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Model Prediction Maximum Oxygen Intake (VO_2max) Using the Bleep Test in Male Junior Athletes

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ABSTRACT

The bleep test has long been used to predict maximal oxygen uptake (VO_2max) in Indonesian athletes. However, the results of these examinations are not as good as the results reported abroad. This research was conducted to obtain a correction formula that can provide results closer to the gold standard VO_2max examination results. This cross-sectional study recruited 190 subjects. Twelve subjects were excluded because they did not follow the whole study. All subjects underwent a physical examination: vital signs, posture, leg length, and laboratory tests: treadmill test, pre-post treadmill lactic acid, spirometry, a maximum pulse, and field examinations: Bleep test, temperature, room humidity. The data obtained were analyzed according to the proper method using SPSS. The results of the analysis obtained a new predictive modeling formula, namely the Ruli formula: VO_2max = 49.795 + 0.238 (Total Shuttle) + (-0.173) (BW) + (-0.086) (HRmax Field) + 0.229 (Field Temp). Internal validity and reliability tests using Bland-Altman show that this formula is quite good and can be used. However, an external validity test is still needed before this formula can be widely used in male junior athletes.

Keywords: Bleep test, junior athletes, men, oxygen consumption, prediction, VO_2max

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INTRODUCTION

Maximum oxygen consumption, commonly referred to as maximal oxygen consumption, maximal oxygen uptake, peak oxygen uptake, or maximal aerobic capacity (VO_2max), defined the ability to transport and use oxygen during maximum muscle work.[1] Long known and used approximately half a century ago, VO_2max is closely related to the cardiovascular system's durability. The value of VO_2max depends on the ability to transport oxygen by the blood vessels and the cell's ability to take the oxygen delivered and use this oxygen to produce the energy the body needs. VO_2max measurement is usually done by direct or indirect means in the laboratory. Measurements can also be done indirectly in the field.[2]

Field tests are alternative ways of measuring VO_2max in athletes, including the harvard step test, cooper test, balke test, and bleep test.[2] Among the several field tests mentioned, the VO_2max testing method that is easy to use and has a reasonably high validity value is the bleep test.[3] Besides being able to do with simple means and equipment, the bleep test's advantage is that many subjects can do it and be carried out simultaneously. It is necessary to pay attention to several factors: weight, age, gender, genetics, body mass index, type of exercise, highest heart rate, hemoglobin, lactate, temperature and humidity, total shuttle, and pulmonary function.[4–7]

Aerobic capacity peaked at 16–19 years of age, followed by a gradual decline. This decrease in aerobic capacity is partly due to decreased heart function. Astrand argues that reducing aerobic capacity is due to a reduction of the maximum heart rate, reduced stroke volume, and a decrease in the maximum difference in arterial-venous oxygen.[8] In trained people, the aerobic capacity reduction is mainly due to lower heart rate and stroke volume. Breeding of Indonesian athletes' achievements to go to world achievement events such as the Olympics is needed, including the cardiorespiratory endurance component. At the athlete's age in the nursery, VO_2max measurement is still essential because that age is the right time to increase cardiorespiratory capacity. [9]

Bleep tests are repeatedly conducted, especially in junior athletes, to assess the exercise's progress according to the exercise's periodization, so the bleep test's validity is fundamental. The formula used to assess bleep test results is VO_2max = 18.043461 + (0.3689295 x TS) + (- 0.000349 x TS x TS). TS is the total number of shuttles.[10] The formula only enters the total number of shuttles, whereas according to Tim Noakes[11], many other factors affect VO_2max levels, such as age, sex, physical exercise, altitude, and respiratory muscles. [11–14]

While measuring the maximum oxygen intake level (VO_2max) using the bleep test on junior athletes' population in Indonesia, problems are found. The bleep test formula used today uses a formula originating from Europe.[15] When used in the population of junior athletes in Indonesia, it will cause the VO_2max value to decrease. Trainers who know that the VO_2max score of junior athletes is low will develop an unproper training program to achieve a predetermined VO_2max value to become a champion. The training program designed by the trainer could be too severe and may cause sports injuries.

