_s \max\limits_t \left|x_0(t) - x_s(t)\right|$ is two-level maximum difference. Generally speaking, the bigger resolution coefficient ρ is, the bigger resolution percentage would be; the smaller ρ is, the smaller resolution percentage would be.

Formula (1)defined correlation coefficient is an indicator that describes one athlete contrast series and reference series correlation degree, due to each athlete has a correlation number, information turns to be too scattering, not helpful for comparation, therefore it can adopt average correlation degree to carry out comparation.

$$r_i = \frac{\sum\limits_{k=1}^{n} \xi_i(k)}{n}$$ (r_i is series x_i to reference series x_0 correlation degree) (2)

According to Table 1 and Table 2 data, apply MATLAB software program calculation get China and world excellent athletes decathlon performance and each single event correlation degree as following Table 3 and Table 4 shows.

Table 3: Chinese excellent athletes' decathlon performance and each single event correlation degree

Item	110m hurdle	100m	Long Jump	400m	High Jump
Correlation degree	0.9123	0.9106	0.9096	0.9064	0.9037
Sequence	1	2	3	4	5
Item	Pole vault	Shot	Javelin	Discus	1500m
Correlation degree	0.8998	0.896	0.8951	0.8948	0.8907
Sequence	6	7	8	9	10

Table 4: World excellent athletes' decathlon performance and each single event correlation degree

Item	110m hurdle	Long Jump	100m	400m	Pole vault
Correlation degree	0.964	0.9612	0.9611	0.9584	0.9577
Sequence	1	2	3	4	5
Item	High Jump	Javelin	Shot	Discus	1500m
Correlation degree	0.9536	0.9509	0.9503	0.9495	0.9459
Sequence	6	7	8	9	10

From Table3 and Table 4, it is clear that foreign athletes each single event influence on total performance as well as correlation sequence as 110m hurdle > 100m > long jump > 400m > high jump > pole vault > shot > javelin > discus > 1500m; While world sequence is: 110m hurdle > long jump > 100m > 400m > pole vault > high jump > javelin

> shot > discus > 1500m. Compared with foreign athletes sequence, ten single event 110 hurdle, 400m, discus and 1500m sequence are the same, successively rank in 1、4、9、10，domestic top three are also long jump, 100m and 110m hurdle，but sequence are different, these three items all require horizontal speed cover absolute dominates; Foreign pole vault, javelin are respectively rank in the front of high jump and shot, while it is on the contrary at home. It is clear that domestic athletes has longer gap from foreign excellent athletes in special techniques high requested pole vault and javelin such two events, which indicates that our country athletes still have shortcomings on technical motions completion with high speed, high rhythm that should be taken seriously by our country all-round coaches.

CHINESE AND FOREIGN MEN DECATHLON PERFORMANCE FACTOR ANALYSIS

Men decathlon is a special competitive sport event that composed of running, jumping, throwing three large kinds of athletic events, its score rules as well as its comprehensive features decide that participating athletes must be versatile, any one event imbalance development would influence on decathlon total performance. However, to athletes, it is impossible to achieve each event fully balance. Due to each event has connection and each event develop status decides athletes total performance, the model according to statistics principal and method, apply SPSS 19 statistics software making statistics and handling with 28 Chinese and foreign men decathlon athletes' sport performance as well as each single event performance, research each large kinds of event levels influences on total performance.

Correlation coefficient matrix test

The model adopts KMO test making factor analysis adaptation test, KMO is Kaiser-Meyer-Olkin sampling adequacy measure. The higher KMO measurement value is (close to 1.0), indicates that more variables common factors would be, research data fit for factor analysis. Normally explain the indicator value with following criterion: KMO value arrives at above 0.9 means excellent, 0.8~0.9 means good，0.7~0.8means normal，0.6~0.7 means bad，0.5~0.6 means worse. If KMO measurement values are lower than 0.5, indicates samples are too small and needs to expand samples.

