Statistical and Empirical Modeling of Relationship between Physical State and Exercise Observables of College Students Based on Measured Data

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Abstract. This paper statisticaly investigates the physical state and physical exercise observables, using the VIP method and the data measured in the physical exercise of the college students. The physical state observables include stature, avoirdupois, thigh circumference, calf girth, waistline, upper arm, circumference, and so on. The physical exercise observables include 100m race, standing long jump, shot put, deep squat, pull back, bench press and biceps curl. The VIP values of the observables are then analyzed to evaluate the importance of the individual physical exercise observables influencing the physical state observables, or the importance of the individual physical state observables influencing the physical exercise observables. The data for the male and female students are respectively analyzed to compare their difference. Finally, an empirical modeling is conducted to propose the relationship between a physical exercise index and the corresponding training time and training intensities of physical state or exercise observables. The obtained importance order of these observables and the proposed methods might be a useful reference for the instructor or trainer to instruct the students' physical exercise activities.

Introduction

It is well known that physical health/fitness and physical exercise have consequential relationship which have been studied by many researchers around the world in the past decades. Since the object of study is human being with the complicated factors and great variation in human physical exercise performance, the researches on this relationship are also considerable and extensive. Basically, the purpose for addressing an issue in physical exercise activities is basically to discover the certain intrinsic characteristics in the physical state and exercise of the people, and then applies them to serve for human physical health/fitness.

Hence, this study has tried a method to combine some functions of the statistical and empirical methods to mine out some unseen knowledge on the relationship, from the data measured in the practical physical exercise of college students. A relationship is established between an investigated physical exercise index and the relative physical state observables based on the statistical results of the measured data.

A Brief of the Observable's Data. An empirical modeling of a system is to orgeanize the knowledge on the system involving in state changes, agency and interaction with the model in an open exploratory manner and in an experimental way. In this tudy,

In order to obtain an empirical model which could be referred to the coming the physical exercise of students, the practical data were taken from the operation of the system. The data records the measured physical exercise and state values. A part of the data is shown in Tables 1 and 2.The data characteristcs embody in

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Table 1 Data of Students' Physical Exercise（male）

No	Age	Stature(cm)	Avoirdupois (kg)	Circumference(cm)	Waistline(cm)	Upper arm(cm)	Thigh circumference(cm)	Calf girth(cm)	Biceps Curl	Pull back	Bench press（kg）	Deep squat（kg）	100m race	Shot put（5kg）	Standing long jump	Exercise time(year)
1	21	183	75	87	78	30	54	39	11	150	60	140	12.4	11.5	2.7	1
2	20	175	68	90	71	31	53	37	41	200	20	100	12.8	11	2.5	1
3	20	177	85	97	93	35	60	42	30	180	20	90	12.5	11	2.5	2
…																

Table 2 Data of Students' Physical Exercise（female）

No	Age*	Stature(cm)	Avoirdupois(kg)	Circumference (cm)	Waistline(cm)	Hipline	Thigh circumference(cm)	Calf girth(cm)	Upper arm(cm)	100m race(sec)	Shot put（5kg）	Deep squat（kg）	Bench press(kg)	Sit-ups	Push-up	Standing long jump(m)	Biceps Curl (30LB/time)	Drop down (LB)	Lunge squat (min/times)	Exercise time (year)
1	21	164	53	90	65	100	51	36	25	13.8	7	70	25	47	20	2	20	50	3/130	1
2	22	166	60	91	71	102	55	39	28	14.12	9	80	30	42	20	2	60	100	3/120	3
3	21	164	43.5	85	60	90	50	34	23	14.5	7.4	50	30	35	30	2	30	60	3/110	1
…																				

