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New Regression Equations for Estimating the Maximal Oxygen Uptake of College of Physical Education and Sports Students in Turkey

Mehmet Fatih Akay[a] *, Cukurova University, Computer Engineering Department, Adana, Turkey
Fatih Abut[b], Cukurova University, Computer Engineering Department, Adana, Turkey
Kiymet Kaya[c], Cukurova University, Computer Engineering Department, Adana, Turkey
Ebru Cetin[d], Gazi University, School of Physical Education and Sport, Ankara, Turkey
Imdat Yarim[e], Gazi University, School of Physical Education and Sport, Ankara, Turkey

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Abstract

Aerobic endurance describes the ability of the body's cardio-respiratory system to perform physical activity for an extended period of time and resist fatigue. Standard tests to determine aerobic endurance involves measuring the maximum volume of oxygen (VO_2max) an athlete uses up while exercising at maximal capacity. Given that the tests of direct measurement of VO_2max needs expensive equipment, a great deal of time, and trained staff with expertise, many researchers have attempted to find indirect and simpler ways of predicting VO_2max based on prediction equations. The aim of this study is to establish new prediction equations for estimating the VO_2max from gender, age, height, weight, body mass index (BMİ), maximal heart rate (HRmax) and test time (TT) for college-aged students in Turkey. Particularly, 18 students from the College of Physical Education and Sports at Gazi University volunteered for this study. Gender has been used as a common predictor variable in all prediction models. By using different combinations of the rest of predictor variables together with the common predictor variable, twelve VO_2max prediction equations have been established with the help of Multiple Linear Regression (MLR). The performance of the prediction equations have been evaluated using two well-known metrics, namely standard error of estimate (*SEE*) and multiple correlation coefficient (*R*). The results reveal that the regression equation, VO_2max = - (12.331 x

* ADDRESS FOR CORRESPONDENCE: **Mehmet Fatih Akay***,* Cukurova University, Computer Engineering Department, Adana, Turkey
E-mail address: : mfakay@cu.edu.tr / Tel.: +90-322-3387101 - x16

gender) - (0.805 x age) + (0.883 x height) - (1.167 x weight) - (0.052 x HRmax) - (0.158 x TT) + 6.473, gave the lowest *SEE* (i.e. 3.49 mL.kg^{-1}.min^{-1}) and the highest *R* (i.e. 0.88). Application of this VO_2max regression equation on an independent validation group including 6 subjects yielded an *SEE* of 6.24 mL.kg^{-1}.min^{-1}.İt can be concluded that in situations where it is difficult or even not possible to measure VO_2max using exercise tests, coaches and trainers may use the given equation to predict VO_2max of College of Physical Education and Sports students with acceptable error rates.

Keywords: multiple linear regression; maximal oxygen uptake; cardio respiratory fitness

1. Introduction

Aerobic endurance describes the ability of the body's cardio-respiratory system to perform physical activity for an extended period of time and resist fatigue. Standard tests to determine aerobic endurance involves measuring the VO_2max. VO_2max deals with the maximal quantity of oxygen that an athlete can consume while exercising at maximal capacity (Davis, Carlstedt, Chen, Carmichael, & Murphy, 2010; Karahan, 2012). VO_2max can be described as a relative rate in milliliters of oxygen per kilogram of body mass per minute (mL.kg^{-1}.min^{-1}). The knowledge of VO_2max is used for many different aims in sport sciences. VO_2max is especially used as a sign of the endurance capacity of athletes (Liberato, Maple-Brown, Bressan & Hills, 2013).

During the maximal exercise test, measurement of VO_2max is known as the most proper technique for the evaluation of endurance capacity. Although the maximal exercise tests for measurement of VO_2maxareprobably the most accurate way, they come with many difficult requirements. For example, maximal exercise tests need expensive and elaborated laboratory equipment (such as gas analyzers) and a great deal of time. Also, trained staff is needed in order to carry out the VO_2max measurements and evaluate the test results (Chatterjee, Banerjee & Das, 2010; Karp, 2008).

Considering that the tests of direct measurement of VO_2max have some difficulties, many researchers have attempted to find indirect and simpler ways of predicting VO_2max based on prediction equations (Hunn, Lapuma & Holt, 2002; McComb, Jacalyn, Roh & Williams, 2006). The development of various techniques for estimating VO_2max depends on either maximal exercise tests, sub maximal exercise tests, non-exercise tests or a combination of these tests known as hybrid tests.

