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Excellent women's triple jump three phases jumping parameters correlation degree research based on GRA model

Zhiqiang Zhao
Teaching Department of Physical Education, Dalian Medical University, Dalian, (CHINA)

ABSTRACT

Triple jumpers sport abilities' are up to sport technique, psychological and physical quality, as well as training conditions. Present excellent triple jumpers are mostly from America and Europe, Chinese women triple jump has made constant progress in 1990s, seen from around 20 years performance, it has ever always got close to world advanced level, broke though Asian women triple jump record for times, Chinese athletes are in Asian leading position,, but they keep paces with American and European countries, which still needs to further catch up with world level. The paper makes research on women triple jumpers' performance and parameters in sports relations, by theoretical exploring and discussing, it defines parameters indicators. Apply grey mathematical model, solve indicator and performance correlation degree, and initialize data. In three phases' jumping, it respectively establishes parameters and performance correlations, solves weight and establishes performance and factor equations, By comparing with excellent athletes' parameters, it gets each factor importance in performance by analyzing and researching that is weight, and verifies. By mathematical model establishment, it further analyzes performance influence factors. Finally it proposes that improve horizontal speed, and takeoff vertical speed is the important way to improve triple jump performance.

KEYWORDS

Women triple jump;
Weight;
Grey relational Analysis (GRA);
Parameters analysis;
Correlation degree.

INTRODUCTION

Triple jump, one of the athletics events, is from Ireland. It has higher requirements on physical quality, especially in physical ability, legs explosive power and coordinate ability. It is high difficulty sport combining technique with physical quality. In the end of 20th century, International Association of Athletics Federations defined women triple jump as formal competition event. China has ever achieved splendid records in the aspect of women triple jump, women triple jump world record was established by Chinese athlete Li Hui-Rong; Since 21st century, Chinese triple jump level has been gradually fell behind world level, except for physical difference from foreign athletes, the main reason is lacking of triple jump theoretical research, no correct theory to guide training. With application of high science and technology, research on long jump has become more and more deeply, experts and scholars take how to change techniques so as to move triple jump

performance to next level as research direction. By searching documents, it finds by consulting that lots of scholars have made deeply research on long jump performance influence factors analysis; they get some conclusions by numerical analysis, data comparison, and regression analysis as well as other methods researching.

Among them, Jiang Jiu-Jiang made statistical analysis of Beijing Olympic Games men's triple jump long jump performance, analyzed and researched on triple jump kinematic features through data handling, he thought that three phases jumping distances proportion is the key to achieve high performance. Zheng Xuan researched on 11th national games men's triple jump top eight athletes' performance, by mathematical analysis and other methods; he analyzed kinematic parameters and triple jump performance relations, and revealed triple jump internal features. Comparing with foreign excellent athletes, he got that Chinese athletes' muscular explosive power are lower than international level, which provided theoretical basis for training guidance. Liu Tao by statistic data, he analyzed speed and performance relations, and established parameters and performance correlations, solved correlation degree to parameters importance and ranked them, the conclusion was that improving horizontal speed could largely improve triple jump performance. Dai Li-Ping, by statistical method, analyzed second level, third level women jumpers' sports levels and physical quality correlation coefficients so as to define main influence factors, her research result showed that 30m and standing ten level jump events are crucial to triple jump performance, which provided important reference for triple jump sport training.

This paper based on previous researches, it will further reveal long jump performance and its influence factors relations. On the basis of previous research, it defines researched triple jump technical parameters, and makes deeply theoretical analysis. In traditional numerical analysis, it applies Grey Relational Analysis(GRA) into establishing mathematical model, defines different parameters effects on triple jump performance. Define each parameter and performance correlation degree; it gets factors contribution rates in performance by normalization. Factors contribution rates decide athletes training direction, as well as training indicator emphasis problems, which provides theoretical basis for further improving athletes performance.

TRIPLE JUMP TECHNICAL GRA MODEL

Triple jump is also called three levels jump; main jumping technical ways are :(1) positive take-off, (2) vertical, (3) surface-piercing, (4) running. It is composed of hop, step, and jump three parts distances. Athlete runs-up along straight line, he uses hop before take-off board and after moving along straight line, after take-off leg landing, it then use taking-off step, swinging leg landing takeoff jumping, use two legs landing into sandpits that is composed of run-up, takeoff, flight and landing as well as other motions. In competition, jumping distances decide ranking. To better take-off, generally it needs to go through some distance accelerated running, let human body achieve maximum horizontal speed. Trip jump three phases jumping are respectively hopping, step in take-off after take-off legs landing, jumping from swinging legs landing take-off, use two legs landing into sandpit. As Figure 1 show.