Statistical Modeling of the Relationship between Physical Observables

VIP Method for Analyzing importance of Observables. In multi-variable regression analysis, the importance of variable in projection (called as the VIP method) is based on partial least squares regression. The VIP method reflects the interpreting ability of independent variable to dependent variable[14-15]. The formula definited by the VIP method is Eq. 1

$$VIP_j = \sqrt{\frac{k}{Rd(y;t_1,\cdots,t_m)}\sum_{h=1}^{m} Rd(y;t_h)\omega_{hj}^2} \tag{1}$$

where, ω_{hj} is the jth component of Axis $\boldsymbol{w_h}$, which is the measurement of the contribution of the independent variable $\boldsymbol{x_j}$ in the principle component $\boldsymbol{t_h}$. $Rd(y;t_h)$ and $Rd(y;t_1,t_2,\cdots,t_m)$ interpreted by $\boldsymbol{y}$ and $\boldsymbol{t_1}$, $\boldsymbol{t_2}$, …, $\boldsymbol{t_m}$ respectively are the precision of variation called as "determination coefficient", which respectively represents the ability to interpret $\boldsymbol{y}$ from $\boldsymbol{t_h}$ and $\boldsymbol{t_1}$, $\boldsymbol{t_2}$, …, $\boldsymbol{t_m}$. refer with: Eq. 2, Eq. 3.

$$Rd(y;t_h) = r^2(y,t_h) \tag{2}$$

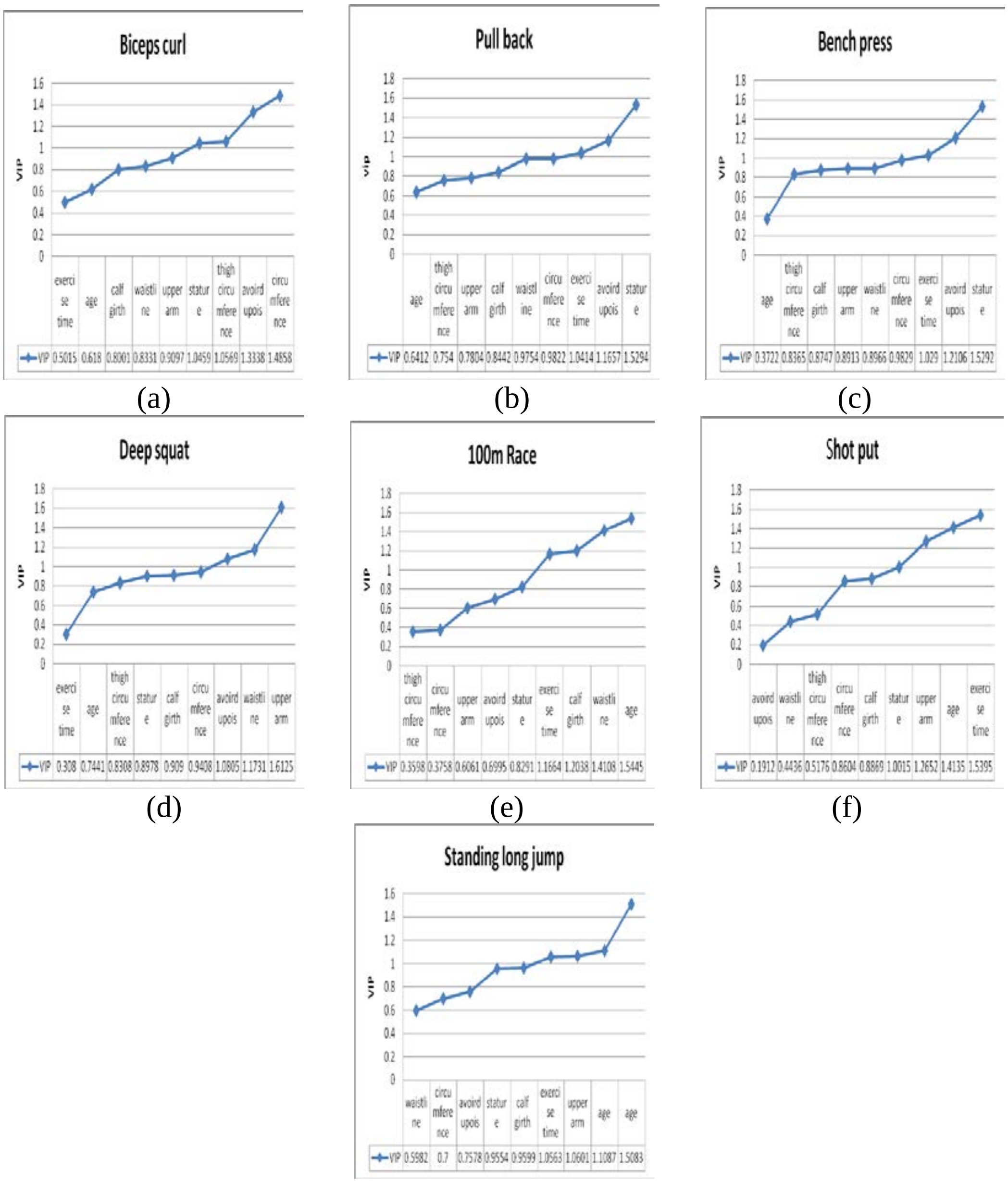
$$Rd(y;t_1,\cdots,t_m) = \sum_{h=1}^{m} Rd(y;t_h) \tag{3}$$