Maximal exercise tests (Bandyopadhyay, 2011; Machado & Denadai, 2013; Silva et al., 2012; Veronese da Costa et al., 2013). and sub maximal exercise tests (Billinger, Swearingen, McClain, Lentz, & Good, 2012; Tonis, Gorter, Vollenbroek-Hutten, & Hermens, 2012)are usually performed on a treadmill, ergometer or a track. Different protocols and exercise types are applied to participants. These exercises could be stepping, walking, jogging, running or cycle ergometry. Sub maximal exercise tests need lower time, cost and effort to be realized compared to maximal exercise tests. Sub maximal and maximal exercise tests use variables such as gender, age, height, weight, BMİ, TT and HR max to estimate VO_2max. Regarding non-exercise tests (Jang et al., 2012; Schembre & Riebe, 2011). they use non-exercise variables including physical activity rating and perceived functional ability questionnaires.

Although there exist several VO_2max regression equations in literature (Chatterjee, Banerjee, Das, & Debnath, 2010; Koutlianos et al., 2013; Schembre & Riebe, 2011; Veronese da Costa et al., 2013), they are not suitable for accurate prediction of the VO_2max of college-aged sports students in Turkey as the equations were developed on subjects that have different genetic properties and race than the ones in Turkey. The aim of this study is to establish new prediction equations for estimating the VO_2max of college-aged sports students in Turkey using maximal exercise test variables. 24 students from the College of Physical Education and Sports at Gazi University volunteered for this study. Maximal exercise test was applied on the subjects to assess their VO_2max. Utilizing the data of 18 subjects, severalVO_2maxregression equations have been developed with the help of MLR.VO_2max regression equations have been applied on an independent validation group including 6 subjects. The performance of the regression equations have been evaluated using *SEE* and *R*. The results show that MLR models can be used to predict VO_2max accurately for college-aged sports students in Turkey.

The content of the paper is structured as follows. Section 2 gives details of dataset generation. Section 3 presents results and discussion. Lastly, Section 4 concludes the paper.

2. Dataset Generation

In this study, subjects with different sport branches were chosen as volunteers among current students of College of Physical Education and Sportsat Gazi University. All subjects were informed prior to the maximal exercise test and they signed a consent participant form before participating in the tests.

Maximal exercise test was applied to subjects to obtain their VO_2max values. During the exercise test that was performed on a treadmill (HP COSMOS, Germany),a subject had been forced until he/she showed maximal performance. In other words, the test continued until the subject was exhausted.

During the maximal test using the maximal stepwise running exercise protocol, each subject's HR max was measured and registered every 15 seconds. The maximal oxygen consumption capacities of participants were measured with the Cosmed Quark CPET system (Cosmed Quark CPET; Rome, Italy) by breath-by-breath technique. In addition to HR max, tidal volume, VO_2maxand respiratory exchange ratio were also recorded every 15 seconds.VO_2maxtest protocol started with running at 0^o incline and at a speed of 8 km/h for women and at a speed of 10 km/h for men. Speed was incremented by 1km/h every minute until 15km/h speed level was reached. Upon reaching 15 km/h speed, the incline started to increase by 1.5^oeach minute and the test continued until the athlete got exhausted.

Table 1 shows the descriptive statistics of the dataset.

Table 1.Descriptive statistics of the dataset.

Predictor Variables	Sample		Validation Sample	
	Mean ± SD	Range	Mean ± SD	Range
Gender(M-0/F-1)	0.22 ± 0.43	0 – 1	0.20 ± 0.45	0 - 1
Age (year)	21.06 ± 1.92	18 – 24	20.20 ± 1.79	18 - 23
Height (cm)	175.17 ± 8.73	153 – 191	178.60 ± 8.96	169 - 193
Weight (kg)	67.22 ± 8.36	50 – 80	75.20 ± 11.84	63 - 95
BMİ ($kg.m^{-2}$)	21.81 ± 1.08	20 - 24.70	23.38 ± 1.33	22 - 25.50
HRmax (bpm)	191.11 ± 15.60	150 – 210	188.80 ± 8.44	182 - 198
TT (min/sec)	11.55 ± 1.53	9.45 - 15.09	11.34 ± 0.71	10.40 - 12.11

3. Results and Discussion

By using different combinations of the predictor variables, twelveVO_2max prediction models have been established with the help of MLR. The prediction models can be split in four categories. The first category includes gender, age and BMİ as common predictor variables. In the second category, height and weight are used instead of BMİ as common predictor variables. The third and fourth categories include the same predictor variables, except for age, as the ones in the first and second categories, respectively. The performance of the prediction models has been evaluated using *SEE* and *R,* the formulas of which are given in (1) and (2), respectively.

$$SEE = \sqrt{\frac{\sum(Y - Y')^2}{N}} \quad (1)$$

$$R = \sqrt{1 - \frac{\sum(Y - Y')^2}{\sum(Y - \overline{Y})^2}} \quad (2)$$

In (1) and (2), Y is the measured VO_2max, Y' is the predicted VO_2max, $\overline{Y}$ is the average of the measured values of VO_2max and N is the number of subjects in the dataset.

