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Original Article

Indirect estimation of fitness level through assessing maximal oxygen uptake using the 1-mile and 2000-meter jogging protocols

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Abstract:
The evaluation of fitness levels play an important role and strongly associated with health, physical condition, motor activity, and quality of life. Fitness level indicators can be obtained by measuring maximum oxygen uptake (VO2max). The measurement of VO2max basically can be carried out directly or indirectly. 1-mile and 2000-meter jogging are generally used as one of the methods in determining VO2max. The research aims to develop a regression model to predict VO2max in 1-mile and 2000-meter jogging. Thirty-three male university students (age = 18,58 ± 0,58 y, weight = 57,92 ± 6,02, kg, height = 166,07 ± 5,30 cm, heart rate exercise = 192,48 ± 5,36 beat/minute) participated in this study. Each of them was actively performed physical activities 3-5 times per week. All participants performed both direct and indirect measurements separately with a 4 x24 hours gap after the first test. The indirect measurement of VO2max used 1-mile and 2000-meter, was exercised in two stages, while the direct measurement of VO2max applied Astrand protocol by jogging on treadmills for 7 minutes. The research found that indirect tests using the 1-mile and 2000-meter running protocols are strong predictors of predicting fitness through VO2max measurements and there is no difference witnessed between the calculation result of the formula of the indirect and direct test. The SEE of the two different measurement mentioned were 0,001 (ml.kg-1..min-1). Average discrepancy of standard deviation between VO2max and 1-mile and 2000-meter jogging was 0,8 (0,47 ml.kg-1..min-1) and 0,53 (-0,41 ml.kg-1..min-1). The formula of 1-mile and 2000-meter jogging, thus, can be used to predict VO2max accurately.
Keywords: VO_2max, prediction,indirect methods, running

Introduction

Individuals who are physically active have a better physical function and quality of life (Prasad, Fredrick, & Aruna, 2021)meanwhile individuals who have low physical activity will be very susceptible to the risk of disease (Kolokoltsev et al., 2021; Ma, Zhou, Xu, Ma, & Wang, 2020; Xu, Zhu, & Han, 2020). Therefore, it is very important to do physical activity regularly and programmed based on age because it can prevent various risk factors of cardiovascular disease and improve fitness(WHO, 2020). One of the indicators in measuring fitness status and as theparameter of health which directly has a positive effect on physical condition and motor activity (Apaychev et al., 2018; Fonseca del Pozo, Alonso, Álvarez, Orr, & Cantarero, 2017)can be done by measuring the maximum oxygen uptake (VO_2max) which is also the gold standard in determining fitness levelused both by the general public and athletes(Beltz et al., 2016; Peric & Nikolovoski, 2017; Ranković et al., 2010).

The measurement of VO_2max can be conducted directly or indirectly. Direct measurement of VO_2max is an accurate method to determine the maximal aerobic capacity(Åstrand & Rodahl, 1987). However, the direct test method is demanding for the general public since, apart from the expensive supporting device, the test calls for competent experts and can only be done for an individual at a time(Dolezal, Barr, Boland, Smith, & Cooper, 2015; Riebe, Ehrman, Liguori, & Magal, 2018). By contrast, the indirect measurement is more applicable because it can be performed in a measured field and with more than one individual(Chatterjee, Banerjee, & Das, 2011b).

Indirect measurement is prevalent among the general public and sports practitioners. This test is very easy to perform and does not require expensive equipment(Grant, Joseph, & Campagna, 1999). in addition, indirect measurement methods can predict exercise intensity (Martins, Coelho E Silva, Cumming, & Sardinha, 2012) and maximal oxygen uptake and various submaximal activity (A. Klusiewicz, Faff, & Starczewska-Czapowska, 2011; Lambrick, Faulkner, Rowlands, & Eston, 2009) and maximal activity(Andersen et al., 2008; A. Klusiewicz et al., 2011). Moreover, the indirect method is still useful for evaluating only amateur athletes but also professional athletes, especially during field tests or pre-selection which aims to estimate their physical

