

Healthy adults maximum oxygen uptake prediction from a six minute walking test

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Abstrak

Latarbelakang: Suatu parameter diperlukan dalam layanan atau kegiatan kesehatan, antara lain untuk menentukan kapasitas fungsional. Penelitian ini bertujuan mendapatkan parameter kapasitas fungsi untuk dewasa sehat Indonesia berupa rumus prediksi O_2 maksimal.

Metode: Penelitian ini menggunakan 123 subjek (58 laki-laki dan 65 perempuan) dewasa sehat Indonesia dengan sikap hidup sedentary, dengan metode potong-lintang.

Hasil: Dirancang dengan memasukkan jarak tempuh disertai berturut-turut tinggi badan, berat badan, jenis kelamin, umur, denyut jantung tertinggi yang didapat dari uji jalan di lintasan dan kapasitas paru (VEP1 dan KVP) setelah didapati berkorelasi baik (kecuali berat badan) dengan O_2 maksimal. Diperoleh tiga rumus baru dengan delapan variabel, enam variabel dan lima variabel. Pada uji menggunakan rumus baru didapati hasil O_2 maksimal yang sesuai dengan baku emas O_2 maksimal menggunakan Cosmed[®] C-P ex.

Kesimpulan: Rumus Nury merupakan prediksi ambilan oksigen maksimal yang tepat untuk dewasa sehat Indonesia karena dirancang dengan subjek Indonesia (ras Mongoloid) dibanding rumus Cahalin (ras Kaukasia). Rumus Nury dengan lima variabel lebih mudah diaplikasikan karena tidak memerlukan alat ukur dan tenaga yang berkompentensi khusus. (*Med J Indones 2011; 20:195-200*)

Abstract

Background: A parameter is needed in medical activities or services to determine functional capacity. This study is aimed to produce functional capacity parameter for Indonesian adult as maximum O_2 .

Methods: This study used 123 Indonesian healthy adult subjects (58 males and 65 females) with a sedentary lifestyle, using a cross-sectional method.

Results: Designed by using the followings: distance, body height, body weight, sex, age, maximum heart rate of six minute walking test and lung capacity (FEV and FVC), the study revealed a good correlation (except body weight) with maximum O_2 . Three new formulas were proposed, which consisted of eight, six, and five variable respectively. Test of the new formula gave result of maximum O_2 that is relevant to the golden standard maximum O_2 using Cosmed[®] C-P ex.

Conclusion: The Nury formula is the appropriate predictor of maximum oxygen uptake for healthy Indonesians adult as it is designed using Indonesian subjects (Mongoloid) compared to the Cahalin's formula (Caucasian). The Nury formula which consists of five variables is more applicable because it does not require any measurement tools neither specific competency. (*Med J Indones 2011; 20:195-200*)

Key words: maximum O_2 , Nury's formula, six minute walking test

A parameter is needed in medical activities or services to determine functional capacity, to diagnose, determine risk factors, plan a program, and evaluate a medical service program.¹ Functional capacity in physical and rehabilitation medicine's point of view depicts personal capability to perform an expected task. A functional capacity involves daily activities related in a person's daily life for her/him and with other people and environment performed individually by her/him self.² Basically, most daily activities are aerobic activities. Maximum $\dot{V}O_2$ aerobic capacity is the most appropriate measurement to determine functional capacity.²⁻⁴

The six minute walking test and the Cahalin's formula, where distance is used as the main component is used to determine maximum $\dot{V}O_2$ prediction.⁵ The Cahalin's formula is designed in United States of America (USA) using American subjects, meanwhile *step length* of Indonesian people is different compared to American's.^{5,6} Mistivani⁶ found that adult healthy Indonesians' *step*

length was 50 cm, Rachmawati et al⁷ found that *step length* of Indonesian adult males was 45.67 cm and females' 42.6 cm while Simoneau⁸ found that healthy Americans' *step length* was 72 cm.⁶⁻⁸ Iwama⁹ found that anthropometric and demographic influences distance of six minute walking test. The Cahalin's formula is used in rehabilitation service and in many researches in Indonesia as it is easily applicable, simple, but the prediction result does not determine the real functional capacity.¹⁰⁻¹³

The inappropriate anthropometric characteristics among American and Indonesian, the need of a simple and applicable functional capacity test motivates the researcher to determine a new more applicable formula to predict maximal oxygen uptake of a healthy Indonesian adult.