This study aims to obtain the bleep test correction formula that can be applied to male junior athletes. The procedure is made based on physical characteristics and the Western environment. Indonesians' biological and environmental factors are different, so the formula is not appropriately used in Indonesia's male junior athletes.

MATERIALS AND METHODS

Ethical Clearance

The study protocol was approved by the Institutional Review Board (IRB) committees of FKUI-RSCM Research Ethical Committee, Universitas Indonesia, with protocol number 18-11-1288.

Study Design

This study aims to obtain a modified formula bleep test to measure the maximum oxygen intake in junior athletes. The design used is a cross-sectional study that seeks to assess the difference between the predicted value of maximum oxygen intake (VO_2max) based on laboratory tests to

evaluate the expected value of VO_2max based on the bleep test. The two variables will be tested for correlation between age, height, weight, body mass index, highest heart rate, field temperature, field humidity, Hb levels, lactic acid, FVC, and FEV_1 against the predicted value of the treadmill test. The research was conducted in the Laboratory of the Somatokinetika State University of Jakarta and the respective Schools of the research subjects. The study was conducted from February 2019 to March 2020.

Setting and Participants

The target population was junior athletes 16 to 19 years of age derived from High Schools and Universities in Jakarta who were active in sports such as soccer, futsal, basketball, volleyball, and athletics located in Jakarta. The affordable population is junior athletes active in the championship's student leagues and students in the soccer branch, futsal, basketball, volleyball, and athletics. Sample selection is an affordable population that meets the acceptance criteria by using purposive sampling. It will then be stratified based on age group into four groups: age group 16 years, 17 years, 18 years, and 19 years. Furthermore, each age group will be stratified into five sports groups: soccer, futsal, basketball, volleyball, and athletics.

Inclusion and Exclusion Criteria

Inclusion criteria were male junior athletes trained in sports, namely soccer, futsal, basketball, volleyball, athletics (routinely doing exercises), and healthy subjects. Subjects aged 16–19 years. Subjects were willing to follow the research and signed informed consent. Exclusion criteria were the subject resigned, did not complete the research stage, and the subject has musculoskeletal disorders of the lower limbs.

Data Collection

Researchers and research assistants carry out initial data collection. The type of data retrieved is the primary data. Age data were obtained by asking directly on looking at the resident id card for those who already have. Gender was derived from the observation of the physical characteristics of the subject. The number of workouts per week was asked to see if athletes were routine in training. Height was measured in meters with a senoh brand height meter®. The subject stood upright with his back resting on the pole and the legs' position at a predetermined place. Weight gain is obtained from the scales of the Yamato®. Weight is displayed in kilograms. BMI was calculated based on weight per quadratic height.

FEV_1 and FVC in liters were obtained from spirometry examination with standard assessment when FEV_1/FVC > 75% while FVC was normal when FVC > 80% against the predicted value. The test was done three times on each subject using Fitmate™ pro brand spirometry; then, the best deal was taken by looking at the chart results.

Hemoglobin is obtained by taking a venous blood sample of 2 mL, then put in a tube containing anticoagulants, then put in a cooling box, and immediately sent to the laboratory for analysis on the same day.

Bleep test produces total shuttle, the highest heart rate on the track. The total number of shuttles obtained is then entered into the formula to value VO_2max is obtained. At the time of the Bleep test, the subject wears Polar to calculate the highest pulse. Polar is used as high as the xiphoideus process connected to the polar receiver on the IPAD Pro 10" using the Polar Team application. Pulse data at the time of the test will be recorded on the polar receiver®, including the highest pulse at the test time.

Measuring Athlete VO_2max laboratory test (Cosmed Fitmate™ Pro) was obtained from CPEX (CardioPulmonary Exercise) Brand Cosmed® type Fitmate™ Pro. Subjects were asked to walk up to run according to treadmill test speed. Before the test, the subject is polarized so that the pulse can be measured in this test using the protocol 10 kilometers.

