ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN – POLONIA
VOL. LXV, N 1,10 SECTIO D 2010

Department of Physical and Health Education, University of Rzeszów[1], Department of Gastroenterology, Medical University of Lublin[2]

JOANNA CZAJKOWSKA-KOZIK[1], HALINA CICHOŻ-LACH[2]

Oxygen efficiency evaluated in 18-year old girls in the light of blood cell count

Wydolność tlenowa 18-letnich dziewcząt na tle wyników morfologii krwi

INTRODUCTION

Physical fitness is body ability to endure hard or long physical effort when large groups of muscles are engaged, without fast increasing tiredness and alterations in the internal environment conditioning its development (1, 2, 3, 4). The notion also covers tolerance to after-effort changes and restitution time after work done. It is so called general physical efficiency which depends on multiple factors. (Table 1).

Table 1. Conditions of efficient oxygen supply (2)

1. Maximal pulmonary ventilation
2. Diffusion of pulmonary capacity
3. Oxygen volume and capacity of blood
4. Maximal cardiac output per minute (maximal cardiac ejection volume and maximal frequency of hart rate
5. Difference of oxygen arteriovenous saturation of blood:
a) vasomotor regulation ("distribution" of blood pumped by the heart)
b) muscular blood flow (arteriovenous blood flow through arteriovenous anastomoses / nourishing vessels ratio)

Physical efficiency is measured directly by the time of physical effort of fixed constantly increasing intensity, like jogging, walking, cycling, etc. until complete rundown of the body (5). Such measurements are difficult therefore indirect parameters of physical effectiveness are often used. The most common parameter is maximal oxygen consumption (VO_2max). VO_2max reflects oxygen efficiency very well. It can be directly measured at maximal effort or calculated from the frequency of heart rate (HR) at submaximal effort. Indirect evaluation of VO_2max is based on linear dependence between oxygen consumed and heart rate at functional balance at submaximal effort. It can be used to predict at what amounts of oxygen consumed the examined person achieves maximal (average) frequency of HR within the range for his age group (6). VO_2max indirectly measured by step test is one of the best criteria to evaluate physical efficiency. VO_2max can be measured on the basis of Astrand-Ryhming nomogram as well (7). To assess maximal consumption of oxygen by Astrand-Rhyming the effort should be programmed in such a way that pulse rate ranges 120-170 beats/min, best 130-170 beats/min in the steady state. Then it is possible to precisely read oxygen top level from the nomogram established by Astrand and Ryhming. The studies found that in people of average physical efficiency (untrained) and at various age the differences between direct VO_2max at effort measured by cycloergometer and its evaluation based upon Astrand-Ryhming nomogram do not exceed 10%. Moreover they found the results obtained by calculating VO_2max upon nomogram, cycloergometer and step test do not differ significantly and restorable (2). Indirect methods, although convenient and easy to use are erroneous. But they are very useful to evaluate oxygen efficiency when performed in the same laboratory conditions by the same persons (8). VO_2max is expressed either as an absolute rate in liters of oxygen per minute (l/min) or as a relative rate in milliliters of oxygen per kilogram of bodyweight per minute (ml/kg/min), the latter expression is often used to compare the performance of endurance sports athletes. Table 2 illustrates the classification of physical efficiency according to VO_2max value (9).

Table 2. Classification of physical efficiency according to VO_2max value according to Magiera (5).

$VO_{2\,max}$ (ml/min/kg)	Physical efficiency
80-60	Excellent
59-40	Very good
39-30	good
29-21	weak
20-16	very weak
15-11	moderate circulatory insufficiency
10-6	acute circulatory insufficiency

Since the objective of this investigation is to define the correlation between oxygen efficiency and blood parameters we will consider the role of red blood cell parameters in the transport of oxygen to the tissues. In extra-foetal life red blood cells i.e. erythrocytes are produced by bone marrow. They enter the circulation where they live for ca. 120 days; the time of their half-degradation determined by erythrocyte chromium isotope staining is 28 days. Their main function is to transport oxygen from the lungs to the tissues. The following parameters of erythrocytes are determined: the number of red blood cells in 1 l blood – RBC, haematocrit – HCT, haemoglobin content – HGB, mean corpuscular volume – MCV, mean corpuscular haemoglobin – MCH, mean corpuscular haemoglobin concentration – MCHC and mean red corpuscle diameter – MC, red cell distribution width - RDW (10).