A simple test is obviously useful because it is known that the height of Indonesians is different compared

to American's therefore the step length is obviously different.¹⁴ Cahalin did not differentiate between male and female, while it is known that male's step length is different compared to female's. The Cahalin's formula predict maximum $\dot{V}O_2$ by converting distance, body weight, and age. Maximum $\dot{V}O_2$ in many literatures is influenced by heart rate,¹⁵ lung^{12, 16} and sex,¹⁷ hence those variables are accounted in the new formula.

METHODS

This is a cross-sectional study using 123 healthy Indonesian adult subjects (aged 18-50 years) with sedentary life style. A sedentary lifestyle is defined as a person that does not do exercise with full sweating within one week.¹⁸ This study was done in Medical Rehabilitation Department of Cipto Mangunkusumo Hospital (RSCM) and Kinematics Laboratory Universitas Negeri Jakarta (UNJ) in January 2010 until August 2010. The subjects have to undergone physical examination, haemoglobin measurement, ECG, and spirometry to fulfill inclusion criterias.

All participants performed six minute walking test three times. The first walking test was performed on 15 cm flat track, marked by three meters each, 30 cm width to the right and left of midline, walked in Borg scale intensity of 12-13, performing a turn at the edge of both track with three steps maneuver (Nury's protocol). Afterwards, the six minute walking test was performed on Cosmed® C-P ex to gather gold standard value of maximum $\dot{V}O_2$ by using certain speed which

is resulted from the walking test on track. On the other day, another walking test was performed using on Biodex® *gait trainer* to gather gold standard value of distance; also with the same speed which is resulted from the walking test.

The new formula was trialed in forty people (20 males and 20 females), which were randomized from subject who had undergone the study activities to determine appropriateness of the formula as well as to determine whether using the new protocol of six minute walking test result as a maximum six minute walking test and safe as it is determined as an aerobic zone by using lactic measurement.

Data analysis was performed by SPSS version 13. Univariate analysis is used to show frequency distribution by descriptive statistic form and mean comparative test based on sex of each variables. Bivariate analysis is used to find correlation between dependent and independent variables to determine whether the correlation is statistically significant. Multivariate analysis is used to know the magnitude influence of which dependent variable that is used to formulate the regression model formula upon the maximum $\dot{V}O_2$ as the dependent variable.

RESULTS

The subject of this study was 123 people. There were 65 female (52.8%) and 58 (47.2%) male subjects. Table 1 shows that between male and female, age, body height, and body weight, FEV₁ and FVC are not similar.

Table 1. Subject characteristics based on age, body height, body weight, FEV₁ and FVC

Variable	Mean	SD	Minimum	Maximum	95% CI	P value*
					Minimum-maximum	
Age (years)						
- Male	26.78	7.03	18	45	24.93 – 28.62	< 0.001
- Female	21.92	5.50	18	42	20.56 – 23.29	
Body height (cm)						
- Male	165.47	6.23	151	184.90	163.83 – 167.11	< 0.001
- Female	155.22	4.44	144	163	154.12 – 156.32	
Body weight (kg)						
- Male	58.58	7.33	46.60	80	56.66 – 60.51	< 0.001
- Female	52.18	5.35	39.40	64.90	50.85 – 53.51	
FEV ₁ (liter)						
- Male	3.35	0.45	2.26	4.19	3.23 – 3.46	< 0.001
- Female	2.49	0.30	1.73	3.10	2.41 – 2.56	
FVC (liter)						
- Male	3.70	0.50	2.70	4.80	2.70 – 4.80	< 0.001
- Female	2.73	0.33	1.98	3.39	1.98 – 3.39	

*independent sample t-test

Table 2. Subjects based on maximum heart rate during walking on the 6 minute walking test track

Variable	Mean	SD	Minimum	Maximum	95% CI	P value*
					Minimum-maximum	
Maximum heart rate on track (beat/minute)						
- Male	156.09	28.80	120	229	148.52-163.66	0.851
- Female	156.91	18.92	122	227	152.22-161.60	

*independent sample t-test

Table 2 shows subjects based on maximum heart rate at zone of 120-170 beats per minute (tests were performed within aerobic zone).