Blood pressure was checked before and after the test using a Riester brand blood pressure apparatus. Lactate levels were obtained by taking blood from the subject's fingertips, then dripping on the lactate test strip using the Accutrend brand lactate test tool. Measuring lactate was done twice before and immediately after the bleep test and treadmill test. Field temperature was calculated using a room thermometer measurement results in Celsius. A hygrometer measures field humidity results in percent.

Data Analysis

To analyze the data, using IBM SPSS Statistic and R Studio. Bivariate analysis with Pearson and Spearman analysis. The multivariate analysis uses stepwise by entering all variables to get a prediction model.

RESULT

Based on age, the largest sample was 18 years old, as many as 65 people (36.7%), and the smallest subject was 19 years old, as many as 17 people (9.6%). The most frequent sports performed was futsal for 74 people (42%), and the least performed was athletics as many as seven people (4%).

The largest tribe was from the Javanese tribe of 63 people (35.4%), and the smallest is from the Aceh tribe, Banjar, Dayak, China-Java, Papua, Sumatra, China, Tobelo as many as one person (0.6%).

The average height was 169.55 cm (SB 6,067), with the shortest students, 155 cm, and the highest 188 cm. The middleweight value was 59 (53–66), with the lowest weight of 45 kg and the heaviest weight of 115 kg. The body mass index (BMI) median value was 20.57 (19.05–22.88) with the following classification, namely Underweight (< 18.5) as many as 33 subjects (18.5), Normal (18.5–22.9) as many as 102 subjects (> 57.3), Overweight (23–24.9) as many as 21 subjects (11.8), Obesity (> 25) as many as 22 subjects (12.4). The Hemoglobin (Hb) level had the median value of 14.8 (14.10–15.60) with the lowest 12.2 mg/dL and the highest level of 17.6 mg/dL.

The average apparent leg length value was 96.22 (SB 4.52), with the lowest value of 86 cm and the highest value of 108.5 cm. For true leg length, the average value was 89.27 (SB 4.64), with the lowest value of 70 cm and the highest value of 101.5 cm. Based on the result of Spirometry FVC (Forced Vital Capacity), the median value was 3.59 (3.27–4.023), and the median value of FEV_1 (Forced Expiratory Volume) was 3.44 (3,128–3,705). The field humidity had a median of 0.57 (0.52–0.67), while the lowest field temperature was 26 ^oC, and the highest was 41.9 ^oC. The lowest room humidity was 45%, and the highest was 59%, while the lowest room temperature was 22.5 ^oC, and the highest was 26 ^oC. The number of shuttles had a median of 63 (54–79), with the lowest number of 26 and the highest of 125.

The highest average heart rate obtained from the treadmill test was 190.9 times/minute, and the average VO_2max obtained from the treadmill test was 45.05 mL/kg/min.

Using the bleep test showed the minimum lactate level pre-test was 0,80 mmol/L, and the maximum level was 10,70 mmol/L, while the post-test minimum lactate level was 2,90 mmol/L, and the maximum level was 21,40 mmol/L. When using the treadmill test, the pre-test lactate level was a minimum of 0,8 mmol/L and a maximum of

15,7 mmol/L, while the post-test lactate level minimum was 3,8 mmol/L, and the maximum was 21,7 mmol/L.

Sports	Mean
Treadmill Test	
Athletic	53,47
Soccer	49,4
Volleyball	44,45
Futsal	44,26
Basketball	43,52
Bleep Test	
Athletic	49,19
Soccer	45,61
Basketball	40,25
Volleyball	39.84
Futsal	39,45

Table 1. VO_2max Distribution Obtained from Treadmill Test and Bleep Test Based on Sports

The athletic branch had the highest average VO_2max of 53.47 mL/kg/minute followed by the soccer branch of 49.4 mL/kg/minute followed by the Volleyball branch of 44.45 mL/kg/minute followed by the futsal branch of 44.26 mL/kg/minute, and the least was basketball branch of 43.52 mL/kg/minute.

