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Originalni naučni rad
Original study
UDK 796.015.57:796.077.2-055.1

JEDNOSTAVAN, POUZDAN STEP-TEST ZA INDIREKTNU PROCENU AEROBNE SPOSOBNOSTI

A SIMPLE AND RELIABLE STEP-TEST FOR INDIRECT EVALUATION OF AEROBIC CAPACITY

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Sažetak - Da bi fizička aktivnost imala povoljan zdravstveni efekat, treba je pravilno dozirati u odnosu na aerobnu sposobnost svakog pojedinca. Pri ispitivanju velikog broja ljudi neophodno je primeniti brz, pouzdan, jeftin i lako primenjiv test. Cilj rada je da proverimo primenjivost novog step-testa na populaciji fizički aktivnih ispitanika. Trideset osam sportista muškog pola, uzrasta 16,6±0,3 i 38 nesportista istog uzrasta i pola testirani su Astrandovim progresivnim testom opterećenja na bicikl-ergometru i novim ergometrijskim step-testom. U step-testu je korišćeno opterećenje od 12 kJ, visina klupice (h) određivana je prema telesnoj masi ispitanika po formuli h = W / 2TM · g · n (n = broj stepova u minuti, to jest 25/min). Test je trajao 6 minuta. Vrednosti VO_2max određivane su prema nomogramu, u odnosu na W i srčanu frekvencu. Poređenjem izračunate vrednosti za VO_2max u Astrandovom i step-testu utvrđeno je da nisu dobijene značajne razlike u obe grupe: sportisti (3505,6±784,7 vs. 3294,9±653,4 mL·min^{-1} za step-test; p > 0,05), nesportisti (2563,3±469,3 vs. 2471,8±353,6 mL·min^{-1}; p > 0,05). Mišljenja smo da novi, modifikovani step-test može da zameni inače najčešće upotrebljavani test za indirektnu procenu kondicionog stanja - Astrandov test.
Ključne reči: Test opterećenja; Potrošnja kiseonika + fiziologija; Fizička spremnost; Sport; Kardiovaskularne bolesti + prevencija i kontrola

Summary - *Substantial data confirm the benefits of physical activity, but it is necessary to prescribe exercise correctly in regard to aerobic capacity of each patient. When undertaking investigation of a great number of people, it is necessary to apply a simple, fast, reliable and inexpensive test. The aim of this study was to evaluate the validity of a new step-test in physically active subjects. Thirty-eight male athletes (mean age 16.6 ±0.3 years) and 38 nonathletes of the same age, underwent Astrand cycle-ergometer test and a new ergometric step-test. In the ergometric step-test a fixed workload (W) of 12kJ was used, whereas the bench height (h in cm) was determined according to body mass of each subject (h = W/2 · g · n) (W = workload in kJ; BM = body mass in kg; n = step rate, 25 steps + min^{-1}). The step-test lasted 6 minutes. Values of maximal oxygen consumption (VO_2max) were determined using a nomogram, according to workload and heart rate (HR). Comparing data concerning VO_2max in Astrand and step-test, no significant differences were observed in either group: athletes (3505,6 ± 784,7 vs. 3294,9 ± 653,4 mL· min^{-1} for the step-test; p > 0.05) and in nonathletes (2563,3 ± 469,3 vs. 2471,8 ± 353,6 mL + min^{-1}; p > 0.05). In our opinion our new, modified ergometric step-test is a test with high degree of validity and can be used as an easy and fast procedure instead of Astrand test which is most frequently used for indirect evaluation of aerobic capacity.*
Key words: *Exercise Test; Oxygen Consumption + physiology; Physical Fitness; Sports; Cardiovascular Diseases + prevention and control*

Uvod

Poslednjih nekoliko godina pažnja svetske javnosti usmerena je ka proučavanju rizika i pozitivnog uticaja fizičke aktivnosti na funkciju kardiovaskularnog sistema [1-10]. Brojne epidemiološke studije saopštavaju da su fizička neaktivnost i sedentarni način života vodeći faktori rizika za razvoj kardiovaskularnih oboljenja [11-24]. Iste studije iznose da redovna fizička aktivnost aerobnog tipa značajno doprinosi očuvanju zdravlja, smanjuje rizik od infarkta miokarda i drugih kardiovaskularnih oboljenja. Fizička aktivnost aerobnog tipa je stoga u mnogim zemljama sveta sastavni deo primarne i sekundarne prevencije kardiovaskularnih oboljenja [1,2,10,24]. Po ovim preporukama fizičku aktivnost, kao meru primarne prevencije, treba započeti u detinjstvu i sprovoditi je

Introduction

Risks and benefits of physical activity and its effects on cardiovascular system are in the focus of attention in recent years [1-10]. Numerous epidemiological studies concluded that physical inactivity and sedentary lifestyle are risk factors number one for developing of cardiovascular diseases [11-24]. These studies are stressing that regular aerobic physical activity positively affects health, reduces risks of myocardial infarction and other cardiovascular diseases. That is the reason why aerobic physical activity is in many countries part of primary and secondary prevention of cardiovascular diseases [1,2,10,24]. According to these recommendations, regular physical activity as part of primary prevention should start in childhood and continue life long [1,25,26].