Input Table 1、Table 2 data into SPSS software, operate and get as following Table 5：

Table 5: KMO and Bartlett test

Sampling enough measure Kaiser-Meyer-Olkin measurement		.765
Bartlett sphericity test	approximate Chi-square	173.277
	df	45
	Sig.	.000

From Table 5, it can know KMO test result is 0.765 larger than 0.5, indicates data weaker than correlation, which is fit for factor analysis. Bartlett value equal to 173.277, P<0.001, indicates related matrix is not a unit matrix which can implement factor analysis.

Factor analysis

At first extract principal component, convert each variable value into standard value. Principal component analysis is constructing a multiple dimensions space with variety of variables, then project line in space to explain maximum variance, achieved line is common factor which can represent each variable natures to the maximum degree, while values in the line construct a variable is the first common factor , or is called the first factor (F_1). But there is still remaining variance in space; therefore it needs to project the second line to explain variance. At this time, it needs to follow the second criterion that project the second line and first line form direct relations (that is uncorrelated), which means represent different aspects. Values in the second line construct a variable is called the second factor (F_2). According to the principal it can determine the third, the fourth or more factors. Principally, factors numbers and original variables numbers are the same, but after extracting main factors, if rest variance is very small, it can give up other factors so as to achieve the purpose simplify data.

The model defines 10 events into variables, successively are 1500m, javelin, pole vault, 110m hurdle, 100m, 400m, shot, high jump, long jump, discus. Take athletes total performance as samples observation value; apply SPSS implementing factor analysis get as following Table 6:

Table 6: Each event variance and accumulative contribution ratio

Explanatory total variance						
Element	Initial feature value			Extract square sum loading		
	Total	Variance %	Accumulation %	Total	Variance %	Accumulation %
1	5.333	53.332	53.332	5.333	53.332	53.332
2	1.446	14.457	67.789	1.446	14.457	67.789
3	.927	9.274	77.063	.927	9.274	77.063
4	.730	7.297	84.359	.730	7.297	84.359
5	.502	5.025	89.384	\	\	\
6	.363	3.627	93.011	\	\	\
7	.301	3.012	96.023	\	\	\
8	.183	1.826	97.850	\	\	\
9	.151	1.509	99.359	\	\	\
10	.064	.641	100.000	\	\	\

From Table 6, it is clear that according to professional knowledge judging, select 4 principal components. These four principal components accumulative contribution ratio arrive at 84.359% larger than 80%. It can be known that these four principal component loaded sport single events are athletes' main scoring events in decathlon.

Then factor rotation, usually extract initial factors, then cannot make effect explanation on factors. At this time, it usually needs to make factors rotation, through coordinate transformation can make factor solution significance more easily explaining. The purpose of rotating shaft is changing subjects each factor load quantity size, adjust each factor loading quantity size according to subject and factor structural relations closely degrees when rotating shaft. After rotating shaft, variables in each factor loading quantity is growing bigger (close to 1) or smaller (close to 0), while each factor loading quantity size almost the same before non-shaft that let name common factors and explain variables more easily. After revolving shaft, every common factor feature values would change, but each variable communality would not change.

After extracting factors and rotating, principal component accumulative contribution ratio as following Table 7:

Table 7: After factors rotation each principal component accumulative contribution ratio

Explanatory total variance			
Element	Rotation square sum loading		
	Total	Variance %	Accumulation %
1	3.083	30.826	30.826
2	2.582	25.820	56.646
3	1.391	13.913	70.558
4	1.380	13.801	84.359
5	\	\	\
6	\	\	\
7	\	\	\
8	\	\	\
9	\	\	\
10	\	\	\

From Table 7, it is clear that after extracting factors and rotating each principal component accumulative contribution ratio hasn't changes still is 84.359%, but feature values tend to concentration and values all above 1.

