Research of Mathematical Modeling about Maximal Oxygen Uptake (VO_2max) Speculation through 3000m Run

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***Abstract*—Nowadays, sports sector seldom mentions the method of speculating VO_2max by 3000m run. In this text, we gather VO_2max by Metabolic gas analyzer when conducting3000m run and Treadmill exercise, and conduct correlation analysis, difference detection according to relevant indexes. Then, we take VO_2max as dependent variable and subjects' relevant indexes measured in 3000m run which are of statistical significance as independent variables. Finally, we can get the optimal regression model through regression analysis step by step.**

Keywords-3000mrun;VO_2max;speculation;mathematical model。

I. INTRODUCTION

VO_2max is one of the important indexes that can evaluate one's heart and lung function level and aerobic capacity when enduring maximum load intensity. The methods of speculating VO_2max can be divided into direct measurement and indirect speculation, but the former takes much more time and effort. The purpose of this text is to speculate VO_2max indirectly with subjects' running time and other relevant indexes of 3000m run.

II. RESEARCH OBJECTS

In the research, we randomly selected 66 male students who are 18—22 years old as subjects, and got 53 effective samples in which 48 ones were used to build up the 3000m run VO_2max Speculation model and the other 5 were used for back substitution test. These students' basic information is showed in Table 1.

TABLE 1 SUBJECTS' BASIC INFORMATION（MEAN±SD）

	N	Age[year]	Height[cm]	Weight[kg]
Effective sample	53	21.1±1.71	173.0±4.99	66.9±8.07
Modeling group	48	21.2±1.72	173.1±5.02	67.1±8.32
Back substitution test group	5	20.4±1.60	172.7±5.31	65.4±5.63

III. RESEARCH METHOD

A. Basic morphological index

In the resting state, we utilized the test instruments to test the subjects' basic morphological indexes, such as HRrest, waistline, hipline, blood pressure, Vital Capacity (VC), etc. The concrete test results are showed in Table 2.

B. Direct test in the laboratory

Subjects should keep quiet when being tested in the laboratory. At the same time, temperature should be controlled from 21 to 23℃ and test time ought to be controlled from 8 to 15 minutes as well. Test instruments are Cortex MetaLyzer 3B solid Metabolic gas analyzer (Made in Germany) and TECHNOGYM electric treadmill (Made in Italy). Exercise program is classic Bruce program. The subjects' VO_2max, exercise duration time, RPE and other important indexes are showed in Table 3.

C. In-situ indirect test

After resting for 3—7 days, the same subjects will be tested in-situ by the means of 3000m run. The test instruments are Cortex MetaLyzer 3B portable Metabolic gas analyzer (Made in Germany). The subjects' VO_2peak, instant HRpeak, exercise time and other important indexes are showed in Table 4.

D. Mathematical statistics

We adopted excel for entering all the effective data and conducted statistical analysis by SPSS 16.0. All the computing results are showed in the form of Mean±SD and we conducted correlation analysis by Pearson correlation. Then,setting significance level $P \leq 0.05$, we utilized paired samples T-test to conduct effectiveness analysis.

IV. RESULTS AND ANALYSIS

A. Test results

1). Subjects' basic index information

TABLE 2 BASIC INDEX INFORMATION

Index	N	HRrest [time]	Waistline[cm]	Hipline[cm]	Systolic blood pressure [mmHg]	Diastolic blood pressure [mmHg]	VC[L]	BMI
Test value	53	76.0±15.84	88.9±5.96	76.4±6.44	118.6±11.87	70.6±9.43	4171.6±665.96	22.3±2.35

2) *Direct test VO_2max by treadmill in the laboratory and relevant index information*

TABLE 3 DIRECT TEST VO_2MAX BY TREADMILL AND RELEVANT INDEX INFORMATION(MEAN±SD)

Test index	N	Mean±SD
RPE	53	17.0±2.65
VO_2max [L/min]	53	3.5±0.37
Relative VO_2max Value [ml·kg^{-1}·min^{-1}]	53	52.9±6.07
Instant VEmax[L]	53	120.6±15.47
Instant HRmax [time /min]	53	189.2±10.77
Instant Stopped HR[time /min]	53	194.4±7.26
Instant AT VO_2 [L/min]	53	2.4±17.56
Instant AT VE [L]	53	59.2±7.26
Instant AT HR[time /min]	53	2.4±17.56
Treadmill time [s]	53	832.6±88.71