Blood accounts for 6-8% body mass which equals about 5 l and its volume depends on body mass and is lower in females than males. Blood is composed of plasma which is about 55% of all blood volume, the other 45% are solid corpuscles called blood cells: red blood cells, white blood cells and blood platelets; red blood cells comprise ca. 99%.

The purpose of this study was to assess VO_2max and refer its values to red cells parameters.

MATERIAL AND METHODS

The investigation was carried out in Food Processing Secondary School in Rzeszów on 5 May, 2005. The subjects were 64 healthy 18-year old girls who underwent physical examination to establish contraindications to continue participation in the project. The aim was to evaluate their physical efficiency and blood morphology. The characteristic features of the examined girls are presented in Table 3.

Table 3. Parameters of examined patients

Parameter	Mean	SD
Age	18.6	0.64
Weight (kg)	58.19	0.63
Height (m)	1.63	0.64
Body Index Mass (BMI)	21.55	3.42

VO_2max was indirectly measured by step test. Therefore VO_2max was calculated by the formula (9) based upon HR in a steady state and power values that account for HR increase:

$$VO2max = (a + b \times HR) \times 1$$

a, b –regression equation coefficient for dependence between power and HR

1 – corrective coefficient for age

HR – heart rate

Heart rate (HR) in a steady state (balance period) was determined using a sport-tester. The test was carried out on a 33cm high step, at metronome frequency of 90/min, i.e. 22.5 steps up/min at four-tact rhythm of stepping. These settings for the parameters allowed efficient test ensuring natural technique of stepping up.

The measurement and evaluation of all examined parameters were performed in the same laboratory conditions by the same persons. Blood tests were done in the Medical Diagnostic Laboratory, Rzeszów. Blood for testing was not sampled during menstruation, which was strictly followed.

In order to find the correlation between maximal oxygen consumption and blood test results, Person correlation coefficient and linear determination index were used.

RESULTS

The results showed very weak oxygen efficiency among girls (Table 3-5). Moreover, analysis of blood cell count revealed certain abnormalities which can be related to iron deficiency among the examined subjects.

Table 4. Summary results of VO_2max in examined girls

VO_2max (ml/min/kg)	Physical efficiency	VO_{2max} (ml/min/kg)	
		Number of patients	Percentage of all patients (%)
80-60	Excellent	-	-
59-40	Very good	-	-
39-30	good	12	18.75
29-21	weak	32	50
20-16	very weak	16	25
15-11	moderate circulatory insufficiency	4	6.25

The mean value of HR was 174±11.3 beats/min. in the examined girls. The mean level of VO_2max expressed as an absolute rate in liters of oxygen per minute was 1.35±0.4 l/min and as a relative rate in milliliters of oxygen per kilogram of bodyweight per minute was 23.28± 3.6 ml/kg/min.

The analysis of blood cell count revealed certain abnormalities in the group of examined girls. Mean blood cell count parameters were within haematological norm, some of the erythrocyte parameters however had the signs of anaemia (Table 5).

Table 5. Results of blood cell count in the examined girls

Parameters [normal range]	mean	SD	Parameters below normal range		Parameters above normal range		Sum of results outside the normal range	
			N	%	N	%	N	%
RBC ml/ul [4,3-5,5]	4.53	0.26	9	14.06		-	9	14.06
HCT % [40-48]	39.70	2.732	29	45.31		-	29	45.31
MCV fl [80-94]	87.73	4.43	1	1.56	3	4.68	4	6.25
RDW % [11,5-14,5]	13.96	1.97	6	9.37	14	21.87	20	31.25
HGB g/dl [12-15,5]	12.86	1.01	6	9.37	-	-	6	9.37
MCH pg [27-33]	27.93	1.55	3	4.68	-	-	3	4.68
MCHC g/dl [32-36]	32.35	0.94	22	34.37	-	-	22	34.37

In the study group RDW above the norm was noted in 21.87% of cases and below the norm in 9.37% of cases. There were 71.87% results of RWD less than 14.5% and MCV lower than 94 fl. In the studied group 45.31% girls had HCT value below the norm, which is alarming though. Mean HGB level was 12.86 g/dl and 9.37% of girls had HGB level lower than normal. Mean MCHC ranged below the norm in 34.37% of cases.