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Skraćenice

h	- visina klupice
W	- rad
TM (BW)	- telesna masa
TV (BH)	- telesna visina
ITM (BMI)	- indeks telesne mase
g	- ubrzanje sile gravitacije
VO_2max	- maksimalna potrošnja kiseonika

tokom celog života [1,25,26]. Da bi se obezbedio najveći broj zdravstveno povoljnih efekata fizičke aktivnosti, ona mora biti programirana i individualno dozirana. To je proces koji zahteva individualni pristup svakoj osobi, uz pažljivo proučavanje istorije bolesti, faktora rizika, navika i ličnih ciljeva svakog pojedinca [10]. Doziranje fizičke aktivnosti podrazumeva: određivanje oblika, trajanja, intenziteta, učestalosti i načina progresije intenziteta fizičke aktivnosti. Najpreciznije doziranje fizičke aktivnosti postiže se korišćenjem individualnih vrednosti maksimalne potrošnje kiseonika.

Maksimalna potrošnja kiseonika (VO_2max) najbolji je pokazatelj aerobne sposobnosti organizma, tj. funkcionalne sposobnosti kardiovaskularnog i respiracionog sistema i sposobnosti tkiva da iskoriste kiseonik. Definiše se kao maksimalna količina kiseonika koju organizam potroši u jedinici vremena pri radu progresivno rastućeg intenziteta, koja se pri daljem porastu intenziteta rada ne može povećati. Maksimalna potrošnja kiseonika kao mera aerobne sposobnosti ustanovljena je kao internacionalni standard za fizičku sposobnost [27,28].

Osnovna merna jedinica za maksimalnu potrošnju kiseonika jeste njena apsolutna vrednost izražena u litrima ili mililitrima kiseonika u minutu (L min^{-1}; mL min^{-1}). Međutim, na apsolutnu vrednost VO_2max u velikoj meri utiče telesna masa, pa je stoga objektivnije i opšteprihvaćeno izražavanje aerobne sposobnosti u relativnim jedinicama - mililitrima po kilogramu telesne mase u minutu (mL kg^{-1} min^{-1}). U kliničkoj praksi VO_2max često se izražava u jedinicama metaboličkog ekvivalenta (MET). Jedan MET jeste vrednost relativne potrošnje kiseonika u uslovima mirovanja i približno iznosi 3,5 mL kg^{-1} min^{-1} ako osoba leži, odnosno 4,0 ml kg^{-1} min^{-1} ako osoba stojii. Vrednost VO_2max u MET-ima preračunava se deljenjem vrednosti relativne potrošnje kiseonika sa 3,5 [28,29]. Ona nam pokazuje koliko puta je povećana vrednost potrošnje kiseonika u odnosu na stanje mirovanja.

Određivanje aerobne sposobnosti moguće je izvršiti sa velikom preciznošću direktnim merenjem maksimalne potrošnje kiseonika u laboratorijskim testovima maksimalnog fizičkog opterećenja. Sa većom ili manjom tačnošću možemo je i indirektno proceniti iz različitih submaksimalnih laboratorijskih i

Abbreviations

h	- bench height
W	- workload
BW	- body weight
BH	- body height
BMI	- body mass index
g	- gravitation
VO_2max	- maximal oxygen consumption

The effects of regular physical activity are: increase in physical ability, improvement of health and decrease of risks for various diseases. For best effects on health, physical activity should be accurately programmed and individually adjusted. It is a process that requires an individual approach to every person, evaluating personal health history, risk factors, habits and personal goals [10]. Prescription of physical activity includes: type of activity, time-schedule, intensity, frequency and planned progression of physical activities. The best results in prescription of physical activity are achieved by personal maximal oxygen consumption values evaluation.

Maximal oxygen consumption (VO_2max) is the best indicator of aerobic capacity and of functional ability of cardiovascular and respiratory systems and the ability of tissues to use oxygen. It is defined as the volume of oxygen used by tissues of the body, during graded exercise test, which cannot be further increased by raise of work rate. VO_2max, as an indicator of aerobic capability is widely accepted as the standard unit of physical ability [27,28].

