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Statistical analysis of triple jump's dynamics and its grey forecasting model of result

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ABSTRACT

On the dynamics and mechanical problems of triple jump, using statistical software to analyze the raw data based on mathematical statistics, this study finds that when the speed conversion rate > 0.6, the results increase with increasing of the conversion rate, generally higher than the speed conversion rate. Speed conversion rate of 0.6 as the cut-off point, the analysis result shows that the speed conversion rate significantly affects the long jump results. The regression curve shows the relationship between the horizontal velocity and vertical velocity (force), which is a quadratic function, and lays foundation for the reasonable allocation of forces in the horizontal and vertical directions. Besides, this study also explains why the jump result is the best when the triple jump proportion is 0.382:0.236:0.382, which provides certain theoretical basis for the selection and evaluation of jump athletes from another point of view.

KEYWORDS

Triple jump;
Linear regression;
Grey prediction model.

INTRODUCTION

Former studies on triple jump techniques are mostly focused on the special qualities, that is by studying the relationship between special qualities and special achievements, identify the main factors affecting the specific performance, in order to strengthen the training of corresponding special quality. Some scholars also establish the evaluation system of triple jump athletes' performance with the comprehensive evaluation method, which guides the athletes' training through the value of each evaluation index. There are not many researches on the speed conversion rate of triple jump. Performance of triple jump athletes is in a stable improving process. Only by accurately mastering the future results, can the athletes set goals and make efforts toward the goal in the training process. Therefore, it is necessary to predict the future results of the triple jump. Scholars have carried out a lot of researches on performance predicting of triple jump. Some scholars build the prediction model of the performance and time with regression model, and others use gray prediction model to forecast the results directly. However, there is no intrinsic relation between triple jump performance and time. So the result of regression analysis is not very believable. More accurate forecast of future performance can be obtained by utilizing grey model. But there are certain difficulties in the implementation of such methods.

The research first conducts analysis of mechanics and kinetics characteristics of the triple jump. Utilize gray forecasting model to predict the final run-up speed. And establish the regression model of the performance and the final run-up speed, in order to provide certain theoretical basis for the triple jumper's training.

DYNAMICS AND MECHANICS ANALYSIS OF TRIPLE JUMP

Six male athletes participating in the 1997 World Athletics Championships and the 2000 Olympic Games are the research objects in this article and are numbered as A1-A6. The symbol explanation in the study is shown in TABLE 1.

TABLE 1 : Symbol explanation

Symbol	Explanation
θ	Conversion coefficient of the horizontal velocity to vertical speed
B1	Horizontal velocity increment
B2	Vertical velocity increment
X	The final run-up speed

TABLE 2 : The relations of 6 male long jump athletes' performance to the horizontal velocity and vertical velocity conversion rate

Athlete	θ	Hop	Striding Jump	Jump	Stage proportion	Long jump distance
A6	0.366	5.79	4.75	6.39	34/28/28	16.93
A5	0.408	6.28	5.26	5.43	37/31/32	16.97
A4	0.837	4.92	4.47	6.69	30/27/43	16.36
A3	0.924	5.13	5.68	7.52	28/31/41	18.33
A2	0.946	4.91	5.26	7.36	28/30/42	17.52
A1	1.299	5.48	5.48	7.31	30/30/40	18.27

Conversion of horizontal velocity to vertical velocity

Seen from TABLE 2, when $\theta > 0.6$, the long jump technical features is to emphasize the proportion of the third jump, and the optimal results can be obtained. And $\theta = 0.6$, can be used as the selection criteria of the triple technical movement, When $\theta < 0.6$, the first stage performance has the maximum proportion, and the technical features is to focus on the hop of first phase to achieve the best results.

Figure 1 shows that, within a certain range, long jump performance is in overall upward trend with the increase of the speed conversion rate. And it reflects that when $\theta > 0.6$, the long jump results are generally higher than the long jump distance when $\theta < 0.6$. So speed conversion rate of 0.6 can be as the cut-off point for analysis. Speed conversion rate significantly affects the long jump results. Appropriate improvement of the speed conversion rate will be the future develop trend of triple jump.