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capacity(A. Klusiewicz et al., 2016). For example, Rockport's 1-mile test is a famous indirect test among the general public. Initially, this indirect measurement was performed by walking and mostly formulated for a population aged 30-40 years(Byars, Greenwood, Greenwood, & Simpson, 2003; Chatterjee, Banerjee, & Das, 2011a; Chaturvedi, Kulandaivelan, & Yadav, 2018). Subsequently, this test is developed to 1-mile jogging for university students with a population aged 22-24 years(George, Vehrs, Allsen, Fellingham, & Fisher, 1992)and other researchers also prove this test has high accuracy (Batista, Romanzini, Castro-Piñero, & Ronque, 2017; Trinh & Matthews, Travis, 2019).Therefore, this present research aims to obtain new formula in the indirect assessment of fitness status through measuring VO_2maxusing 1-mile jogging and develop the measurement of VO_2max on 2000-meter jogging in the population aged 18-19 years.

Material andMethods

Participants

Thirty-three male university students aged 18-19 years involved in this research. Each of them was actively performed physical activities 3-5 times per week. The participant was given a briefing regarding the research conducted, and they were obliged to fill out informed consent and have meal 2-3 hours before the research started. The estimated VO_2max was measured directly and indirectly.

All participants performed both tests separately with a 4x24 hours gap after the first test. During the physical test, all participants were monitored using a pulse meter.

Procedure

Indirect measurement of VO_2maxin 1-mile and 2000-meter jogging

1-mile and 2000-meter jogging were divided into two stages. In the first week, the participants jogged for one mile and on the second week, for 2000-meter. Before running for 1-mile and 2000-meter, the subjects warmed up for 5 minutes. While jogging, the participants were equipped with a polar heart rate to monitor their heart rate. All participants ran with submaximal to maximal intensity. Training heart rate below 180 beats per minute would be automatically excluded from the research.

Direct measurement of VO_2max

Thirty-three participants conducted a direct test of VO_2max on a treadmill with COSMED pulmonary function type for 7 minutes in proportion to Astrand protocol. The pre-performance heart rate should be around 60-70 beats per minute. before the test, they are warmed up for 10 minutes. The treadmill sets up with a speed of 8,05 km/hr (5 mph) and an incline of 0%. After 3 minutes into the test, adjusts the treadmill incline to 2.5%, and then every 2 minutes after those increases the incline by 2.5%. the treadmill will be stops records the time when the athlete is unable to continue.

Statistical analysis

All data obtained in this study were analyzed usingSPSS version 23. Descriptive data on the characteristic of the subjectare presented as mean±standard deviation (SD). Linear regression analysis used to estimate the relationship between the test and the probability of VO_2max prediction, and the Bland and Altman test was used to compare the measurement techniques. The standard of estimate (SEE) to denote random error in testing with a significance level of 95%.

Results

The characteristics of the research subjects consisting of age, weight, height, heart rate exercise, and VO_2maxare presented in table 1.

Table 1. The characteristic of the subject

The characteristic of the subject	n = 33	
	Mean ± SD	Min-Max
Age (year)	18,58 ± 0,58	18,05 – 19,11
Weight (kg)	57,92 ± 6,02	49 – 75
Height (cm)	166,07 ± 5,30	157 - 180
Heart rate exercise (beat/minute)	192,48 ± 5,36	181 - 204
VO_2max 1-mile predict ($ml.kg^{-1}.min^{-1}$)	54,97 ± 1,61	50,85 – 57,40
VO_2max 1-mile George($ml.kg^{-1}.min^{-1}$)	53,29 ± 1,34	50,48 – 55,55
VO_2max 2000-meter Predict ($ml.kg^{-1}.min^{-1}$)	55,85 ± 1,87	51,31 – 59,83
VO_2max Astrands ($ml.kg^{-1}.min^{-1}$)	55,44 ± 2,4	51,22 – 59,85

n – sample size, SD – Standar Deviation

Table 2, on the other hand, shows the result of the linear regression by using the stepwise method. The calculation demonstrated that age and height had no significant impact on the prediction of VO_2max. Only body weight, time, and training heart rate contributed to the formulation of the regression equation for predicting VO_2max.