where, $r(y, t_h)$ is the correlation coefficient between the dependent variable $\boldsymbol{y}$ and the principal component $\boldsymbol{t_h}$.

The definition of VIP_j means that the ability for $\boldsymbol{x_j}$ to interpret $\boldsymbol{y}$ will be considered to be strong if $\boldsymbol{t_h}$ used to transfer the interpretation from $\boldsymbol{x_j}$ to $\boldsymbol{y}$ has a strong interpreting ability to $\boldsymbol{y}$ and $\boldsymbol{x_j}$ also plays an important role in constructing $\boldsymbol{t_h}$.

Statistical Modeling of the Relationship between Physical Observables. Based on the VIP method above, the following studies give out the importance indexes, VIP values, of the individual observables in Tables 1 and 2.

(1) The male student's physical exercise observables include 100m race, standing long jump, shot put, deep squat, pull back, bench press and biceps curl. The male student's physical state observables include calf girth, waistline, upper arm, stature, thigh circumference, avoirdupois, circumference, exercise time and age. It needs to point out that exercise time and age are listed in the physical state observables just for convenience. The curves plotted in Fig. 1 (a)-(g) show that the importance indexes, VIP values treated in order, of the male student's physical state observables correspond to the individual male student's physical exercise observables.



(a) (b) (c) (d) (e) (f) (g)

Fig. 1 The VIP curves of the male student's physical exercise observables

Similarly, the curves plotted in Fig. 2 (a)-(h) show that the importance indexes, VIP values treated in order, of the male student's physical exercise observables correspond to the male student's individual physical state observables.