3). *In-situ indirect test VO_2max by 3000m run and relevant index information*

TABLE 4 INDIRECT TEST VO_2MAX BY 3000M RUN AND RELEVANT INDEX INFORMATION（MEAN±SD）

Test index	N	Mean±SD
VO_2peak[L/min]	53	3.7±0.48
Relative VO_2peak Value [ml·kg^{-1}·min^{-1}]	53	54.8±6.34
Instant VEpeak[L]	53	104.6±17.92
HRpeak[time/min]	53	185.1±13.53
Instant Stopped HRpeak[time/min]	53	194.9±10.56
3000m Instant AT VO_2 [L/min]	53	3.2±0.51
3000m Instant AT VE [L]	53	85.7±18.26
3000m Instant AT HR [time/min]	53	174.5±16.90
3000mTime[s]	53	816.2±81.39

B. Data analysis

Data analysis of the 48 subjects in the test model group is as follows:

1) Difference examination

TABLE 5 TEST RESULTS' COMPARISON BETWEEN TREADMILL AND 3000M RUN（MEAN±SD）

Corresponding Index	Treadmill	3000m	
VO_2max [L/min]	3.5±0.38	3.7±0.50	*
Relative VO_2max Value [ml·kg^{-1}·min^{-1}]	52.8±6.35	54.7±6.49	*
Instant VEmax [L]	120.6±15.67	105.2±17.69	*
Instant HRmax [time/min]	189.8±7.96	184.2±13.85	*
Instant Stopped HR [time/min]	194.1±7.28	194.8±11.01	
Time [s]	831.1±91.12	816.3±84.24	
Instant AT VO_2 [L/min]	2.4±0.49	3.2±0.53	*
Instant AT VE [L]	59.6±18.07	86.4±18.17	*
Instant AT HR [time/min]	149.4±31.99	174.2±17.67	*

Note: *P＜0.05,means that the difference is of significance.

2) Correlation analysis

TABLE 6 TEST RESULTS' CORRELATION BETWEEN TREADMILL AND 3000M RUN

Corresponding Index	Correlation coefficient
VO_2max / VO_2peak [L/min]	0.689**
Relative VO_2max Value/ Relative VO_2peak Value [ml·kg^{-1}·min^{-1}]	0.648**
Instant VEmax / Instant VEpeak [L]	0.539**
Instant HRmax / Instant HRpeak [time/min]	0.342*
Treadmill Instant stopped HR/ Instant 3000m stopped HR [time/min]	0.526**
Treadmill Time/3000m Time [s]	-0.688**
Treadmill Instant AT VO_2/3000m Instant AT VO_2 [L/min]	0.112
Treadmill Instant AT VE/3000m Instant AT VE [L]	-0.137
Treadmill Instant AT HR /3000m Instant AT HR [time/min]	0.194

Note: *P≤0.05 means that correlation is of significant level. *P≤0.01 means that correlation is of highly significant level.

TABLE 7 CORRELATION BETWEEN BASIC MORPHOLOGICAL INDEXES AND AEROBIC CAPACITY

	VO_2max	VO_2peak	Relative VO_2max Value	Relative VO_2peak Value	Treadmill Time	3000m Time
Height	0.469**	0.469**	-0.113	-0.010	-0.120	-0.011
Weight	0.451**	0.527**	-0.578**	-0.377**	-0.458**	0.415**
HR	0.043	0.108	-0.023	0.049	-0.130	0.084
BMI	0.261	0.347*	-0.609**	-0.436**	-0.466**	0.487**
Waistline	0.340*	0.464**	-0.516**	-0.306*	-0.404**	0.349*
Hipline	0.346*	0.433**	-0.531**	-0.349*	-0.443**	0.405**
SBP	0.118	0.302*	-0.384**	-0.151	-0.350*	0.356**
DBP	-0.018	0.147	-0.263	-0.089	-0.255	0.282*
VC	0.318*	0.146	-0.091	-0.195	0.061	-0.150

Note: *P≤0.05 means that correlation is of significance. *P≤0.01 means that correlation is of highly significance.

TABLE 8 CORRELATION MATRIX AMONG INDEXES

	He	Weight	Waistline	Hipline	VC	Step index	3000 Instan	3000	BMI	VO_2
HR	-	0.0	0.02	0.15	-0.3	-0.58	0.22	0.	0.	0.01
Height		0.4	0.19	0.26	0.	-0.15	0.38	-0.0	0.	0.45*
Weight			0.85	0.88	0.	-0.15	0.04	0.	0.	0.44*
Waistline				0.86	0.	0.03	-0.13	0.	0.	0.34*
Hipline					0.	-0.08	-0.10	0.	0.	0.34*
VC						0.22	0.32	-0.1	0.	0.34*
3000								-0.2	-0.1	0.18
3000Tim									0.	-0.47*

Note: *P≤0.05 means that correlation is of significance. *P≤0.01 means that correlation is of highly significance.