Tabel 2. Regression equations VO_2max from 1-mile and 2000-meter protocol

Model	Relative VO_2max 1 mile ($ml.kg^{-1.}.min^{-1}$)	Relative VO_2max 2000 meters ($ml.kg^{-1.}.min^{-1}$)
Constant	108,822	108,824
Bodyweight	-0,164	-0,1636
Heart rate Exercise	-.0,1828	-0,1628
Time	-1,44	-1,438
Adjusted R Square	1	1
SEE	0,001	0,001

SEE – Standard Error of the Estimate

Based on the linear regression analysis in table 2, the VO_2maxequation yielded the following prediction equation:
VO_2max ($ml.kg^{-1.}.min^{-1}$) 1-mile jogging = 108,822 – 0,164 x bodyweight (Kg) – 1,44 x time (minute) – 0,1828 x heart rate exercise (beat/minute)

and

VO_2max ($ml.kg^{-1.}.min^{-1}$) 2000-meter jogging = 108,824 – 0,164 x bodyweight (Kg) – 1,438 x time (minute) – 0,1628 x heart rate exercise(beat/minute)

The result of the equation towards one mile and 2000-meter jogging had a very low standard error of the estimate, namely 0,001 ($ml.kg^{-1.}.min^{-1}$). Thus, it can be said that the equation found is valid in predicting VO_2max.As shown in Table 1, the average discrepancy of the calculation result between VO_2max prediction and VO_2maxAstrand in 1-mile jogging was 0,47 ($ml.kg^{-1}.min^{-1}$), with the difference in standard deviation accounted for 0,8. On the other hand, in 2000-meter jogging, it was -0,41 ($ml.kg^{-1.}.min^{-1}$), with the difference in standard deviation accounted for 0,52.