The results fund no significant correlations between VO_2max and erythrocyte parameters. It was impossible to determine that they had not changed either. There was a slight relationship between MCV, RDW, MCH, MCHC and VO_2max. There was a weak correlation between RBC and VO_2max (-0.174) which can suggest that the higher level of RBC, the less overload on the circulation thus better VO_2max. Also HCT and HGB weakly correlated with VO_2max (0.215 and 0.15 respectively). BMI highly correlated with VO_2max (0.58) and correlations between RDW and MCV (-0.324) and between RBC and HGB (0.66) were significant.

DISCUSSION

Physical efficiency is one of positive determinants of health and depends on many factors of which the most important are cardiorespiratory efficiency and blood ability to bind oxygen aside efficiency of oxygen supply to the tissues. There were only a few papers considering these issue in Polish population, however, there have been no papers evaluating physical efficiency in 18 aged girls published so far (11, 12).

VO_2max is widely accepted as the single best measure of cardiovascular fitness and maximal aerobic power. VO_2max is influenced by age, sex, exercise habits, heredity, and cardiovascular clinical status. Absolute values of VO_2max are typically 40-60% higher in men than in women. A lower VO_2max in women is attributed to their smaller muscle mass, lower hemoglobin and blood volume, and smaller stroke volume compared with men (13). Clearly, then, VO_2max varies considerably in the population, with sex being a primary determining factor in this variability. Physical activity has an important influence on VO_2max (14, 15). After 3 weeks of bed rest, there is a 25% decrease in VO_2max in healthy men. In moderately active young men, VO_2max is about 42 ml/kg/min, whereas individuals performing aerobic training such as distance running can have VO_2max as high as 60 to 85 ml/kg/min (16). The average young untrained male will have a VO_2 max of approximately 3.5 liters/minute and 45 ml/kg/min (17). The average young untrained female will score a VO_2 max of approximately 2.0 liters/minute and 38 ml/kg/min. These scores can improve with training and decrease with age, though the degree of trainability also varies very widely: conditioning may double VO_2max in some individuals, and will never improve it at all in others (18). Maximum values of VO_2max occur between the ages of 15 and 30 years and decrease progressively with age. At 60 years, mean VO_2max in men is approximately two-thirds of that at 20 years. The decline in VO_2max averages 8% to 10% per decade in both sedentary and athletic populations (19). The natural variation in VO_2max related to genetic factors is known (18, 20, 21).

According to reference tables our results of maximal oxygen consumption in the group of examined girls were within low ranges of VO_2max for 40-49 year old females (22).

It is difficult to define the role of the amount of haemoglobin in oxygen supply to the tissues. Oxygen supply depends on many factors (Table 1) and disorder to one of them can be compensated by the activation of others (2). Moreover, there is correlation between maximal oxygen consumption VO_2max and lean body mass (LBM) and between total HGB and LBM. The amount of total HGB depends upon the body size, thus it creates additional difficulty to quantitatively define the role of HGB content as an important determiner of oxygen supply to tissues. In people whose VO_2max remains constant, HGB concentration may vary substantially, e.g. 11.5 g/dl and 15.0 g/dl; in people whose HGB concentration remains constant, e.g. 14.0 g/100ml, maximal oxygen consumption can range 1.8 – 5.2 l/min (2).

In our study low MCHC range was related to the fact that the examined were young 18 year old girls the results were alarmingly low. MCHC is one of three Wintrob's erythrocyte parameters. Physiologically the values are age and gender dependent and the values lower than 31g/dl can occur in certain types of anaemia. Normal range for MCHC is 32-36g/dl.