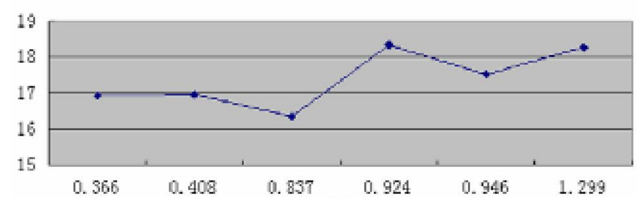

Figure 1 : The relationship of speed conversion rate and the long jump results

Calculate the horizontal velocity increment and vertical velocity increment of six athletes, and the data is shown in TABLE 3.

TABLE 3 : The relationship of horizontal velocity and vertical velocity

Athlete	Horizontal velocity increment	Vertical velocity increment
A1	-2.959	-2.263
A2	-1.876	-1.18
A3	-1.666	-1.453
A4	-1.619	-1.053
A5	-0.18	-0.614
A6	-0.157	-0.348

With the vertical velocity increment as the dependent variable, and the horizontal velocity increment as the independent variables, conduct correlation analysis and regression analysis of the data in TABLE 3. The results are shown in TABLE 4, TABLE 5.

TABLE 4 : Correlation analysis of horizontal velocity and vertical velocity

Variable	Correlation coefficient	P
Horizontal velocity increment	0.952	0.003
Vertical velocity increment		

Judging from above TABLE 5, quadratic curve estimation $R^2 = 0.939$ is greater than the linear regression

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equation= 0.907, so the relationship of horizontal velocity and vertical velocity tends to quadratic regression model.

The mathematical model is:

$$B_2 = -0.437 + 0.252(B_1)^2 - 0.122B_1 \quad (1)$$

Speed conversion rate:

$$\theta = \frac{B_1}{-0.437 + 0.252(B_1)^2 - 0.122B_1} \quad (2)$$

TABLE 5 : Model summary and estimated value of parameters

Equation	Model Summary			Estimated value of parameters		
	R^2	**F**	**P**	Constant	b_1	b_2
Linear	0.907	39.064	0.003	-0.312	0.596	-
Secondary	0.939	23.207	0.015	-0.437	0.252	-0.122

The above analysis shows that the level of speed reduction and vertical velocity increment is in quadratic regression relationship, seen in Figure 2.

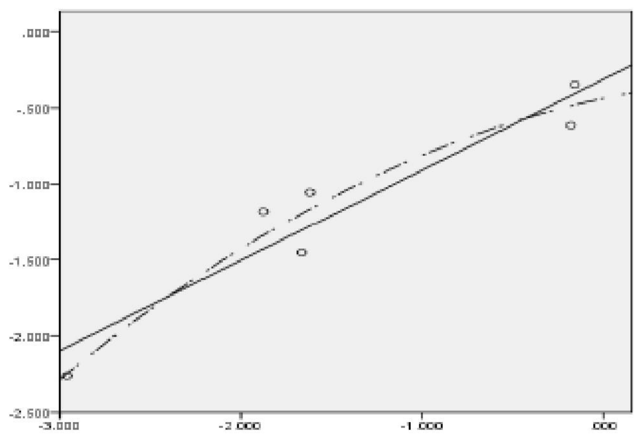

Figure 2 : Regression relationship of horizontal speed and vertical speed

Research on the relations of distribution of power and sports performance

Supplement the proportion data of three Chinese elite male triple jumpers' performance and the triple jump distance, and conduct statistical process of the data. The results of first, second, and third jump is numbered as respectively a, b and c. Calculate the percentage of the total results of the first and second jump in the overall results.

As can be seen from Figure 3, long jump results increase with the increase of (a+b)/c within a certain range. Exceeding a certain limit, the long jump results decrease with the increase of (a+b)/c. According to TABLE 3 (appendix), it shows when the proportion of (a+b) phases to total results reaches 60%, the performance is the best. Based on the mean value analysis, the ratio (a + b) phase to c phase is approximately close to the golden section point, the ratio as 0.618:0.382. On this base, this study puts forward the hypothesis that technical development in modern men's triple jump has the tendency that the triple jump proportion is reaching the golden ration 0.618. When the proportion reaches to 0.618, the optimal solution can be obtained.