Mean of $\dot{V}O_2$ Cosmed® C-P ex in male subject is (24.73±5.26) with minimum 16.44 and maximum 36.14, 95% CI 23.35 – 26.12. Mean of $\dot{V}O_2$ Cosmed® C-P ex in female subject was (19.67±3.56) with minimum value of 11.74 and maximum 30.34, 95% CI 18.79 – 20.56.

Table 3 shows that distance in 15 meter track is not different with the one in Biodex® gait trainer as Gold Standard.

Correlation between dependent variables (distance, age, body height, body weight, maximum heart rate on track, FEV₁ and FVC) and maximum $\dot{V}O_2$ is calculated by using *Pearson* correlation. Table 4 shows significant correlation between the dependents variables with the maximum $\dot{V}O_2$ (P<0.05), except the body weight. However, the body weight is still calculated in the formulation as it is found to be correlated with maximum $\dot{V}O_2$ in several studies.^{13, 17, 19}

Table 3. Distance on 15 Meter track compared to distance on Biodex® Gait Trainer

Variables	N	Mean	SD	P value
Distance (m)				
- Track	123	547.45	54.24	0.693
- Gait trainer	123	544.72	54.11	

independent sample t-test

Table 4. Correlation between distance, age, body weight, body height, maximum heart rate on track, FEV₁ and FVC with maximum $\dot{V}O_2$

Variable	N	Pearson correlation	P value
Distance	123	0.65	< 0.001
Age	123	0.19	0.036
Body height	123	0.28	0.002
Body weight	123	0.10	0.29
Maximum heart rate	123	0.19	0.03
FEV ₁	123	0.37	< 0.001
FVC	123	0.35	< 0.001

Table 5. New formula of maximum $\dot{V}O_2$

(1)	Distance + age + body height (BH) + body weight (BW) + sex + maximum heart rate on track + FEV ₁ and FVC $\text{Maximum } \dot{V}O_2 = 0.05 (\text{distance}) + 0.042 (\text{age}) + 0.04 (\text{BH}) - 0.158 (\text{BW}) - 2.3 (\text{sex}^*) + 0.013 (\text{maximum heart rate on track}) + 2.299 (\text{FEV}_1) - 2.144 (\text{FVC}) - 4.783$ $r = 0.692; r^2 = 0.479; r_{\text{adjusted}} = 0.443; p < 0.005$
(2)	Distance + age + body height + body weight + sex + maximum heart rate on track $\text{Maximum } \dot{V}O_2 = 0.05 (\text{distance}) + 0.033 (\text{age}) + 0.04 (\text{BH}) - 0.17 (\text{BW}) - 2.316 (\text{sex}^*) + 0.015 (\text{maximum heart rate on track}) - 4.302$ $r = 0.689; r^2 = 0.474; r_{\text{adjusted}} = 0.447; p < 0.005$
(3)	Distance + age + body height + body weight + sex $\text{Maximum } \dot{V}O_2 = 0.053 (\text{distance}) + 0.022 (\text{age}) + 0.032 (\text{BH}) - 0.164 (\text{BW}) - 2.228 (\text{sex}^*) - 2.287$ $r = 0.686; r^2 = 0.47; r_{\text{adjusted}} = 0.448; p < 0.005$

Explanation : * 0= Male 1= Female

Walking Distance in meter

Age in years old

height in centimeter

body weight in kilogram

max heart rate on track in times/minute

FEV₁ dan FVC in liter

After the Nury's formula is formulated, a differential test is performed with the Cahalin's formula finds that $\dot{V}O_2$ mean of Nury's formula (21.92 ± 3.51) which is differ significant statistically ($p < 0.05$) compared to the Cahalin's formula (14.06 ± 1.23). Afterwards the Nury's formula was trialed in 40 subjects by using residual normality test. The residual normality test gives *P* value of 0,941 ($P > 0,05$), which can be concluded that distribution of the residual formula is normal. Figure 1 shows residual plots nearby approaching linear line which indicates that the data distribution is normal. It shows that *error* of maximum $\dot{V}O_2$ by using the new formula with linear regression model close to zero or in other words the prediction value of the new formula approaching the gold standard value of maximum $\dot{V}O_2$.