Through great variance orthogonal rotation, after 5 times rotation get as following Table 8:

Table 8: After rotation factor loading

Rotation components matrix				
\	Component			
	1	2	3	4
100m	.917	.192	-.028	.139
400m	.882	.268	.106	.217
110m hurdle	.742	.009	.187	.406
Long jump	.706	.417	.279	.026
Discus	.186	.880	.107	.064
Javelin	.169	.856	.165	.051
Shot	.250	.784	.179	.403
High jump	.080	.186	.947	.058
1500m	.446	.327	.539	.393
Pole vault	.292	.184	.092	.906

From Table 8 can know the first principal component larger loading variable is 100m、400m、110m hurdle、long jump; The second principal component larger loading variable is discus, javelin, shot. The third principal component larger loading variable is high jump. The fourth principal component larger loading variable is pole vault.

From factor analysis result ,it is clear that in Chinese and foreign athletes' performance structure, 100m、400m、110m hurdle these three single event have the greatest functions, they can call speed, explosive force factor, discus, javelin and shot these 3 events functions are the secondary, they can call strength factors; High jump functions are the next that call nimble factor; Minimum functions event is 1500m, it can call speed endurance factor. These four factors structure can explain Chinese and foreign excellent athletes still focus on absolute speed training in training; Rank two factors discus, javelin and shot these three single events not only requests athletes has sufficient guarantee in absolute strength, and it have higher correlation in individual speed quality. Though it is not significant in score contribution ratio aspect that compare throw kinds event with other classification events, under current versatile sport balance development, eliminate weak events guiding thoughts, the kind factor functions go without saying; Rank three factors only high jump such one event, due to high jump is horizontal speed and vertical speed common function inter transformation generate dynamics, meanwhile it also asks special for athletes 'body shape, therefore classify separately into one kind; In speed endurance factors, similarly it have requests to athletes body shape but not the same as the first ,second factors, but these four kinds factors always correlated to speed quality. It can be seen that men decathlon core with speed is conform to current development tendency. For men decathlon athletes, it is necessary to comprehensive develop each physical quality ,especially speed ,strength and techniques, in future training it need to focus on strengthen techniques aspects training on the basis of speed ,strength consolidation.

MULTIPLE REGRESSION PREDICTION MODELS

Give all-round events 10 single event performance as independent variable, total performance as dependent variable. Adopt full model method carrying out linear regression, apply SPSS software in handling Table 1 can get as following Table 9、Table 10 and Table 11：

Table 9: Model Summary b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.995a	.991	.986	78.31389
a. Predictors: (Constant), discus, 110m hurdle, high jump, pole vault, long jump, javelin, 1500m, 100m, shot,400m				
b. Dependent Variable: total performance				

Table 9 is model fitting goodness test, from table can know that both square coefficient and after adjust square coefficient arrive at more than 0.99, indicates model has higher fitting goodness.

Table 10: ANOVA b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.135E7	10	1134536.674	184.987	.000a
	Residual	104262.120	17	6133.066	\	\
	Total	1.145E7	27	\	\	\
a. Predictors: (Constant), discus, 110m hurdle, high jump, pole vault, long jump, javelin, 1500m, 100m, shot, 400m						
b. Dependent Variable: total performance						

Table 10 is model variance test, from Table can know $F = 184.987$, significant correlation probability is 0.000^a , which is in significant difference.

Table 11: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-298.001	232.235		-1.283	.217
	1500m	1.396	.433	.155	3.225	.005
	Javelin	1.134	.200	.216	5.677	.000
	Pole vault	1.074	.211	.180	5.091	.000
	110m hurdle	.837	.339	.102	2.472	.024
	100m	1.962	.482	.214	4.066	.001
	400m	.355	.676	.037	.525	.606
	Shot	.363	.407	.044	.890	.386
	High jump	1.158	.278	.137	4.160	.001
	Long jump	.948	.282	.125	3.366	.004
	Discus	1.170	.230	.196	5.088	.000
a. Dependent Variable: total performance						

Table 11 is regression calculation process each equation coefficient table, from which can know t test shows significance level.