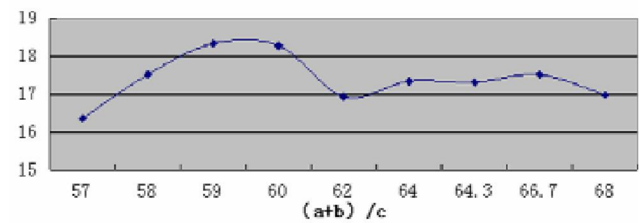

Figure 3 : The relation of the percentage proportion of the first and second jump to the performances

Model improvements: based on the assumption, first select the data of world elite male triple jumpers for more accurate discussion and introduce the concept of the same degree, L. About the calculation of the same degree of the two data, according to the provisions set pair analysis theory, the larger data divides by the smaller data, i.e. L=min(x1, x2)/max(x1, x2). On this basis, describe the approximation degree of the two real numbers x1 and x2. (a+b)/c

Seen from TABLE 6, the ratio of the first two long jumps' distance to the total result for Edwards is 0.6162, which is only 0.10018 less than the golden dividing point 0.618, with the same degree of the golden ratio 0.618

TABLE 6 : The world's top athletes' triple jump proportional relationship

		Hop		Striding Jump		Jump		
Athletes	**Results (m)**	**Results a**	**Proportion**	**Result b**	**Proportion**	**Results c**	**Proportion**	**Proportion (a+b)**
Edwards	18.29	6.05	33.08	5.22	28.54	7.02	38.38	61.62
Conley	18.17	5.7	31.37	5.47	30.1	7	38.52	61.48
Harrison	18.09	6	33.17	5.02	28.75	6.89	38.09	61.91
Average	18.18	5.91	32.54	5.3	29.13	6.97	38.33	61.67

as 0.9971; the ratio of the first two long jumps' distance to the total result for Conley is 0.6147, which is only 0.0033 less than the golden dividing point 0.618, with the same degree of the golden ratio 0.618 as 0.9947; the ratio of the first two long jumps' distance to the total result for Harrison is 0.6191, which is only 0.0011 less than the golden dividing point 0.618, with the same degree of the golden ratio 0.618 as 0.9982; the above facts show that one of the significant technical features among the world elite male triple jump athletes is that percentage of the first two jumps distance to the total performance has been significantly optimized, which is already highly in the same degree with the golden ratio 0.618.

Figure 4 shows that the results increase with the increase of closeness of two spans grades' percentage to the golden section point. As can be seen, 0.618 is the limit for the proportion of triple jump. When the two spans grades reach to 0.618 of the total score, the performance can show the highest level. In the triple jump for current world top-level triple jumpers, the first two Jumps distance has reached 0.618 of the total score. The next optimization step is to improve the proportion of the first jump and the second jump distance, to make the triple jump distance proportion in accordance with the golden section ratio 0.382:0.236:0.382.

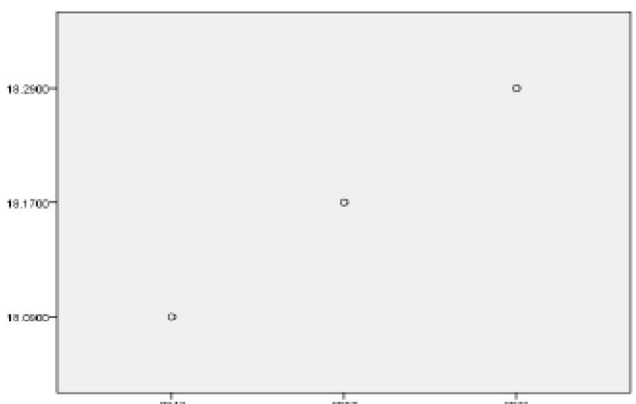

Figure 4 : The relation of the same degree of two jump scores' percentage and the golden dividing point to the performance

The gap of Chinese men's triple jump with the world advanced level mainly is the lack of optimization of triple jump proportion. Essence of the difference is that the comprehensive optimization of the technical level is not high. It needs to improve the run-up speed, increase the vacated and jumping forces, shorten support time and coordinate the triple jump proportion. Increase the first jump distance percentage in the final result toward 0.382; appropriately decrease the second jump distance percentage in the final result toward 0.236; and after the reasonable relaxation and energy saving in the second jump, do the maximum jumps pediment in the third jump to accomplish the remaining 0.382. All these contribute to tying the world advanced level in the world men's triple jump.