Triple jump performance influences parameters effects are very complicated, their each factor and performance internal relations, structure, as well as features, we cannot fully understand them. Only establish their relations by some unclear connection. It is called system with partial known information and partial unknown information as grey system. The paper starts from grey system original feature grey, researches on information greatly lacking of clear correlations system. Grey system can better fit and find out things grey relations, establish parameters and triple jump performance correlations, and accordingly solve and handle with performance and parameters relations. Calculate parameters and performance correlation degree so that explore long jump performance and influence factors internal connections.

Correlation analysis and solution

Correlation degree analysis method is put forward by grey system theory. Different from regression equation, it has unique advantages. Grey correlation degree, according to factors development states similarity or difference degree to judge factors correlation degree, it reveals factors dynamical correlation features and de-

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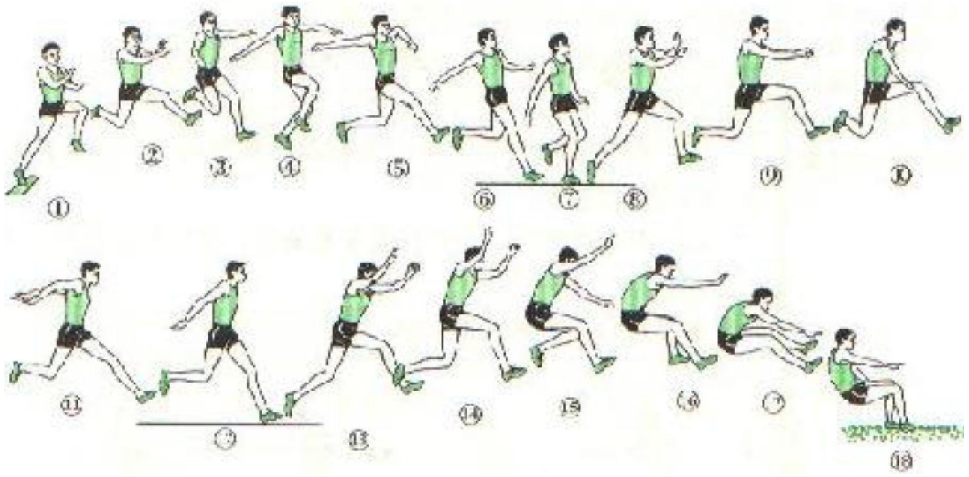

Figure 1 : Triple jump motions display chart

grees. Correlation degree geometric significance is similarity degree after factor converted into function images. Its calculated amounts are less and not prone to appear correlation degree quantization result and qualitative analysis inconsistent status.

(1) Research objects

Select national games top 8 women triple jump performance and speed parameters as research objects, top eight athletes' performance and parameters are as following TABLE 1.

(2) Correlation analysis

In triple jump, performance influence factors tend to be heavy and complicated. We tend to need making analysis of the performance influence factors, so as to define during these factors which is the major one, which is the secondary one, which needs to be developed, which needs to be restrained, which is potential, and which is obvious. To improve triple jump performance, factors importance is problems with great concerns. In fact, how do factors correlations like and how to quantify correlation degree and other problems are key and starting points of system analysis. Correlation analysis, which is also system's each factor relative statistical data geometric relations comparison. As a developing and changing system, correlation analysis actually is dynamical process development trend quantization comparative analysis. Athletes' speed parameters are as following TABLE 2.

In TABLE 2, x_1, x_4, x_7 respectively represents hop, step, jump landing speed, x_2, x_5, x_8 respec-

TABLE 1 : Athletes performance table

Name	Chen Yu-Fei	Xie Li-Mei	Liu Ya-Nan	Li Yan-Mei	Xu Ting-Ting	Hu Qian	Lin Nv-Ai	Qiu Hui-Jing
Performance	14.11	14.08	14.04	13.7	13.69	13.59	13.58	13.58