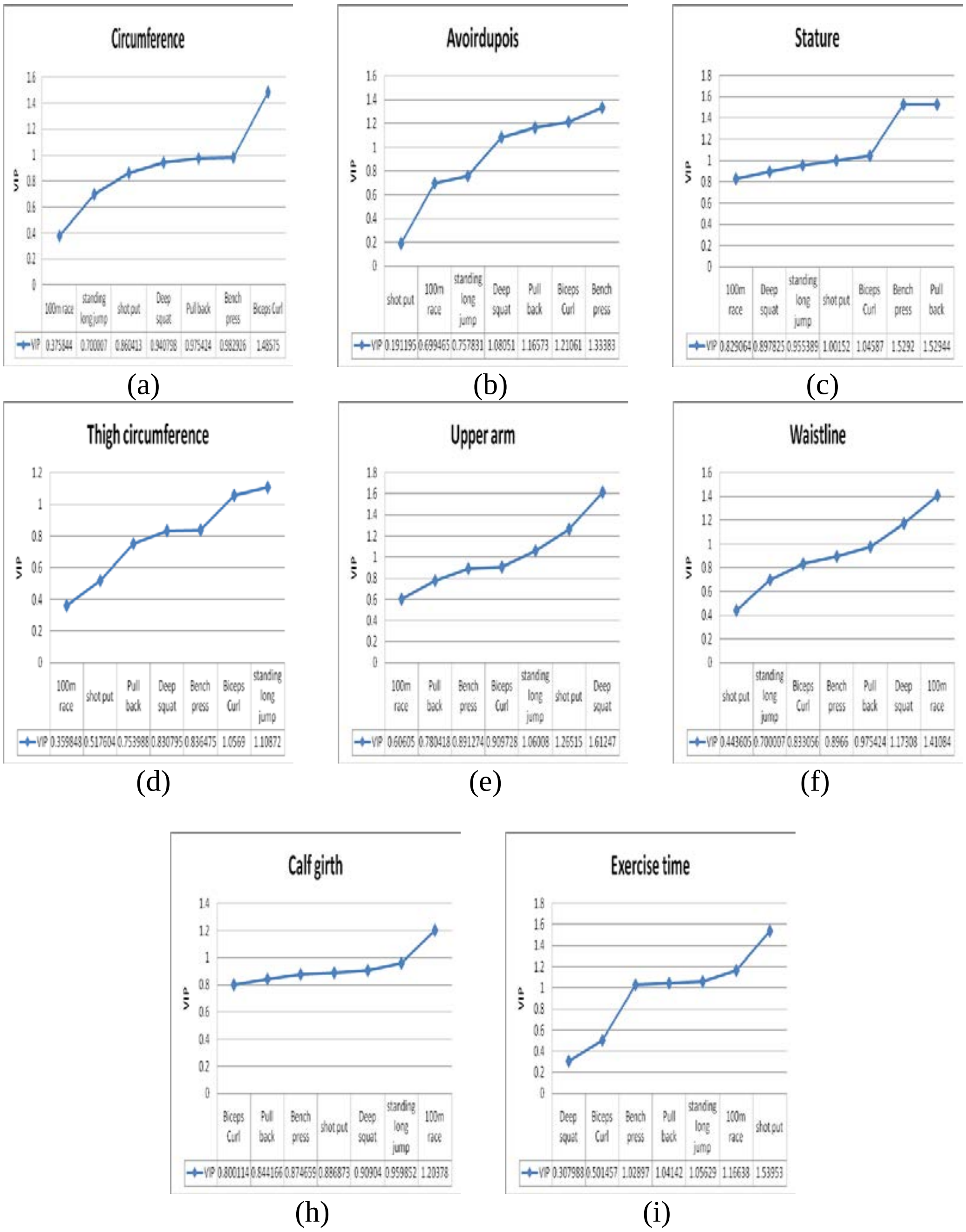
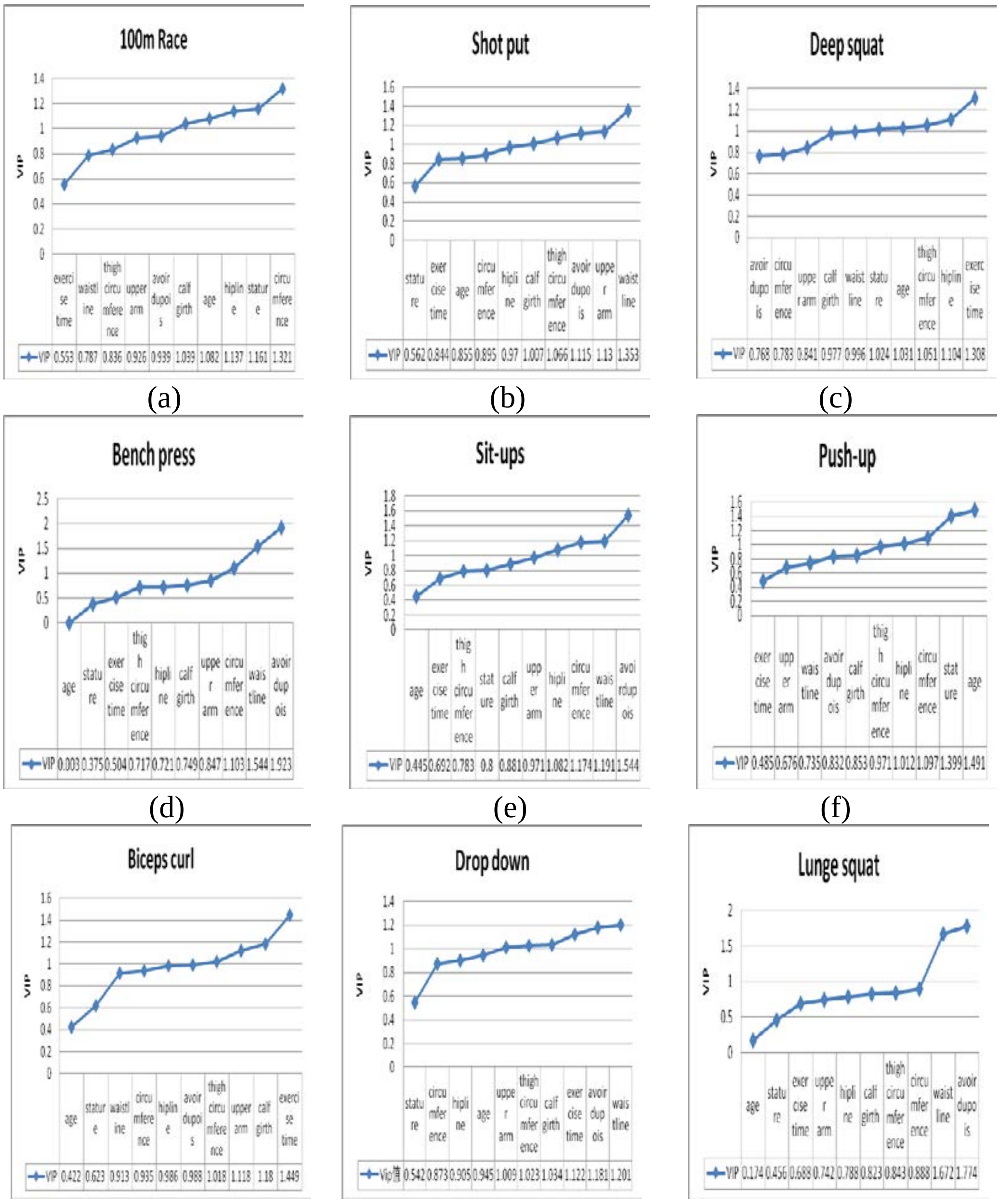