From Table 8 we can see that the indexes which have significant correlation with VO_2max are weight, waistline, hipline, VC and 3000time. It means that the indexes that can have a greater impact on VO_2max are weight, waistline, hipline, VC and exercise time. These indexes can be substituted into the regression equation as independent variables.

Weight, waistline, hipline, VC, 3000time and BMI respectively have correlation significance with other 5 more indexes and correlation coefficients are relatively high. It means that the above indexes have a greater impact on other indexes so that they can be substituted into the regression analysis as independent variables.

The above results showed that height, weight, waistline, hipline, VC, 3000time and BMI can be substituted into the regression analysis as independent variables.

V. MATHEMATICAL MODELING AND BACK SUBSTITUTION TEST

A. Mathematical modeling

We chose VO_2max as dependent variable, and height, weight, waistline, hipline, VC, 3000 time and BMI as independent variables to conduct stepwise analysis. Finally, in these indexes, weight and 3000time entered into the regression equation. The results of regression analysis are showed in Table 9 to Table 11.

TABLE 9 REGRESSION MODEL PARAMETERS

Model	R	R^2	Correct R^2	SEE
1	0.466[a]	0.217	0.200	0.334
2	0.829[b]	0.688	0.674	0.213

Note: "a" Predictors: [Constant]: 3000m time; "b" Predictors: [Constant]: 3000m time, weight; SEE: Std. Error of the Estimate

From Table 9, we can get a model in which VO_2max is the dependent variable, and 3000m time and weight are the independent variables. The multiple correlation coefficient of this model can reach over 0.83, which means the independent variables can explain the dependent variable to a large degree. The R^2 of the model also reached over 0.69, which means the regression model we build up has a highly fitting degree to the sample data. The model is meaningful to our speculation.

Analysis of variance is showed in Table 10. If $P<0.05$, it can be deemed that there exists linear relationship between the dependent variable VO_2max and the independent variables. Significant level reached.

TABLE 10 ANALYSIS OF VARIANCE

	F	Sig
2	48.517	0.000[b]

Note: "b" Predictors: [Constant]: 3000m time, weight

TABLE 11 REGRESSION EQUATION PARAMETERS OF VO_2MAX

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
（Constant）	4.062	0.334		12.150	0.000
3000 Time	-0.207	0.025	-0.783	-8.443	0.000
Weight	0.034	0.004	0.756	8.149	0.000

From Table 11 we can see that the regression parameters that correspond with the variables in the equation are under significant level 0.05, which means all the parameters have significance. Therefore, we can utilize the model as the method of speculating servicemen's VO_2max and the model is:

$$VO_2max=4.062-0.207\times3000time[min]+0.034\times weight[kg]$$

$$（R=0.83,R^2=0.69,SEE=0.213）$$

B. Back substitution test

After preliminary establishment of the modeling of 3000m run VO_2max speculation, we test the validity of the speculation equation with the samples in test group.

According to the model:

$$y(VO_2max)=4.062-0.207\times3000time[min]+0.034\times weight[kg]$$

We take the relevant parameters of the subjects in test group into the regression equation and compute the estimated value of VO_2max. The compared results between the estimated value and the actual value are showed in Table 12:

TABLE 12 VO_2MAX DIFFERENCE COMPARISON BETWEEN ESTIMATED VALUE AND ACTUAL VALUE

Estimated value[L/min]	Actual value[L/min]	r
3.5±0.15	3.5±0.23	0.721**

From Table 12, we can see that the estimated value is 0.05 lower than the actual value and P＞0.05. It means that the difference isn't of significance. Correlation parameter is 0.721, which showes high correlation.

The above results shows that there is no difference between the estimated value and actual value and the two are highly significant. It means that this equation is effective at the aspect of speculating VO_2max.

VI. CONCLUSION

Through the research, this text confirms that VO_2max speculation through 3000m run has relatively good validity and credibility. The optimal regression model is as follows:

$$VO_2max=4.062-0.207\times3000time\ [min]+0.034\times weight\ [kg]$$

（$R=0.83$, $R^2=0.69$, Correct $R^2=0.674$, SEE=0.213）

The exercise load of 3000m run approaches ultimate load and the process of test is simple. Testers can speculate the VO_2max relatively accurate, only needing to correctly record the subjects' running results and weight.

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