Table 2 shows the performance, in terms of *SEE* and *R,* of all VO_2max prediction models.

Table 2.*SEE* and *R* values of VO_2max prediction models.

MODELS		SAMPLE GROUP		VALİDATİON GROUP	
Model No	**Variables**	***SEE* ($mL.kg^{1}.min^{-1}$)**	***R***	***SEE* ($mL.kg^{1}.min^{-1}$)**	***R***
1	Gender, Age, BMI, HRmax	3.54	0.88	5.66	0.63
2	Gender, Age, BMI, TT	3.65	0.87	5.60	0.64
3	Gender, Age, BMI, HRmax, TT	3.54	0.88	5.63	0.64
4	Gender, Age, Height, Weight, HRmax	3.50	0.88	6.30	0.51
5	Gender, Age, Height, Weight, TT	3.58	0.87	6.18	0.54
6	Gender, Age, Height, Weight,HRmax, TT	3.49	0.88	6.24	0.52
7	Gender, BMI, HRmax	3.83	0.85	6.09	0.56
8	Gender, BMI, TT	3.98	0.84	6.15	0.54
9	Gender, BMI, HRmax,TT	3.81	0.86	6.16	0.54
10	Gender, Height, Weight, HRmax	3.73	0.86	6.74	0.39
11	Gender, Height, Weight, TT	3.85	0.85	6.76	0.38
12	Gender, Height,Weight,HRmax, TT	3.72	0.86	6.80	0.37

Figure 1 and Figure 2 show the average *SEE*'s of the prediction models in each category for the sample and validation groups, respectively.

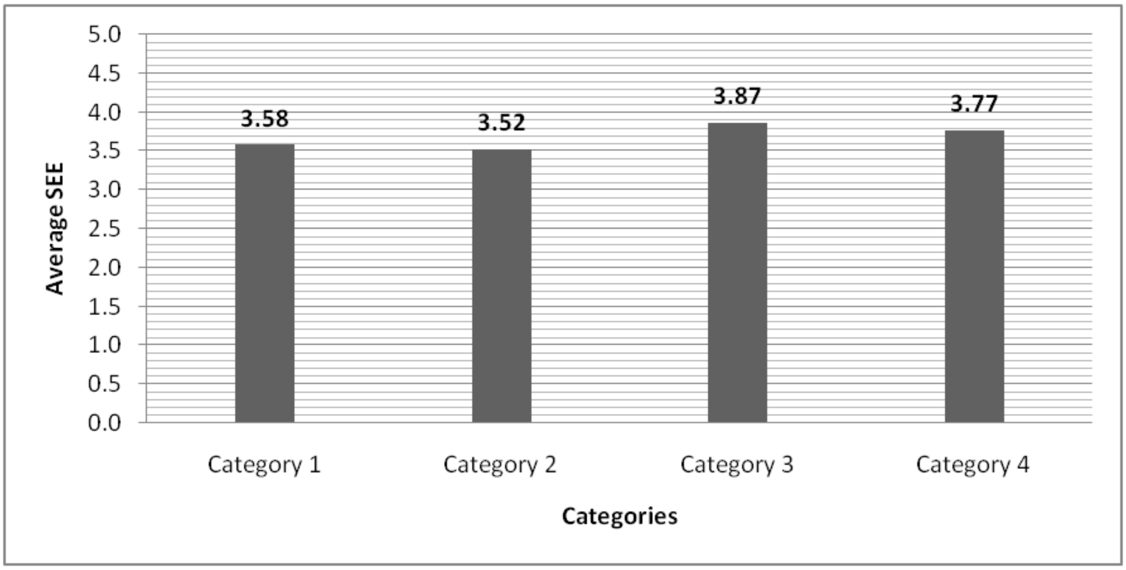

Figure1.Average *SEE*'s of the prediction models for the sample group.