Fig. 2 The VIP curves of the male student's physical state observables

(2) The female student's physical exercise observables include 100m race, shot put, deep squat, set-ups, push up, draw down, bench press and biceps curl, lunge squat.The female student's physical state observables include exercise time, age, calf girth, waistline, hipline, upper arm, stature, thigh circumference, avoirdupois and circumference. The curves plotted in Fig. 3 (a)-(i) show that the importance indexes, VIP values treated in order, of the female student's physical state observables correspond to their individual physical exercise observables.



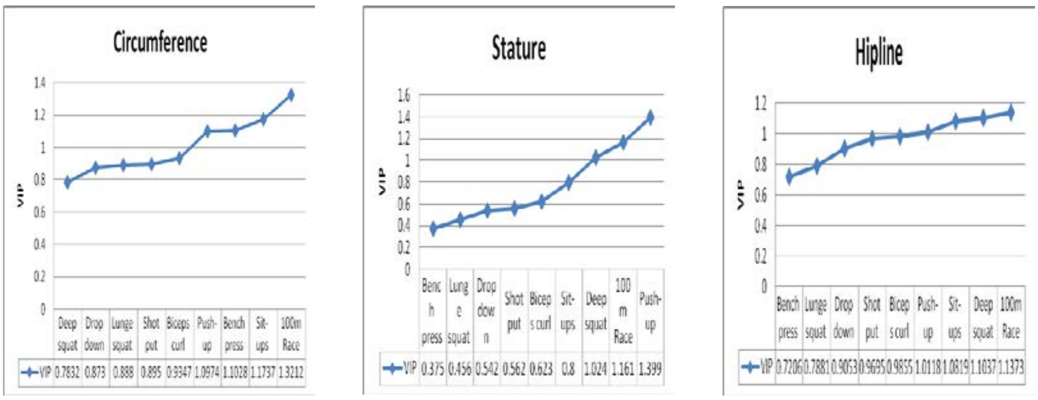
(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

Fig. 3 The VIP curves of the female student's physical exercise observables

Similarly, the curves plotted in Fig. 4 (a)-(j) show that the importance indexes, VIP values treated in order, of the femal student's physical exercise observables correspond to their individual physical state observables.