TRIPLE JUMP PERFORMANCE PREDICTION

Linear regression model of run-up speed and the performance

Several excellent foreign triple jumpers' run-up speed and the performance are shown in TABLE 7.

TABLE 7 : Several excellent foreign triple jumpers' run-up speed and the performance

Athlete	Performance (m)	The final run-up speed(m)
Markov	17.92	10.62
Conley	17.61	10.42
Edwards	18.29	11.9
Wellman	17.62	11.63
Henriksen	16.92	11.11

With the final run-up speed as the independent variables, and athletic performance as the dependent variables, establish the regression model. And the Goodness-of-fit test results of the regression model are shown in TABLE 8.

TABLE 8: Fitting test results of regression model

R	$\overline{R}^2$	$\overline{R}^2_{adj}$	The standard error of the estimated value
0.841	0.707	0.414	0.386

Adjust the determination coefficient and conduct the goodness-of-fit test of the regression equation according to the table. Then the adjusted determination coefficient is 0.707, which is closer to 1. The better the goodness of fitting of the regression equation, the more explanatory variables that can be explained by the model, as shown in TABLE 9.

The significant test statistics of the regression equation F = 2.412, the probability p = 0.43, which is less than the significant level of 0.05, indicating that

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regression coefficients are not simultaneously 0, and the interpreted variables and interpretation variables are significantly related and the established model is appropriate.

TABLE 9 : Significance test results of regression model

Source of variation	Sum of squares	df	Mean square	F	Sig.
Return	0.718	2	0.359	2.412	0.043
Residual error	0.298	2	0.149		
Total	1.015	4			

As can be seen from TABLE 10: the probability P value of the regression coefficients are less than the significance level of 0.05. The regression equation of the final run-up speed X and the performances Y can be expressed as: $Y = 15.022 + 0.238X$. The relationship between the final run-up speed and results can be seen in Figure 5.

TABLE 10: Significant test results of regression coefficients

Model	Partial Regression coefficient	Standardized Partial Regression coefficient	t	P
Constant term	15.022	-	3.077	0.049
The final run-up speed	0.238	0.299	0.543	0.025

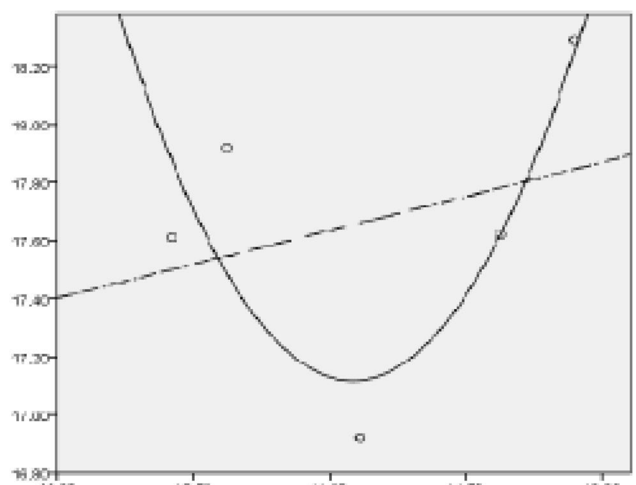

Figure 5 : The relationship diagram of final run-up speed and performance

According to the above model, predict the athletes'performance of and athletes' actual and predicted values are shown in TABLE 11.

Adjust the model by constant plus the forecast difference, to bring it closer to the true level.

The regression model can be explained as: $Y = 15.007 + 0.238 * X$

TABLE 11 : The difference between the actual results and the predicted results based on the regression model

Athlete	Results (m)	Run-up speed(m)	Predictive value	Difference
Markov	17.92	10.62	17.54956	0.37044
Conley	17.61	10.42	17.50196	0.10804
Yanping Chen	17.51	10.04	17.41152	0.09848
Sixin Zou	17.31	10.44	17.50672	-0.19672
Edwards	18.29	11.9	17.8542	0.4358
Wellman	17.62	11.63	17.78994	-0.16994
Henriksen	16.92	11.11	17.66618	-0.74618
Average	17.6	10.88	17.61144	-0.014297143

Establish a gray model of the selected variable, run-up speed V

Establish the gray model GM (1,1): Assume that the time set $X^{(0)}$ have number n observation values $X^{(0)} = \{X^{(0)}(1), X^{(0)}(2), \ldots, X^{(0)}(n)\}$, generate a new sequence by accumulation $X^{(1)} = \{X^{(1)}(1), X^{(1)}(2), \ldots, X^{(1)}(n)\}$, then the corresponding differential equation of model $GM(1,1)$ is:

$$\frac{dX^{(1)}}{dt} + aX^{(1)} = \mu \qquad \textbf{(3)}$$

Wherein, a means the development grayscale; μ means the endogenous control grayscale.