Variable	VO_2maks (r)	p
Age	0,047	0,534*
Height	-0,207	**0,006**
Body Weight	-0,401	**< 0,001***
Body Mass Index	-0,359	**< 0,001***
HRmax	-0,002	0,98
Field Temperature	0,104	**0,168***
Humidity	-0,079	0,294*
Hemoglobin	-0,155	**0,039***
Pre-test Bleep lactic acid	0,074	0,335*
Post-test Bleep lactic acid	0,140	**0,062***
FVC	-0,089	**0,238**
FEV_1	-0,076	0,312
Total Shuttle	0,624	**< 0,001***
Pearson Analysis *Spearman Analysis*		

Tabel 2. Bivariate Correlation between Independent and Dependent Variables

The Pearson correlation obtained results of 0.691 with $p < 0.001$, so there is a strong positive correlation between VO_2max obtained from the laboratory test results (Cosmed Fitmate™ Pro) compared to the value of VO_2max obtained from field test results (bleep test).

Variable correlation values that have $p < 0.25$ were: height, weight, body mass index, field temperature, hemoglobin, lactic acid post, FVC dan total shuttle, which will then be used to find the best model with stepwise regression method based on correlation value and Akaike Information Criterion (AIC) each variable is free against its bound variable.

New formulas obtained:

$Formula_0$:VO_2max = 27.17 + 0.27 (Total Shuttle)

$Formula_1$:VO_2max = 49,795 + 0.238 (Total Shuttle) – 0.173 (BW) – 0.086 (HRmax Field) + 0.229 (Field Temp)

$Formula_2$:VO_2max = 48,784 + 0.236 (Total Shuttle) – 0.169 (BW) – 0.090 (HRmax Field) + 0.246 (Field Temp) + 0.112 (Post as Lactate).

Description: Total Shuttle = Number of Shuttles on the bleep test

BW = Body Weight in kilogram

HRmax = Maximum pulse in units of times/minutes

Field Temp = Field temperature in units of Celsius

Post as Lactate = Lactic Acid Value after bleep test in mmol/L unit.

DISCUSSION

This research is expected to get a new formula to correct the old formula that is less accurate for Indonesian junior athletes. The number of total shuttles that were the primary variable in determining VO_2max is a collection of steps at the time of running. Chatterjee et al. in 2008[16], conducted VO_2max compared to Multistage Fitness Test/bleep test in junior sprinters. The results obtained were statistically significant ($p < 0.01$), so it can be concluded that the bleep test formula is not suitable for people in Asia because it differs in height from the European person, so it needs to be corrected. The subjects studied were male junior athletes aged between 16–19 years in soccer, futsal, volleyball, basketball, and athletic. The research was conducted on junior athletes because 16–19 is the culmination of value VO_2max.

This research analysis obtained an average value of VO_2max on treadmill test examination of 45.29 mL/kg/minute, which is greater than the average value of VO_2max on the bleep test of 41.1 mL/kg/minute, with a t-test of $p < 0.05$, which means there is a statistically meaningful difference, and this is in

concordance with the hypothesis. When looking at the VO_2max based on treadmill test examination in several sports, the highest average value was of the athletic branch of 53.47 mL/kg, followed by soccer athletes of 49.40 mL/kg/minute, then volleyball athletes of 44.45 mL/kg.bb, then futsal athletes of 44.26 mL/kg/minute and lastly basketball athletes of 43.51 mL/kg/min. In contrast to the treadmill test examination VO_2max value based on bleep test, the highest average value was of the athletics of 49.18 followed by soccer of 45.61 followed by futsal 40.25 then volleyball of 39.83 then basketball of 39.45 mL/kg/min.

In this research, there are three soccer positions: 10 defenders, 11 as a midfielder, and seven as a striker. The analysis results showed that the VO_2max of the striker position had the highest score in the treadmill test of 54.19 and the bleep test 49.46. Then followed by VO_2max from the midfielder position on the treadmill test of 53.61 and in the bleep test of 46.07, then VO_2max lowest from the defender position on the treadmill test of 41.42 and the bleep test of 42.41. The difference in VO_2max value in the position is due to the defender's position waiting for more for the ball to come so that the movement is not too much. The midfielder's role is more significant than the defender's VO_2max value because he is actively running to compose attacks and chase the ball into the field of defense. The striker's position is highest because he actively runs forward and back to score goals.