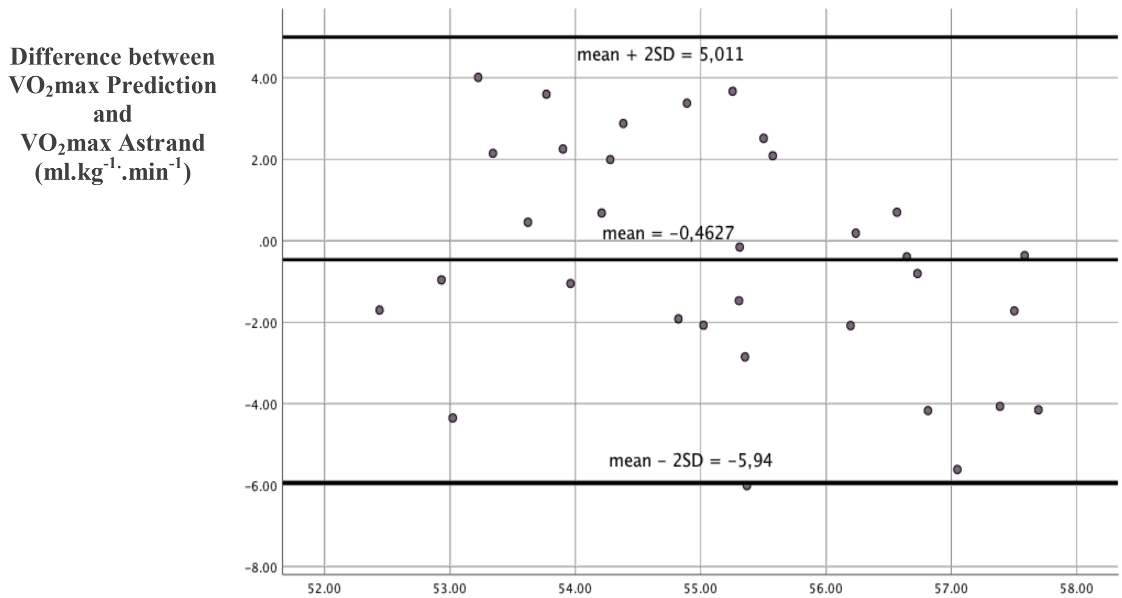

Figure 1. Difference between theVO_2maxvalues obtained from 1-mile prediction and jogging in treadmill Astrand data plotted against their means

Figure 1. shows that the limit of agreement between VO_2maxprediction and VO_2maxAstrand shows the calculation result of the prediction and linear Astrand because the plod lies in the lower limit and upper limit, namely -5,94 and 5,011. Then, Figure 2. showed that in the limit of agreement between VO_2maxprediction and VO_2maxAstrand shows the calculation result of the prediction and linear Astrand because the plod lies in the lower limit and upper limit, namely -5,358 and 6,188.

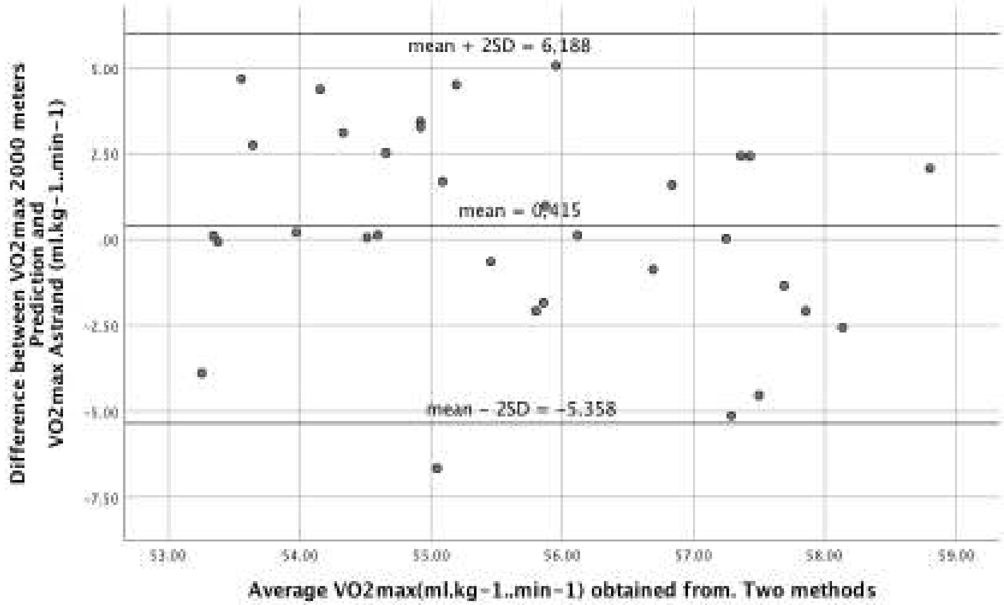

Figure 2. Difference between VO_2max 2000-meter prediction and VO_2max Astrand

Discussion

Direct measurement of VO_2max provides accurate results in describing Vo2max flow. However, this test cannot be done under certain conditions, namely unsupported equipment and a large number of participants(Kour Buttar, Saboo, & Kacker, 2019).Indirect measurement of fitness level by assessing VO2max can be a solution, especially for large populations(Przednowek et al., 2018).The research found that 1-mile and 2000-meter jogging had a similar result to regression statistics. Both methods were accurate in predicting VO_2max. Compared to treadmill jogging with Astrand protocol, those two methods had a slight difference, namely less than 0,47 (ml.kg^{-1}.min^{-1}) for 1-mile jogging and more than 0,41 (ml.kg^{-1}.min^{-1}) for 2000-meter jogging. This result is consistent with the SEE test, which only yielded a value of 0,001 with a strong adjusted R.