(a) (b) (c)

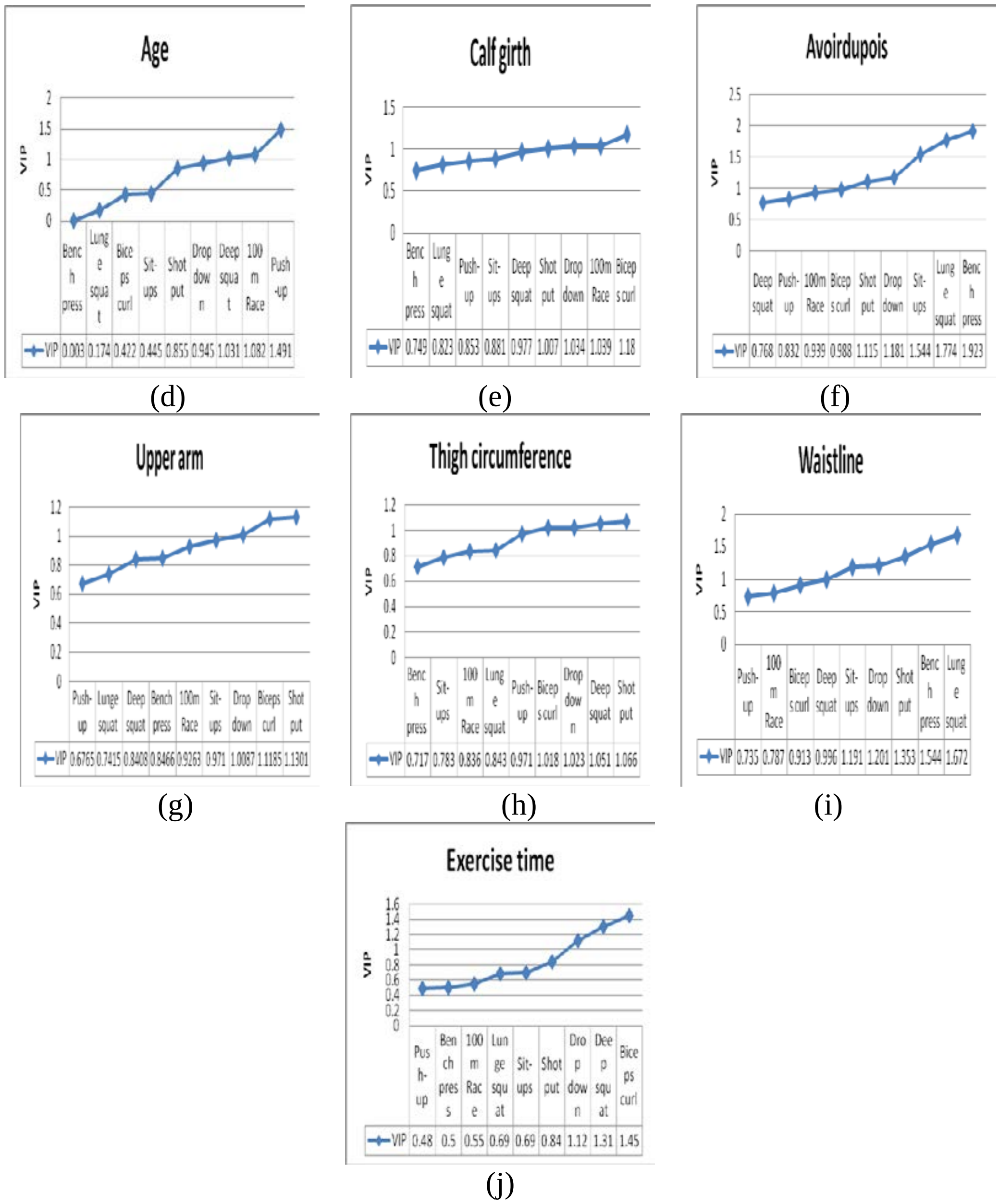


Fig. 4 The VIP curves of the female student's physical state observables

(3) The average VIP values of the male student' physical state and exercise observables are listed in Tables 3 and 4

Table 3 The average VIP values of the male student' physical state observables

Physical state observables (male students)	Average VIP
thigh circumference	0.780618571
circumference	0.903023143
waistline	0.918944571
avoirdupois	0.919881571
calf girth	0.925497714
exercise time	0.948862143
upper arm	1.017881429
stature	1.112615429

Table 4 The average VIP values of the male student' physical exercise observables

Physical Exercise observable (male students)	Average VIP
shot put	0.902157778
100m race	0.910636778
Deep squat	0.944069333
Biceps Curl	0.953855222
Bench press	0.958105444
standing long jump	0.967185778
Pull back	0.968212111

(4) The average VIP values of the female student' physical state and exercise are listed in Tables 5 and 6.