This research also showed that age had no meaningful relationship with VO_2max because it has a p-value of 0.534 ($p > 0.05$) and r of 0.047. This study was conducted only in the same age group of junior athletes with an age range of 16–19. Also, t-test results between VO_2max age 16 and 19 obtained t-count -1,824 with a p-value of 0.0837 ($p > 0.05$), which means there is no meaningful difference between VO_2max age 16 with age 19. And also conducted testing for all ages of 16, 17, 18, and 19 using Kruskal-Wallis produced chi-square count of 4.1046 with p-value 0.2504, so it was concluded that there was no significant difference value of VO_2max based on age.

The correlation of Height to VO_2max in this research showed a significant negative correlation with r of -0.207 and a p-value of 0.006 ($p < 0.05$). So, it can be said that each increase of one unit of height will lower VO_2max by 0.207. This is likely due to the higher the athlete will increase weight and may also be due to exercise factors carried out. Weight Correlation in this research showed a significant negative correlation between weight and VO_2max with r of -0.401 and p-value 0.001 ($p < 0.05$). So, it can be said that each increase of one unit of weight will decrease VO_2max by 0.401. These results are in accordance with the theory that weight gain affects VO_2max.

The correlation of BMI in this research showed a significant negative correlation between body mass index and VO_2max with r of -0.359 and p-value 0.001 ($p < 0.05$). So, it can be said that each increase of one unit of body mass index will lower VO_2max by 0.359.

This study's results prove the theory that Weight, Height, and Body Mass Index greatly influence the value of VO $_2$max in athletes.

This study showed no significant correlation between the highest heart rate and VO_2max with r of -0.002 and p-value of 0.983 ($p > 0.05$); between field temperature and VO_2max with r of 0.104 and p-value of 0.168 ($p > 0.05$); and between field humidity and VO_2 max with r of -0.079 and p-value of 0.294 ($p > 0.05$).

This research showed a significant negative correlation between Hb and VO_2max levels with r of -0.155 and p-value 0.039 ($p < 0.05$), meaning that each increase of one unit of Hb level will lower VO_2max by 0.155. Theoretically and many studies prove that Hb is very influential on the value of VO_2max of athletes. In this research, it is likely that other factors, namely weight and exercise, could have some influence.

This research also showed no significant correlation between lactic levels with VO_2max before the test with r of 0.073 and p-value 0.335 ($p > 0.05$) and after the test with r of 0.140 and p-value of 0.062 ($p > 0.05$). The results showed that at the time before the test, some athletes had lactic acid values of more than four mmol, indicating that athletes underwent previous sports activities and did not undergo a good recovery so that the lactic acid value before the test was still high. High lactic acid will affect VO_2max results.

This research showed no significant correlation between FVC and VO_2max with r of -0.089 and p-value of 0.238 ($p > 0.05$), and there was no significant correlation between FEV_1 and VO_2max with r of -0.076 and a p-value of 0.312 ($p > 0.05$). This was probably because the study subjects were of the same age, so the FVC and FEV_1 values were homogeneous.

CONCLUSION

There is a significant difference in value VO_2max obtained from treadmill test results with value VO_2max from bleep test results. There is a correlation between total shuttle, weight, and HRmax with VO_2max score from bleep test results in male junior athletes. Through regression modeling, a new formula was obtained to predict values of VO_2max in male junior athletes, which is Ruli Formula: VO_2max = 49,795 + 0.238 (Total Shuttle) – 0.173 (BW) – 0.086 (HRmax Field) + 0.229 (Field Temp). External validation cannot be done because of the covid 19 pandemics. Internal validation through Monte Carlo simulation 10,000 times repetition of the overall power value in this modeling is worth 78%.

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