TABLE 2 : Triple jump speed parameters

Name	Performance	x1	x2	x3	x4	x5	x6	x7	x8	x9
Chen Yu-Fei 1	14.11	8.95	8.67	2.16	7.89	7.27	1.45	6.87	6	2.46
Xie Li-Mei 2	14.08	8.8	8.56	2.03	7.86	7.14	1.23	6.64	5.73	2.47
Liu Ya-Nan 3	14.04	8.68	8.25	1.98	7.5	6.72	1.17	6.25	5.37	2.54
Li Yan-Mei 4	13.7	8.66	8.23	2.17	7.41	6.85	1.25	6.2	5.14	2.31
Xu Ting-Ting 5	13.69	8.59	8.21	2.03	7.32	6.72	1.16	5.87	4.74	2.24
Hu Qian 6	13.59	8.63	8.19	2.09	7.26	6.66	1.09	5.91	4.94	2.51
Lin Nv-Ai 7	13.58	8.77	8.27	2.14	7.29	6.73	1.16	6.02	4.93	2.43
Qiu Hui-Jing 8	13.58	8.55	8.18	2.12	7.19	6.56	1.18	5.78	4.76	2.36

tively represents hop, step, jump liftoff speed, x_3, x_6, x_9 respectively represents hop, step, jump liftoff instantaneous vertical speed.

(3) Correlation solution

By investigation on excellent athletes, it achieves long jump performance and parameters statistical result. According to correlation degree calculation, it makes factor analysis of long jump performance. At first calculate foreign excellent athletes' correlation degrees, use matrix to express TABLE 2 parameters. And then it is matrix A:

$$A=\begin{pmatrix} 8.95 & 8.80 & 8.68 & 8.66 & 8.59 & 8.63 & 8.77 & 8.55 \\ 8.67 & 8.56 & 8.25 & 8.23 & 8.21 & 8.19 & 8.27 & 8.18 \\ 2.16 & 2.03 & 1.98 & 2.17 & 2.03 & 2.09 & 2.14 & 2.12 \\ 7.89 & 7.86 & 7.5 & 7.41 & 7.32 & 7.26 & 7.29 & 7.19 \\ 7.27 & 7.14 & 6.72 & 6.85 & 6.72 & 6.73 & 6.73 & 6.56 \\ 1.45 & 1.23 & 1.17 & 1.25 & 1.16 & 1.16 & 1.16 & 1.18 \\ 6.87 & 6.64 & 6.25 & 6.20 & 5.87 & 6.02 & 6.02 & 5.78 \\ 6.00 & 5.73 & 5.37 & 5.14 & 4.74 & 4.93 & 4.93 & 4.76 \\ 2.46 & 2.47 & 2.54 & 2.31 & 2.24 & 2.43 & 2.43 & 2.36 \end{pmatrix}$$

In matrix A, row represents x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9. Performance uses sequence B to express, and then:

$$B=(14.11 \quad 14.08 \quad 14.04 \quad 13.70 \quad 13.69 \quad 13.59 \quad 13.58 \quad 13.58)$$

At first carry out data transformation. Because collected original data with different dimensions that have no comparability, to ensure modeling result accuracy, it should proceed with data transformation. Method is as following:

Define 1 Ordered sequence

$$x=(x(1),x(2),\cdots x(n))$$

And then call it as map:

$$f: x \to y$$

$$f(x(k))=y(k), k=1,2,\cdots n$$

It is sequence x to sequence y data transformation. Its data transformation has: initialization transformation, mean transformation, percentage transformation, multiple transformation, normalization transformation, maximum range transformation, interval values transformation and so on. Here adopts transformation:

$$f(x(k))=\frac{x(k)}{x(1)}=y(k), k=1,2,\cdots n, x(1)\neq 0$$

That is f initialization transformation. Make initialization transformation on matrix A, adopting matrix form transformation.

Define transformation matrix C: Let original data matrix A convert into initial value matrix D 's matrix is called transformation matrix. Relationship is:

$$C \bullet A = D$$

Matrix C general form is:

$$C=\begin{pmatrix} 1/a_{11} & 0 & \cdots & 0 \\ 0 & 1/a_{21} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1/a_{n1} \end{pmatrix}$$