According to Table 11can get relative each event all-round non-standard regression model.

$$Y = -298.001 + 1.396X_1 + 1.134X_2 + 1.074X_3 + 0.837X_4 + 1.962X_5 + 0.355X_6 + 0.363X_7 + 1.158X_8 + 0.948X_9 + 1.170X_{10}$$

Among them, $X_1 - X_{10}$ are independent variables， respectively corresponding represent 1500m、javelin、pole vault、110m hurdle、100m、400m、shot、high jump、long jump、discus single event performance；Y is dependent variable， represents decathlon total performance.

Table 12: Compare prediction value and actual value

Name	Prediction total performance	Actual total performance	Predict accuracy ratio
Qi Hai-Feng	7902.37434	7,941.00	0.99513592
Yu Bin	7833.507706	7,791.00	0.994543999
Zhu Heng-Jun	7843.854998	7,708.00	0.982374806
Liu Hai-Bo	7898.012259	7,427.00	0.936581088
Hao Ming	7849.591999	7,370.00	0.934926459
Wang Jian-Bo	7733.213342	7,346.00	0.947289226
Zhao De-Ning	7843.356905	7,261.00	0.919796598
Lu Huan-Yong	7882.3557	7,256.00	0.91367755
Guo Wei -Zhao	7864.222777	7,230.00	0.912279007
Li Xian-Gui	7830.45619	7,106.00	0.898050072
Lin Qing-Quan	7730.492957	7,012.00	0.897533805
Yang Wen-Liang	7898.52487	7,009.00	0.873088191
Tang Jun	7788.761997	6,761.00	0.847986689
Zhou Bin	7829.138226	6,323.00	0.761800059
Ashton Eaton	8011.43	8,869.00	0.903307024
Terre Hardy	7945.818	8,671.00	0.91636697
Lionel Suarez	8043.538	8,523.00	0.943744925
Hans Van Alphen	8114.734	8,447.00	0.960664615
Warner	8046.33	8,842.00	0.910012441
Rico Freimuth	7975.134	8,320.00	0.95854976
Oleksiy Kasyanov	8011.43	8,283.00	0.96721357
SergeySviridov	7984.906	8,219.00	0.971517946
Kerzen	8077.042	8,173.00	0.988259146
Pascal Behrenbruch	7976.53	8,126.00	0.981605956
Elko	8033.766	8,034.00	0.999970874
Newdic	7970.946	7,988.00	0.997865048
Barroilhet	7882.998	7,972.00	0.988835675
Garcia	7966.758	7,956.00	0.998647813
Accuracy ratio average value	\	\	0.939343758

Input Chinese and foreign versatile athletes each single event performance into prediction model, get prediction total

performance, compare prediction value with actual value. It can get as following Table12.

From Table 12 can get model prediction accuracy degree average value is 0.9393, it can be concluded that model prediction accuracy degree quiet high. The prediction equation fully can predict Chinese and foreign excellent decathlon athletes total performance.

CONCLUSION

Grey correlation analysis results show that Chinese and foreign athletes each single event influence on total performance as well as correlation sequence as 110m hurdle > 100m > long jump > 400m > high jump > pole vault > shot > javelin > discus > 1500m；While world sequence is：110m hurdle > long jump > 100m > 400m > pole vault > high jump > javelin > shot > discus > 1500m.It is clear from that Chinese athletes still have greater gap by comparing with foreign excellent athletes on high requested special techniques pole vault and javelin such two events which indicates our country athletes still have shortcomings on technical motions completion with high speed, high rhythm that should be taken seriously by our country all-round coaches.

From factor analysis result ,it is clear that in Chinese and foreign excellent athletes' performance structure,100m、400m、110m hurdle these three single event have the greatest functions, they can call speed, explosive force factor, discus, javelin and shot these 3 events functions are the secondary, they can call strength factors; High jump functions are the next that call nimble factor; Minimum functions event is 1500m, it can call speed endurance factor. These four factors all are related to speed quality, which reveals that men decathlon feature is core with speed.

Take 10 single event performance as independent variable, take total performance as dependent variable, adopt full model method establish men decathlon performance multiple regression equation, through samples back substitution, equation precise arrives more than 99%, therefore can regard as Chinese and foreign excellent decathlon athletes' sports performance prediction model.

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