Red cell distribution width – RDW defines relative homogeneity of the red corpuscles. The normal range is 11.5-14.5%, The values over 15% can suggest heterogeneity (anisocytosis) of red blood cells. Generally altered values of RWD are interpreted upon MCV to differentiate anaemia. RWD lower than 14.5% and MCV less than 94 fl produce anaemia due to iron and folic acid deficiency, vitamin B_{12} deficiency, haemolytic and immunizing anaemia and cold aglutinines occur too. In the presented study group there were 71.87% such results.

Haematocrit represents erythrocyte mass volume/total blood volume ratio and is determined by centrifuging in calibrated test tube or capillary dish under specified conditions (speed and time). Lowered HTC occurs in anaemias and its higher values in erythemias. In our study group nearly half of the examined girls had HTC below the norm, which is alarming though. Mean HGB was 12.86 g/dl and nearly 10% of the examined girls had HGB lower than normal. Haematological data suggested that the girls examined did not have normal blood cell count results (23). Considerably reduced oxygen consumption and physical efficiency are often observed in anaemias characterized by decreased RBC, HGB concentration and total erythrocyte volume in the circulating blood lower than the norm. Typical manifestations include pallor, dyspnoea, tachycardia, drowsiness and lowered tolerance to physical effort. The most common among women is iron deficiency anaemia. Clinically there are also anaemias due to folic acid and vitamin B_{12} deficiency, haemolytic, plastic anaemias and anaemias in the course of chronic diseases. Heamatological assessment of basic parameters can help predict the type of anaemia an examined person has (24). To precisely diagnose the type of anaemia the person has other additional investigations are necessary.

In Poland physical condition of youth has been investigated systematically by Przewęda, the research began as early as in 1932 by Mydlarski (25). Accelerated somatic development of Polish youth goes together with earlier sexual maturity; also secular trends of tall body height prove good health of the population (26, 27, 28, 29, 30). However it is also true that Polish population is among least physically active, which does not allow to presume advantageous trends (31, 32). Circulatory and respiratory efficiency examined in students of Katowice universities, using Cooper's test, indicates unfavourable phenomenon of decrease of physical efficiency among young girls (12). These findings confirm the results of our study. Unsatisfactory results of our investigation could have been caused by ill-balanced diet and lack of directed physical activity detected in the group of examined girls.

The results of the presented study let us conclude that the state of physical efficiency of the examined girls did not fit the norms of physical efficiency for their age and erythrocyte parameters obtained during the investigations went beyond the norm. The results confirmed very weak oxygen efficiency among girls. Unsatisfactory results of our investigation could have been caused by ill-balanced diet and lack of directed physical activity detected in the group of examined girls.