Assume δ is the parameter vector to be evaluated and $\delta = \begin{bmatrix} a \\ \mu \end{bmatrix}$. Calculate by the least multiplication method:

$$\delta = (B^T B)^{(-1)} B^T Y_n$$

Wherein: $B = \begin{bmatrix} -\frac{1}{2}[X^{(1)}(1) + X^{(1)}(2)] \\ -\frac{1}{2}[X^{(1)}(2) + X^{(1)}(3)] \\ \vdots \\ -\frac{1}{2}[X^{(1)}(n-1) + X^{(1)}(n)] \end{bmatrix}$, $Y_n = \begin{bmatrix} X^{(0)}(2) \\ X^{(0)}(3) \\ \vdots \\ X^{(0)}(n) \end{bmatrix}$.

Solve the differential equations and the prediction model can be obtained:

$$X^{(1)}(\hat{k}+1) = [X^{(0)}(1) - \frac{\mu}{a}] \cdot e^{-ak} + \frac{\mu}{a} \qquad (k = 0, 1, 2 \ldots, n) \qquad \textbf{(4)}$$

Model checking and correcting: Gray prediction model checking generally contains residual error test, association test and posterior error testing. Posterior error testing is adopted in this study:

The standard deviation of the original

sequence: $S_1^{'} = \sqrt{\frac{\sum [X^{(0)}(i) - \overline{X}^{(0)}]^2}{n-1}}$

Variance ratio: $C = \frac{S_2^{'}}{S_1^{'}}$

Small error probability: $P = p\left\{\left|\Delta^{(0)}(i) - \overline{\Delta}^{(0)}\right| < 0.6745 S_1^{'}\right\}$ and if $e_i = \left|\Delta^{(0)}(i) - \overline{\Delta}^{(0)}\right|$, $S_0^{'} = 0.6745 S_1^{'}$, then $P = p\{e_1 < S_0^{'}\}$.

First suppose that $X^{(0)}(1), X^{(0)}(2), X^{(0)}(3), X^{(0)}(4), X^{(0)}(5)$ are corresponding to the original sequence data.

(1) Construct accumulated generating column: $X^{(1)} = [X^{(1)}(1), X^{(1)}(2), X^{(1)}(3), X^{(1)}(4), X^{(1)}(5)]^T = []$

(2) Structure matrix B and data vector Y_n.

(3) Calculate $B^T B, (B^T B)^{(-1)}, B^T Y_n$, then: $\delta = (B^T B)^{(-1)} B^T Y_n$

(4) Prediction model is: $X^{(1)}(\hat{k}+1) = [X^{(0)}(1) - \frac{\mu}{a}]e^{-ak} + \frac{\mu}{a}$

As variables affecting the results only can be statistically analyzed after the game statistics, it cannot be used directly on regression prediction of the final performance. Besides, gray model prediction of the run-up speed on time series is also needed to realize the indirect solving of the modeling purpose.

CONCLUSIONS

In this study, a correlation analysis algorithm is used for the quantitative statistics and analysis of evaluation index data. By analyzing the correlation among various evaluation indexes and the correlation between the evaluation indexes and long jump athletes' performances, the conclusion that the horizontal velocity decrement is in quadratic regression relationship with the vertical velocity increment can be obtained. According to the study on the relation of power allocation and performance, this article puts forward that hypothesis that the technical development of modern men's triple long jump has the tendency that the triple jump proportion is close to the golden segmentation ratio 0.618, and the optimal solution can be obtained when the ratio reaches 0.618.

Variables affecting the Athletes' Result, the run-up speed and the results of regression analysis. Although the final regression equation of the run-up speed and the performance is obtained, but because the run-up speed can be statistically analyzed only after the game. As a result, it cannot be used directly in the regression forecast of the performance. The run-up speed also needs the gray model prediction on time series, in order to achieve the solving of model purpose.

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