Table 6 shows that the mean of lactic level after walking test was approximately 4 mM, which is appropriate with maximum exercise zone and is categorized as an aerobic zone.

Table 6. Lactic level prior and after six minute walking test in 40 subjects

Variable	Mean	SD	Minimum	Maximum	CI 95%
					Minimum-maximum
Lactic prior (mMol)					
- Male	1.8750	0.60426	1.20	3.80	1.5922 – 2.1578
- Female	1.8300	0.53123	0.90	2.60	1.5814 – 2.0786
Lactic after (mMol)					
- Male	4.2150	1.30597	2.50	7.80	3.6038 – 4.8262
- Female	4.0600	0.98803	2.30	6.70	3.5976 – 4.5224

DISCUSSION

This study is aimed to formulate a new calculation formula of maximum $\dot{V}O_2$ that is more appropriate and relevant to Indonesian, because the current formula has been found to be irrelevant as it was formulated based on physiologic physical characteristics of western people. Meanwhile the characteristics of Indonesian people differ from western people; therefore, it is assumed that the current maximum $\dot{V}O_2$ predictive value is irrelevant to Indonesian people.

Subject involved in this study were 123 people which differentiated based on sex. Moreover, they were described in several characteristics such as distance, age, body height, body weight, FEV₁ and FVC, heart rate, and maximum $\dot{V}O_2$. Variables such as age, body height, body weight, FEV₁ and FVC were differentiated among males and females. Those variables showed significant different among male and female subjects ($P < 0.05$) (Table 1). However, there was no significant different between maximum heart rate on track among male and female subjects ($P > 0.05$) (Table 2).

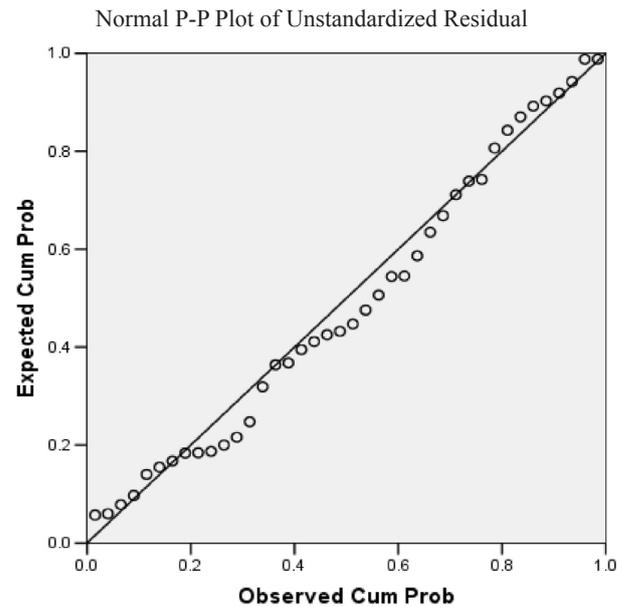


Figure 1. Residual normality test

Variables such as distance, age, sex, body height, body weight, maximum heart rate on track, FEV₁ and FVC were calculated to form new formulas of maximum $\dot{V}O_2$. The gold standard value of maximum $\dot{V}O_2$ is gathered from six minute walking tests at Cosmed® C-P ex. Based on the correlation test on several variables on maximum $\dot{V}O_2$, a value of influenced magnitude towards variable then is calculated to achieve the expected formula. R square increases by each addition of dependent variables, while R adjusted decreases by each addition of heart rate variable and FEV₁. R adjusted is constant despite of addition of FVC variable. Distance has a 42% influence towards the validity of formula, and 48% if added with age, body height, body weight, sex, maximum heart rate, and FEV₁ and FVC. Three formulas of maximum oxygen uptake prediction are gathered using eight, six, and five variables consecutively.

If the data from this study is used to calculated the maximum $\dot{V}O_2$ by using the Cahalin's formula then it is compared with the Nury's formula, as well as the gold standard maximum $\dot{V}O_2$ from Cosmed® C-P ex, it is found that there is a significant mean difference

between maximum $\dot{V}O_2$ of Nury's formula ($P < 0.05$) compared to the Cahalin's formula. After formulated, the Nury's formula then was trialed in 40 subjects with residual normality test. The residual normality test shows *P value* of 0.941 ($P > 0.05$), hence it is concluded that the formula is in normal distribution assumption.