REFERENCES

1. Traczyk W.Z., Trzebieski A. 2007. Fizjologia człowieka z elementami fizjologii stosowanej i klinicznej. PZWL Warszawa.
2. Kozłowski S., Nazar K. 1995. Wprowadzenie do fizjologii klinicznej. PZWL Warszawa.
3. Hawkins S.A., Wiswell R.A. Rate and mechanism of maximal oxygen consumption decline with aging: Implications for exercise training. Sports Medicine 2003; 33: 877-888.
4. Vaisberg M., Tulio de Mello M., Leite Seelaender M.C., Thomatieli dos Santos R.V., Costa Rose L.F.B. Reduced maximal oxygen consumption and overproduction of proinflammatory cytokines in athletes. Neuroimmunomodulation 2007; 14: 304-309.
5. Lukaski H.C. Magnesium, zinc and chrominum nutriture and physical activity. Am J Clin Nutr 2000; 72: 585S-593S.
6. Nunes R.A., Vale R.G., Simão R., et al. Prediction VO2max during cycle ergometry based on submaximal ventilatory indicators. J Strength Cond Res 2009; 23: 1745-1751.
7. Cink R.E., Thomas T.R. Validity of the Astrand-Ryhming nomogram for predicting maximal oxygen intake. Br J Sports Med 1981; 15: 182-185.
8. Jaskólski A., Jaskólska A. 2006. Podstawy fizjologii wysiłku fizycznego z zarysem fizjologii człowieka. AWF Wrocław.
9. Magiera A. Określanie poziomu wydolności fizycznej za pomocą wspomaganych komputerowo (CAE) testów pośrednich. Sport Wyczynowy 2000; 11/12: 58-68.
10. Maj S. Wartość diagnostyczna wskaźników krwinek czerwonych. Diagn Lab. 1990; 26: 3.
11. Suliga E. Physical development and work capacity of short-statured boys and girls from the świętokrzyski region *Phys Educ Sport 2006; 50: OA43-47.*
12. Palica D. Wydolność krążeniowo-oddechowa – wyniki testu Coopera u studentek katowickich uczelni. Wychowanie Fizyczne i Zdrowotne 2008; 1: 17-22.
13. Hyde T.E., Gengenbach M.S. 2007. Conservative Management of Sports Injuries. Jones & Bartlett Sudbury.
14. Kainulainen H. Run more, perform better--old truth revisited. J Appl Physiol 2009; 106: 1477 - 1478.
15. El-Sayed M.S., Ali N., Al-Bayatti M. Aerobic power and the main determinants of blood rheology: is there a relationship? Blood Coagul Fibrinolysis 2009; 20: 679-685.
16. Nagasawa T. Oxygen consumption in nonexercising muscle after exercise. Int J Sports Med 2008; 29:624-829.
17. Geddes A., Linda F. 2007. Superhuman. New Scientist. Jones & Bartlett Sudbury.
18. Bouchard C., An P., Rice T., et al. Familial aggregation of VO(2max) response to exercise training: results from the HERITAGE Family Study. J Appl Physiol 1999; 87: 1003–1008.
19. Cohn J.N. Quantitative exercise testing for the cardiac patient: the value of monitoring gas exchange: introduction. Circulation 1987; 76(suppl VI): I-1–VI-2.
20. Bouchard C., Daw E.W., Rice T., et al. Familial resemblance for VO_2max in the sedentary state: the HERITAGE family study. Med Sci Sports Exerc . 1998; 30: 252–258.
21. Gonzalez N.C, Kirkton S.D., Howlett R.A. et al. Continued divergence in VO_2max of rats artificially selected for running endurance is mediated by greater convective blood O_2 delivery. J Appl Physiol 2006; 101: 1288-1296.

22. Halicka-Ambroziak H.D., Jusiak R., Martyn A., i wsp. 2001. Wskazówki do ćwiczeń z fizjologii dla studentów wychowania fizycznego. AWF Warszawa.
23. Angielski Ś., Jakubowski Z., Dominiczak M.H., Kabata J. 2001. Biochemia kliniczna. SOPOT.
24. Buys M.C., Guerra L.N., Martín B., et al. Prevalence of anemia and iron deficiency in 12 year old school children from Jujuy (Article in Spanish) Medicina (B Aires) 2005; 65: 126-30.
25. Przewęda R. Jak się zmienia kondycja fizyczna polskiej młodzieży. Wychowanie Fizyczne i Sport 2002; 46 (supl.1): 166-167.
26. Pilicz S., Przewęda R., Dobosz J., Nowacka-Dobosz S. 2004. Punktacja sprawności fizycznej młodzieży polskiej wg Międzynarodowego Testu Sprawności. Kryteria pomiaru wydolności organizmu testem Coopera. Studia i Monografie. AWF Warszawa.
27. Zuchora K., Cendrowski Z. 2005. Indeks Sprawności Fizycznej. AWF Warszawa.
28. Karski J. B. 2008. Postępy promocji zdrowia. Przegląd międzynarodowy. CeDeWu Warszawa.
29. Dobrzański T. 1989. Medycyna wychowania fizycznego i sportu. Sport i Turystyka Warszawa.
30. Pietras A., Kużdżała A., Walaszek R. Wydolność fizyczna dziewcząt 14 i 15 letnich w świetle testu wysiłkowego PWC 170. Wychowanie Fizyczne i Zdrowotne 2008; 6: 30-33.
31. Rochowicz F. Wydolność fizyczna – świadoma wartość zdrowia. Lider 2008: 9: 25-27.
32. Klimowicz P. 2005. Porównanie poziomu wydolności tlenowej studentów o różnej aktywności fizycznej. W: Współczesna kultura fizyczna studentów w teorii i praktyce. WSB Poznań.