1-mile and 2000-meter jogging tests were conducted to show contrast with Kline's measurement in 1987, which was performed by walking. This is the reason for which Kline measurement is suitable for a population above 30 years for minimizing injuries. Furthermore, the two protocols of the present research corroborate the result of 1-mile estimation measurement by(George et al., 1992) that also yielded the protocol of estimation measurement of VO_2maxin 1-mile jogging. The new protocols investigated in this research have a standard deviation that is similar to the VO_2maxmeasurement of the Astrand treadmill, namely 1,61 (1-mile prediction), 1,34 (1-mile George, 1,87 (2000-meter), and 2,4 (Astrand treadmill).

What is surprising is that the formula produced is similar to the formula researched by George 1992, although George used a sample with a population aged between 22 and 24 years. The similarity is in the variable of bodyweight, training heart rate, and traveling time in 1-mile jogging and 2000-meter. The difference in the three variables mentioned is merely in the constants. George accounted for 108,844; 1-mile accounted for 108,822, and 2000-meter accounted for 108,824. Furthermore, the gap was less than 1 (ml.kg^{-1}.min^{-1}) of the VO_2maxof the Astrand method.

The contribution of bod weight, training heart rate, and traveling time in affecting VO_{2max} in 1-mile jogging was 45%, 30%, and 24%, respectively, with r = -0,732, r = -0,488 dan r = -0,633, in turn. On the other hand, in 2000-meter jogging, bodyweight, training heart rate, and traveling time contributed to affect the result of the measurement of VO_2max at 36%, 42%, and 22%, respectively, and with r = -0,685, r = -0,716, r = -0,672, in turn. This result follows the research of (León-Ariza, Botero-Rosas, & Zea-Robles, 2017; Loe, Rognmo, Saltin, & Wisløff, 2013; A. M. Rexhepi & Brestovci, 2014)that demonstrated the correlation between bodyweight and training heart rate in VO_2maxfulfilment. This present research showed that bodyweight and training heart rate had a significant proportion, compared to jogging traveling time, in determining the estimated VO_2max.

The use of indirect measurement has given a new phenomenon to the fitness measurement pattern with such a large population. This measurement uses an indicator of bodyweight(A. M. Rexhepi & Brestovci, 2014), exercise pulse(Habibi, Dehghan, Moghiseh, & Hasanzadeh, 2014; León-Ariza et al., 2017; Mohammed, Zohar, Gourar, Ali, & Idriss, 2018)and the achievement of running time duration in predicting fitness. The inclusion of pulse indicators in indirect measurements is in line with the many studies that show that pulse is an indicator in determining the performance of biathlon, gymnastic and soccer athletes(Barbero Álvarez, 2008; Fernández-Villarino, Hernaiz-Sánchez, Sierra-Palmeiro, & Bobo-Arce, 2018; Høydal & Nord, 2017; A. Rexhepi, 2017).In addition, this fitness measurement is also carried out in the military world to predict the performance of military members (Stocker & Leo, 2020).Besides, the heart rate is also used as an indicator of young people's health(Nealen, 2016). Measurement indirectly predicting VO_2max in both protocols became accurate because it involved physiological indicators in determining the measurement of VO_2max.

Conclusion

The findings of this study reveal that indirect test using the 1-mile and 2000-meter running protocols are strong predictors of predicting fitness through VO_2max measurements. Both protocols also have a lower SEE when compared to the Astrand test. This study also proves that there are no more obstacles in evaluating and monitoring VO_2max with a large population because this study indirectly provides the same strong accuracy as direct VO2max measurement. In addition, the results of this study also confirm that physiological and anatomical factors also have a strong influence on the achievement of the final test results. The lower the value of bodyweight, exercise heart rate and the travel time will give a positive value on the VO_2max assessment. Further research is encouraged to develop and examine a precise and accurate regression model for children in measuring VO2max.

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