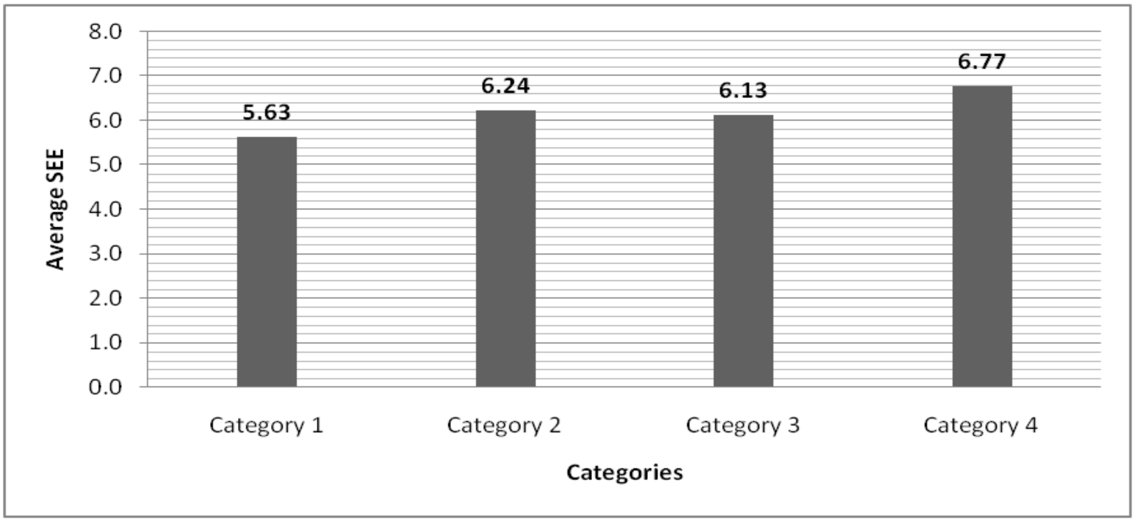

Figure 2.Average *SEE*'s of the prediction models for the validation group

The following discussions can be made regarding the results obtained:

1. The regression equation, VO_2max = 6.473 - (12.331 x gender) - (0.805 x age) + (0.883 x height) - (1.167 x weight) - (0.052 x HR max) - (0.158 x TT), yields the lowest *SEE*(i.e. 3.49 mL.kg^{-1}.min^{-1}) and the highest *R*(i.e. 0.88) for prediction of VO_2max.

2. VO_2max prediction models that include the predictor variable ''age'' (Models 1, 2, 3, 4, 5 and 6) yield on the average 7.6% lower *SEE*'s than the *SEE*'s of the prediction models without the predictor variable ''age''.

3. VO_2max prediction models that include the predictor variable" BMI " (Models 1, 2, 3, 7, 8 and9) give on the average 2.14% higher *SEE*'s than the *SEE*'s of the prediction models without the predictor variable ''BMİ''.

4. Comparing HR max and TT variables, the results show that HR max has a better effect on the performance of the VO_2max prediction models in each category. More specifically, the prediction models including only HR max give in average 3.17% lower *SEE*'s than the prediction models including only TT.

5. The prediction models including both HR max and TT give the lowest *SEE*'s in each category.

6. For the sample group, prediction models in the second category give the lowest *SEE*(i.e. 3.52mL.kg^{-1}.min^{-1}), whereas for the validation group, prediction models in the first category give the lowest *SEE*(i.e. 5.63mL.kg^{-1}.min^{-1}).

7. Application of the VO_2max prediction equations on an independent validation group yields considerable increment rates in *SEE*'s of the models because of the insufficient number of subjects in the sample group.

4. Conclusion

In this study, MLR has been utilized to develop various VO_2max prediction models for college-aged sports students in Turkey. Particularly, twelve different MLR models have been built by using the various combinations of the predictor variables gender, age, height, weight, BMİ, HR max and TT. The performance of the prediction models has been evaluated by computing the *SEE*'s and *R*'s. The results reveal that the most accurate VO_2max prediction model is the one including the predictor variables gender, age, height, weight, HR max and TT which gives an *SEE* of 3.49mL.kg^{-1}.$min^{-1}$and an*R* of 0.88, respectively. In contrast, the model which is made up of the triple of predictor variables including gender, BMİ and TT yields the highest *SEE* and the lowest *R* with 3.98mL.kg^{-1}.min^{-1} and 0.84, respectively. Also, it has been shown that the predictor variables age, height and weight play an important role in VO_2max prediction. Although additional research is required using a larger number of samples, the prediction equations developed in this study can be used to estimate VO_2max of college-aged sports students in Turkey within certain limits of error.

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