Table 5 The average VIP values of the female student' physical state observables

Physical state observables (female students)	Average VIP
exercise time	0.649892622
age	0.716465056
stature	0.771357889
upper arm	0.917763778
thigh circumference	0.922884444
calf girth	0.949174333
hipline	0.967091333
circumference	1.007654333
waistline	1.154670333
avoirdupois	1.229064

Table 6 The average VIP values of the female student' physical exercise observables

Physical Exercise observable (female students)	Average VIP
Bench press	0.84831805
Lunge squat	0.8846962
Push-up	0.9549591
Sit-ups	0.9563155
Biceps curl	0.9631713
100m Race	0.9781418
Shot put	0.979596
Drop down	0.9836256
Deep squat	0.9881834

Discussion on the VIP Values of Physical State and Exercise Observables.

- The distributions of the VIP values, obtaned by the statistical analysis using the VIP method, might quantitatively describe and sort the effects of the physical exercise observables on individual physical state observables, or the influence of the physical state observables on individual physical exercise observables, to a limited extent. These curves and VIP values could provide a reference to the instructor and trainer of students' physical exercise activities. Of course, a further verification is also needed by using more measured data and in the application of the VIP curves.

- There is the obvious difference between the orders of the VIP values, for the male and female physical state observables, from Tables 3 and 5. For the female students, the order of physical state observables is avoirdupois, waistline, circumference, and so on; for the male students, the order of physical state observables is stature, upper arm, exercise time, and so on. This difference might be right from an empirical impression.

Empirical Modeling of the Relationship between Physical Observables. An empirical modeling of the traning time and training intensity for a physical state or exercise observable is conducted based on the statistical modeling results of the VIP values/the VIP curves, as follows:

(1) Chose the physical state observables from Fig. 1 or 3, in order to improve the performance of a group of male or female students on a physical exercise observable.

(2) Distribute the physical exercise time values of the individual physical state observable in order, using Eq. 4

$$t_i = \eta_i T\ ,\quad (i = 1, 2, ..., N)$$
$$\eta_i = \frac{VIP_i}{\sum VIP_i} \tag{4}$$

where, t_i is the training time for the *i*th physical state or exercise observable; T is the total time for all the physical state or exercise observables. VIP_i is the VIP value for the *i*th physical state or exercise observable; η_i is called as the distribution coefficient.

(3) Distribute the training intensities of the individual physical state or exercise observables. Suppose

$$s_i = \eta_i S\ ,\ (i = 1, 2, ..., N) \tag{5}$$

where, s_i is the intensity processing the *i*th physical state or exercise observable; S is the total training intensity for all physical state or exercise observables.

（4）Determine the the number of playing the *i*th physical exercise observable. Suggest that the physical exercise intensity is replaced by the corresponding number processing the physical exercise observable, that is,

$$s_i = c_i\ n_i = \frac{VIP_i}{\sum VIP_i} S = \eta_i S,\ (i = 1, 2, ..., N) \tag{6}$$

where, n_i is the number processing the *i*th physical exercise observable; c_i is the physical exercise intensity coefficient of the *i*th physical exercise observable.

In this way, the number of playing the *i*th physical exercise observable is determined as

$$n_i = \frac{\eta_i S}{c_i},\ (i = 1, 2, ..., N) \tag{7}$$

Now, an example is given to show the application of the empirical modeling method above. The example states that an instructor/trainer plans to improve the physical performance of a group of male students on shop put. There are two training schemes,

The first training scheme is stated below.