The new formula of Nury's is more relevant to the Indonesian people compared to the Cahalin's formula as ethnical differences show different physical characteristic such as body height. Indonesian people is defined as Mongoloid whose body height is not as high as Americans (Caucasians) that is the subjects of Cahalin's formula.

This formula is accompanied with a protocol of six minute walking test to achieve an accurate walking distance. The distance shows statistically insignificant calculation for the mean value on the track compared to the mean value of distance on the Biodex[®] gait trainer as gold standard for distance ($P > 0.05$). This shows that the protocol of walking test on the 15 meter track is the correct protocol, as it gives insignificant different of distance while walking with the same velocity at Biodex[®] gait trainer (Table 3). Moreover, the protocol also results submaximum heart rate zone which is ranged 120 – 170 beats per minute (Table 2).

The Cahalin's formula only consists of 3 variables: distance, age, and body weight. The Cahalin's does not consider sex and body height, while sex is known to influence maximum $\dot{V}O_2$ uptake¹⁴. The value of $\dot{V}O_2$ in male and female at Cosmed[®] C-P ex in the new formula is higher compared to the ones in Cahalin's formula. This indicates that there would be false interpretation of functional capacity when using the Cahalin's formula. The mean value of maximum $\dot{V}O_2$ at Cosmed[®] C-P ex in male is 24.73 mL/kgBH/minute, which is higher than the female's maximum $\dot{V}O_2$ at Cosmed[®] C-P ex, 19.67 mL/kgBH/minute. Based on the statistical test, it shows that there is a significant different of mean value of maximum $\dot{V}O_2$ among male and female subjects ($P < 0.05$). Body height is known to have influence to walking distance and lung functional capacity, therefore distance and lung functional capacity differ.^{20, 21} Distance is a variable that gives big impact on maximum $\dot{V}O_2$ prediction, while the lung functional capacity (FEV₁ and FVC) is also positively correlated with maximum $\dot{V}O_2$ prediction.

The ethnical difference does not only cause the difference in the physical characteristics, Roy J.L.P. et al.²² report in their study that in different ethnic there are different genetical oxidative capacity of muscle mitochondria as well as hemoglobin ability to carry the oxygen. Farinatti²³ and Roy J.L.P.²² also report that ethnical differences also influence the stroke volume. The genetic differences of oxidative muscle mitochondria, hemoglobin ability to carry the oxygen

and the stroke volume will influence the maximum $\dot{V}O_2$ predicted value. Therefore, the researcher formulated a new formula designed for Indonesian Mongoloid race which are different compared to the Cahalin's formula that was formulated using American Caucasian people.

In conclusion, Nury's formula for maximum $\dot{V}O_2$ prediction is useful to be implemented in Indonesia, than the Cahalin's formula which is not relevant to Indonesian people. The ethnical differences underlying the physical characteristic and genetic differences influence the factors contributing to maximum $\dot{V}O_2$. Nury's protocol for the six minute walking test is the most appropriate to be used for taking data of walking distance because it has been proved to achieve the submaximum zone and aerobic zone of the six minute walking test.