ABSTRACT

Objective: The purpose of the study was to assess maximal oxygen consumption (VO_2max) and refer its values to blood test parameters.

Material/Methods: In 64 health 18-year old girls their physical efficiency and blood cell count were evaluated. VO_2max which is one of the best criteria to evaluate physical efficiency was indirectly measured by step test. The values of VO_2max calculated from the frequency of heart rate and power at effort were related to blood test results. In order to find the correlation between maximal oxygen consumption and blood test results Person correlation coefficient and linear determination index were used.

Results: We observed very weak oxygen efficiency among the examined girls. Red cell distribution width over the norm was noted in 21.87% of cases and under the norm in 9.37%. There were 71.87% results of red cell distribution width less than 14.5% and mean corpuscular volume lower than 94 fl. 45.31% of girls had haematocrit value below the norm. Mean haemoglobin level was 12.86 g/dl and in 9.37% of girls this parameter was lower than normal. Mean corpuscular haemoglobin concentration ranged below the norm in 34.37% of cases. In studied group no significant correlations between VO_2max and erythrocyte parameters were found.

Conclusion: The state of physical efficiency of the examined girls did not fit the norms of physical efficiency for their age and erythrocyte parameters obtained during the investigations went beyond the norm. The results confirm very weak oxygen efficiency among studied girls.

Key words: physical fitness, oxygen efficiency, maximal oxygen consumption, anaemia, iron deficiency, blood cell count

STRESZCZENIE

Celem niniejszej pracy była ocena maksymalnego pobieranie tlenu przez organizm (VO_2max) oraz odniesienie jej do uzyskanych wskaźników czerwonokrwinkowych.

Materiał/Metody: Badaniem objęto 64 dziewczęta w wieku 18 lat u których oceniano wydolność fizyczną i dokonywano pomiaru morfologii krwi. W badaniach zastosowano metodę pośredniego pomiaru VO_2max mierzonej testem stopnia, należącą do jednych z najlepszych kryteriów oceny wydolności fizycznej. Obliczone w oparciu o częstość skurczów serca i moc rozwijaną w czasie wysiłku VO_{2max} odniesiono do wyników morfologii krwi.

Dla opisania związku pomiędzy maksymalnym poborem tlenu oraz wynikami morfologii krwi dokonano obliczeń współczynnika korelacji Persona oraz wskaźnika determinacji liniowej.

Wyniki: Zaobserwowano bardzo słabą wydolność tlenową u badanych dziewcząt. Wskaźnik rozkładu objętości krwinek czerwonych powyżej normy zarejestrowano u 21,87% badanych, poniżej normy u 9,37%. 71,87% dziewcząt wykazywało wskaźnik rozkładu objętości krwinek czerwonych poniżej 14,5% i średnią objetość erytocyta niższą niż 94 fl. Poziom hemotokrytu poniżej normy zanotowano w 45.31% przypadków. Średni poziom hemoglobiny w badanej grupie wynosił 12.86 g/dl i u 9.37% badanych dziewcząt wykazywał wartości poniżej normy. Wskaźnik średniej masy hemoglobiny w krwince czerwonej poniżej wartości prawidłowych zaobserwowano w 34.37% przypadków. Nie zanotowano znamiennych korelacji pomiędzy VO_2max a wynikami poszczególnych wskaźników czerwonokrwinkowych.

Wnioski: Stan wydolności fizycznej badanych 18-letnich dziewcząt nie mieści się w granicach sprawności fizycznej dziewcząt w ich wieku, a analiza wskaźników czerwonokrwinkowych również wykracza poza wartości graniczne. Uzyskane rezultaty wskazują na bardzo słabą wydolność tlenową w analizowanej grupie dziewcząt.

Słowa kluczowe: wydolność fizyczna, maksymalne pochłanianie tlenu, niedokrwistość, niedobór żelaza, morfologia krwi.