- Chose the physical state observables in superiority order are upper arm, calf, chest, thigh and waist, from the curve in Fig. 1f. Also, the instructor should consider a little more physical exercise time, 30 hours in assumption.
- Chose the physical exercise observables in superiority, corresponding to the physical state observables chosen in the last step, from Fig. 2. Meanwhile, it can obtain the VIP values of the physical exercise observables chosen in this step. Then, calculate the distribution coefficients of the

training intensity, as listed in Table 7.

➢ Using Eqs. 4 and 5, distribute the training time and intensity, *t* and *s*, for each human body part, as listed in Table 7.

➢ Using Eq. 6, calculate the training number of each physical exercise observable.

Table 7 The relative parameter values in the first training scheme

The body parts relative to the shot put	Physical exercise observable	VIP value	c_i	Distribution coefficient η_i	Training Time (hour)	Training Intensity (TI)	Training Number
waist	100m race,…	1.41084	1	0.255225	7.65675	30.62703	30.62703
thigh	standing long jump,…	0.700007	0.31	0.126633	3.79899	15.19601	49.01938
chest	biceps curl ,…	0.833056	0.043	0.150702	4.52106	18.08428	420.5647
calf	100m race,…	1.41084	1	0.255225	7.65675	30.62703	30.62703
upper arm	deep squat,…??	1.17308	0.15	0.212214	6.36642	25.46565	169.771
Note			Just an example		Total training time 30 Just an example	Total training intensity 120 TIs Just an example	Just an example

The second training scheme is as follows.

➢ Chose the physical exercise observables in superiority order are upper arm, calf, chest, thigh and waist, from the curve in Fig. 1f. Also, the instructor should consider a little more physical exercise time, 30 hours in assumption.

➢ Using Eqs. 4 and 5, distribute the training time and intensity, *t* and *s*, for each human body part, as listed in Table 7.

Table 8 The relative parameter values in the second training scheme

Physical state observable	VIP value	Distribution Coefficient η_i	Training time(hour)	Training intensity (TI)
waist	0.443605	0.111637	3.349104	13.39644
thigh	0.517604	0.130259	3.907777	15.63108
chest	0.860413	0.21653	6.495897	25.9836
calf	0.886873	0.223189	6.695664	26.78268
upper arm	1.26515	0.318385	9.551558	38.2062
			Total training time 30 Just an example	Total training intensity 120 Just an example

The values of c_i in Table 7 are inaccurate because of just a simple and conceptual judgement. A relative accurate calculation of c_i value is introduced below.

Definition of the Physical Exercise Intensity Parameters c and S. The first training scheme involves in three parameters, the training intensity coefficient c_i of the *i*th physical exercise observable, the training intensity s_i processing the *i*th physical state or exercise observable and the total training intensity S for a physica exercise observable.

In this study, define the unit of the training intensity as TI. A TI unit equals to the energy expended by a male student in a 100m race. The male student has the average weight and velocity, among a group of male students. Then, the training intensity values of the other physical exercise observables can be obtained by Eq. 8

$$c_i = \frac{E_i}{e} \tag{8}$$

where, E_i is the energy expended by a male student in *i*th physical exercise observable.

Conclusion

(1)The data measured in the college students' physical exercise certainly implies much unseen knowledge, which needs the suitable method to mine out. Hence, the partial least squares regression method, VIP method, is adopted to sort the importance order of the physical state and exercise observables in view of the features shown in the measured data. The obtained VIP curves and tables quantitatively describe the importance difference between physical state and exercise observables to each other. The VIP curves lay a foundation of the proposed methods for instructing the physical training of the students.

(2)Training time and intensity are important for the instructor or trainer to instruct a scientific physical exercise to college students. The methods of calculating the training time and intensity are suggested based on the statistical results (VIP curves) of the measured data. But, it has to be stated that the methods are just as a refetrence to the instructor or trainer at present; in other words, the formula needs to be virified further.

(3)The analytical results embody the diffirence between the physical state observables of the male and female students, according to the importance order of the physical observables. For the male students, stature and upper arm are the most important; for the female students, avoirdupois and waistline are the most important. It seems that the natural physical condition of the students is the most important. It further explains why a sports instructor first investigates the natural physical condition of the athlete candidates in order to train an excellent athlete.

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