Then utilize transformation matrix C to carry out initial value transformation on A, B, it can get matrix:

$$D=C \bullet A=\begin{pmatrix} 1 & 0.983 & 0.970 & 0.967 & 0.960 & 0.964 & 0.980 & 0.955 \\ 1 & 0.987 & 0.952 & 0.949 & 0.947 & 0.944 & 0.953 & 0.946 \\ 1 & 0.940 & 0.917 & 1.00 & 0.940 & 0.966 & 0.990 & 0.981 \\ 1 & 0.996 & 0.951 & 0.939 & 0.928 & 0.920 & 0.923 & 0.911 \\ 1 & 0.982 & 0.924 & 0.942 & 0.924 & 0.916 & 0.925 & 0.902 \\ 1 & 0.848 & 0.807 & 0.862 & 0.800 & 0.752 & 0.800 & 0.814 \\ 1 & 0.967 & 0.910 & 0.902 & 0.854 & 0.860 & 0.876 & 0.841 \\ 1 & 0.955 & 0.895 & 0.857 & 0.790 & 0.823 & 0.821 & 0.793 \\ 1 & 1.00 & 1.32 & 0.939 & 0.911 & 1.02 & 0.988 & 0.959 \end{pmatrix}$$

$$B=C \bullet A=(1 \quad 0.998 \quad 0.995 \quad 0.971 \quad 0.970 \quad 0.963 \quad 0.962 \quad 0.962)$$

Make graphic with data after initialization, observe speed parameters and triple jump performance geometric shape, preliminarily judge its correlations, and parameters to performance correlation degrees. Respectively make relationship Figure when hopping, stepping and jumping, as following Figure 2, Figure 3, Figure 4.

By above three qualitative analysis curve graphs, it is clear that in hopping phase, by Figure 2, it is known that maximum correlation degree to performance is speed when landing, and minimum correlation degree is liftoff instantaneous vertical speed, by ordinary times' experience, we can know that triple jump step one mainly relies on horizontal speed to increase hopping distance that belongs to flat jumping, horizontal speed is larger.

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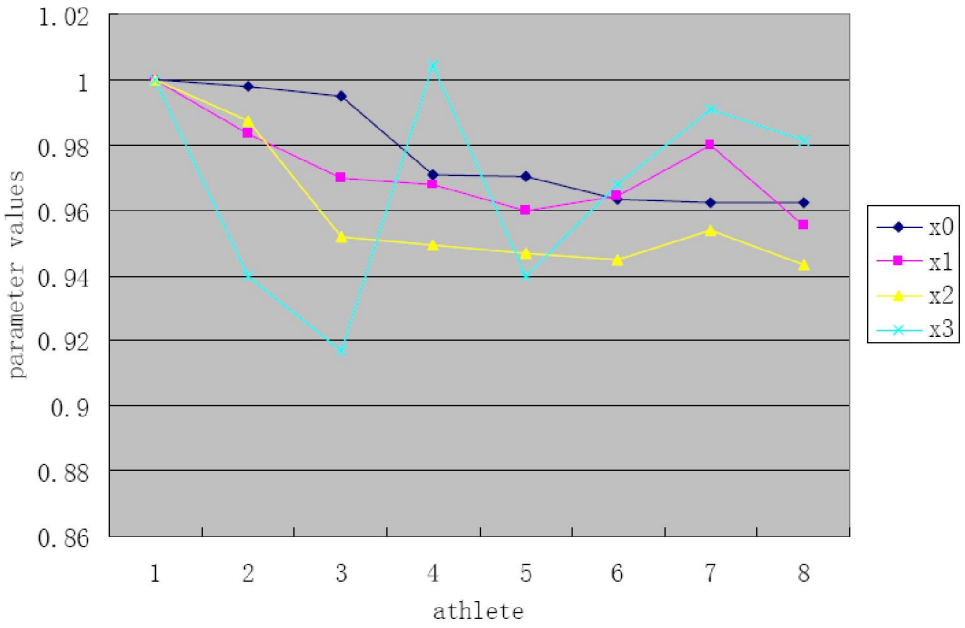