REFERENCES

- Hoberty PD, Serkagis GG, Hoberty RJ. Education in Pulmonary Rehabilitation. In: Hodgkin JE, Celli BR, Connors GL, editors. Pulmonary Rehabilitation Guidelines to Success. fourth ed. Missouri: Mosby Elsevier; 2009. p. 781.
- Kane RA. Functional Capacity [Internet]. eNotes.com; 2010 [cited 2010 November 1]: Available from: <http://www.enotes.com/public-health-encyclopedia/functional-capacity>
- Dahl TH. International Classification of Functioning, Disability and Health: an Introduction and Discussion of its Potential Impact on Rehabilitation Services and Research. J Rehabil Med. 2002;34:201-4.
- Ross A, Jonathan M, A. WM, Martha G, Paul K, J. BG, et al. Assessment of Functional Capacity in Clinical and Research Settings: A Scientific Statement from The American Heart Association Committee on Exercise, Rehabilitation, and Prevention of The Council on Clinical Cardiology and The Council on Cardiovascular Nursing. AHA journal. 2007;116:329-43.
- Cahalin L, Pappagianopoulos P, Prevost S, Wain J, Ginns L. The Relationship of The 6-min Walk Test to Maximal Oxygen Consumption in Transplant Candidates with End-Stage Lung Disease. chest journal. 1995;108:453-9.
- Mistivani I. Uji Jalan Pasien Hemiparesis Pasca Strok. Jakarta: Universitas Indonesia; 2004.
- Rachmawati Mr, Samara D, Tjhin P, Wartono M, Bastian Y. Musculoskeletal Pain and Posture Decrease Step Length in Young Adults. Univesa Medica. 2009;28:92-9.
- Simoneau GG. Kinesiology of Walking. In: Neumann DA, editor. Kinesiology of The Muskuloskeletal System Foundations for Physical Rehabilitation Wisconsin: Mosby; 2002. p. 69-523.
- Iwama AM, Andrade GN, Shima P, Tanni SE, Godoy I, Z. V. The Six-minute Walk test and Body Weight-walk Distance Product in Healthy Brazilian Subjects. Brazilian Journal of Medical and Biological Research. 2009;42(11):1080-5.
- Listiyanti W. Perbandingan Tingkat Kebugaran Pada Penderita Asma Persisten Dengan Non Asma Di RSUPN Dr. Cipto Mangunkusumo. Jakarta: Universitas Indonesia; 2003.
- Tianusa N. Hubungan Jarak Tempuh Berjalan Dengan Kualitas Hidup Pada Penderita Penyakit Paru Obstruktif Kronik. Manado: Universitas Samratulangi; 2003.

12. Rosdiana I. Hubungan Tingkat Obsrtuksi Paru Dengan VO2maks Pada Penderita Penyakit Paru Obstruktif Kronik Laki-Laki Menggunakan Uji Jalan 6 Menit. Semarang: Universitas Diponegoro; 2005.
13. Wijyaningrum L. Nilai tes jalan 6-menit pada subyek sehat usia 25-50 tahun di rummkital dr. Ramelan dan rumkital Tanjung Perak Surabaya. Surabaya: Universitas Airlangga; 2006.
14. Disabled World.com [Internet]. Height Charts of Men and Women in different Countries. c2008 - [cited 2010 Nov 15]: Available from: <http://www.disabled-world.com/artman/publish/height-chart.shtml>.
15. Arnardottir RH, Emtner M, Hedenstrom H, Larsson K, Boman G. Peak Exercise Capacity Estimated from Incremental Shuttle Walking Test in Patients with COPD: A Methodological Study. *Respiratory Research*. 2006;7:127.
16. Fatemi R, Ghanbarzadeh M. Relationship Between Airway Resistance indices and Maximal Oxygen Uptake in Young Adults. *Journal of Human Kinetics*. 2009;22:29-34.
17. Kline GM, Porcari JP, Hintermeister R, Freedson PS, Ward A, Robert, et al. Estimation og VO2max from a one-mile track walk, gender, age, and body weight. *American College of Sport Medicine*. 1987;19(3):253-9.
18. Departemen Pendidikan dan Kebudayaan. *Erobika Kegiatan Sehari-Hari Demi Hidup Sehat*. Jakarta: Balai Pustaka; 1976.
19. Goran M, Fields DA, Hunter GR, herd SL, Weinsier RL. Total Body Fat does not Influence Maximal Aerobic Capacity. *International Journal of Obesity*. 2000:841-8.
20. Gibson RS. *Principles of Nutritional Assessment*. Second ed. New York: Oxford University Press; 2006. p. 233-372.
21. Munadia, Nusdwiningtyas N, Nasution A, Suryanto. Nilai Rerata Jarak Tempuh Uji Jalan Enam Menit pada Anak Kelompok Usia 9-10 Tahun. *Majalah Kedokteran Indonesia*. 2010 5 Mei;60:213-8.
22. Roy JLP, Hunter GR, Fernandez JR, McCharthy JP, Larson-Meyer DE, Blaudeau TE, et al. Cardiovascular factors explain genetic background differences in VO2max. *Am J Hum Biol*. 2006;18:454-60.
23. Farinatti PTV, Soares PPS. Cardiac Output and Oxygen Uptake Relationship During Physical Effort in Men and Women over 60years Old. *Eur J Appl Physiol*. 2009;107:625-31.