Figure 2 : Hop parameters and performance curve graph

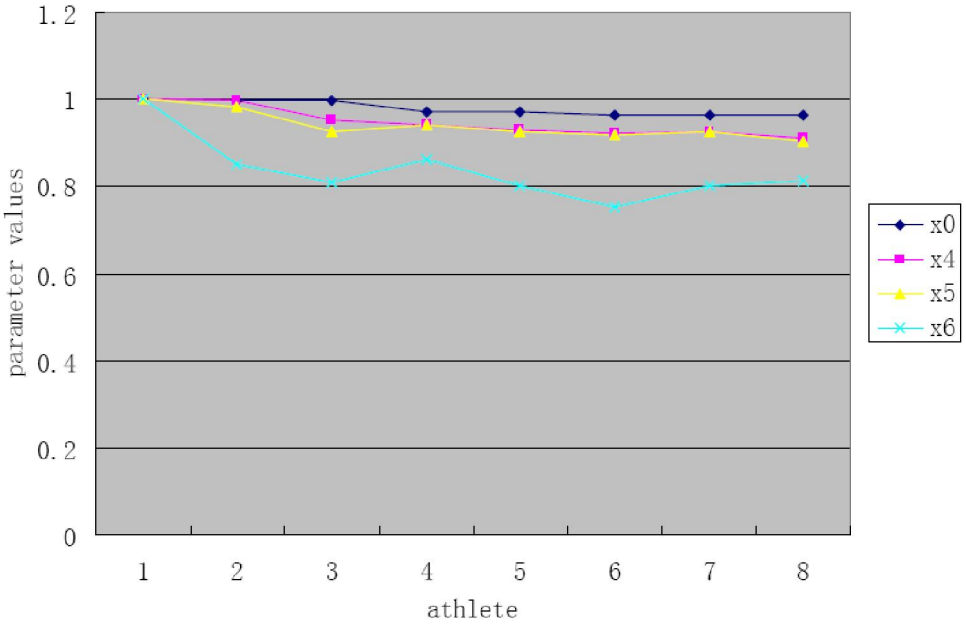

Figure 3 : Step parameters and performance curve graph

In stepping phase, by Figure 3, it is known that maximum correlation degree to performance is still landing speed, but liftoff speed and vertical speed correlation degrees to performance have improvements by comparing with hopping phase. It proves that stepping is still the landing speed takes the leading position in performance, meanwhile liftoff speed and vertical speed contribution rates to performance have been increased. In jumping phase, by Figure 4, it is known that maximum correlation degree to performance is vertical speed, the secondary is landing speed, the third is liftoff speed, due to hopping and stepping lose horizontal speed, let landing speed contribution rate to performance reduces; in case speed reduces, increase takeoff angle is effective method to improve jumping phase distance, which means increasing liftoff instantaneous vertical speed is the method to make up for speed insufficient. Therefore, final jumping phase liftoff instantaneous vertical speed becomes maximum correlation degree parameter. On a whole, landing speed is in re-

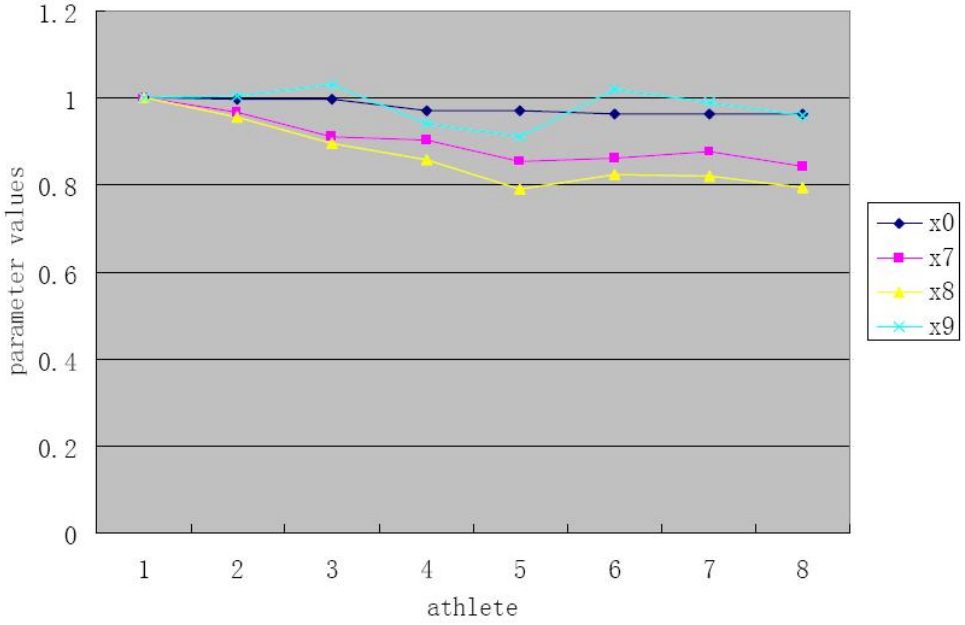

Figure 4 : Jump parameters and performance curve graph

duction trend in three phases' correlation degree, liftoff vertical speed correlation degree is in the rising trend. And liftoff speed correlation degree is in fluctuation state.

(2) Correlation coefficient solution method

Select reference sequence. In the paper, reference sequence is athlete long jump performance x_0. Other sequences are comparison sequences.

Reference sequence

$$x_0 = \{x_0(k) | k = 1,2,\cdots n\} = (x_0(1), x_0(2)\cdots x_0(n))$$

Among them, k represents athlete, assume it has m pieces of comparison sequence

$$x_i = \{x_i(k) | k = 1,2,\cdots n\} = (x_i(1), x_i(2)\cdots x_i(n)), i = 1,2,\cdots m$$

And then it calls

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

It is comparison sequence x_i to reference sequence long jump performance x_0 at t moment correlation coefficient, from which $\rho \in [0,1]$ is resolution coefficient. In above formula, $\min\limits_s \min\limits_t |x_0(t) - x_s(t)|$, $\max\limits_s \max\limits_t |x_0(t) - x_s(t)|$ are respectively two-level minimum difference and two-level maximum difference.

Generally speaking, the bigger resolution ratio is, then the bigger resolution coefficient ρ would be; the smaller resolution ratio is, and then the smaller ρ would be, here the calculation takes $\rho = 0.5$.

Correlation degree solution method

Correlation coefficient is a kind of indicator describing comparison sequence and reference sequence at some time correlation degree, due to each point has a correlation coefficient, therefore it is not convenient to compare, it gives correlation degree definition:

$$r_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i(k) \quad (2)$$

It is sequence x_i to reference sequence x_0 correlation degree. Correlation degree is concentrating each time correlation coefficient into a mean, which is also concentrating handling with excessive scattering information. Utilize correlation degree the concept, it can analyze and research on long jump performance influence factors.

The solution is to input initialized TABLE 3 data into formula (1), (2) and get each sequence correlation degree by calculating, similarly input TABLE 4 data into them to calculate.

Calculated MATLAB program is as following:

clc, clear

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TABLE 3 : Correlation degree value

	Hop			Step			Jump		
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
Correlation degree	0.29	0.56	0.07	0.58	0.36	0.13	0.39	0.30	0.58
Phase ranking	2	1	3	1	2	3	2	3	1
Total ranking	6	2	8	1	4	7	3	5	1

TABLE 4 : Parameters contribution rate table

Parameters	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
Contribution rate	0.089	0.172	0.021	0.178	0.110	0.04	0.120	0.092	0.178

```
load x.txt
for i=1:15
x(i, :)=x(i, :)/x(i, 1);
end
for i=16:17
x(i, :)=x(i, 1)./x(i, :);
end
data=x;
n=size(data, 1);
ck=data(1, :);m1=size(ck, 1);
bj=data(2:n, :);m2=size(bj, 1);
for i=1:m1
for j=1:m2
t(j, :)=bj(j, :)-ck(i, :);
end
jc1=min(min(abs(t')));jc2=max(max(abs(t')));
rho=0.5;
ksi=(jc1+rho*jc2)./(abs(t)+rho*jc2);
rt=sum(ksi')/size(ksi, 2);
r(i, :)=rt;
end
r
[rs, rind]=sort(r, 'descend')
```

Calculation result is as following TABLE 3:

Judge each factor contribution rate

Normalize respective correlation degree, let it can under unified scale, and further compare factors influence degrees. Solve factors to performance contribution rate, normalization that regard correlation degree adding sum:

$$R = \sum r_i$$

It regards as an entirety. Call any correlation degree and entirety ratio as contribution rate:

$$\eta_i = \frac{r_i}{R}$$

By calculation, it can get contribution rate Table 4 as following.

CONCLUSIONS

From TABLE 4, it is clear that in women triple jump, maximum contribution rate is stepping phase liftoff speed and jumping phase liftoff instantaneous vertical speed. The secondary is hopping phase liftoff speed. And triple jump has different speed allocation in different phases, reasonable allocation on triple jump speeds can beneficial to performance improvement. The detailed conclusion is: firstly it should increase horizontal speed to improve hopping distance which is an important path to improve triple jump. Strengthen legs explosive power training to improve jumping phase vertical speed or flight angle. Ensure horizontal speed smoothly reduces so as to provide landing speed for jumping phase, which can improve triple jump performance. In case that landing speed is very high, it should focus on increasing explosive power training.

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