Maximal oxygen uptake is expressed in liters or millilitres of oxygen per minute (L min^{-1}; mL min^{-1}). Absolute value of VO_2max greatly depends on body mass, thus, it is more accurate to express VO_2max as relative value, millilitres of oxygen per one kilogram of body mass per one minute (mL kg^{-1} min^{-1}). It is accustomed that in clinical use the value of VO_2max is expressed in metabolic equivalents (METT). One METT is a value of relative oxygen consumption in rest condition which is 3.5 if a person is laying, and 4.0 if a person is standing. Value of VO_2max may be calculated by dividing relative VO_2max by 3.5 [28, 29]. This value represents the degree of oxygen consumption in comparison to rest condition.

Aerobic capacity can be measured directly very accurately in laboratories, using tests of maximal physical workrate. Aerobic consumption can be estimated by numerous laboratory and field submaximal tests. Mostly used submaximal tests on treadmill and cycle-ergometer fulfill requirements to be called ergometric, but majority of them are inappropriate for testing large groups, they require specific and relatively expensive equipment. For testing large groups of people, outdoors, in short periods of time, ergometric tool of first choice is a step-bench.

terenskih testova. Postojeći submaksimalni ergometrijski testovi za procenu potrošnje kiseonika na tredmilu i bicikl-ergometru udovoljavaju kriterijumima po kojima se mogu svrstati u grupu ergometrijskih testova, ali su nepraktični za testiranje velikog broja ispitanika, zahtevaju posebne uslove i relativno skupu opremu. Kada test treba primeniti kod većeg broja osoba istovremeno ili za relativno kratko vreme u terenskim uslovima, step-klupica je ergometar izbora.

Nažalost, većina testova koji se izvode na step-klupici (tzv. step-testovi) nije standardizovana jer nije zadovoljen osnovni preduslov indirektne procene aerobne sposobnosti - da je spoljašnji rad za sve ispitanike isti.

Na osnovu matematičkog modela mi smo konstruisali novu klupicu za step-test - modifikovana step-klupica (po Vanovićevoj [30]). Suština novine je mogućnost lake izmene visine klupice prema telesnoj masi ispitanika, čime spoljašnji rad postaje standardizovan-isti za sve ispitanike.

Cilj nam je bio da proverimo primenljivost novog step-testa na populaciji fizički aktivnih ispitanika - sportista i da utvrdimo da li novi step-test može da zameni najčešće upotrebljavani test za indirektnu procenu kondicionog stanja kod sportista - Astrandov test.

Materijal i metode

Istraživanjem je obuhvaćeno 38 sportista muškog pola (srednja starost 16,6±0,3 godine), koji se bave različitim sportskim disciplinama i 38 nesportista istog uzrasta.

Sva merenja (antropometrijska i funkcionalna) vršena su u laboratorijskim uslovima, uvek u isto doba dana, istim instrumentima, istom tehnikom i po standardnoj proceduri.

Antropometrijska merenja vršena su po protokolu CSTF (*Canadian Standardized Test of Fitness* [31]), koji sadrži standardizovanu listu antropometrijskih mera koja se realizuje po uniformnoj proceduri.

Vrednost maksimalne potrošnje kiseonika procenjena je pomoću progresivnog kontinuiranog submaksimalnog testa na bicikl-ergometru po Astrandovom protokolu [32].

Neposredno testiranje započinjali smo merenjem frekvencije srčanog rada - f_c (udara/min) i arterijskog krvnog pritiska u mirovanju - TA (mmHg), pridržavajući se uslova protokola. Merenje je vršeno posle petominutnog psihofizičkog opuštanja ispitanika u sedećem stavu. Frekvencija srčanog rada merena je pomoću stetoskopa postavljenog na grudi u projekciji vrha srca.

Kao početno radno opterećenje određena je vrednost od 100 W (600 kP/min), s obzirom na to da se radi o zdravoj mladoj populaciji. Po podešavanju odgovarajuće visine sedišta, ispitanicima je naloženo da okreću pedale istim ritmom (ritam je

Unfortunately, majority of step-tests are not standardized, because the main requirement for estimation of aerobic consumption is not fulfilled - the same workload for all subjects.

According to a mathematical model, we designed a new step-bench - modified step-bench (modification by Vanović). The innovation concerns adjustment of the bench height according to body mass of the subject. By this, we standardized the workload - the same for all subjects.

The aim of this study was to evaluate the validity of a new step-test for testing physically active subjects - athletes and to determine if it is possible to use it instead of a mostly used test for indirect estimation of aerobic consumption in athletes - Astrand test.

Material and methods

The investigation included 38 male adolescent athletes (average age 16.6±0.3) and 38 male non-athletes of the same age.

All the measurements, anthropometric and functional, were conducted in laboratory conditions, at the same time of the day, using same instruments, techniques and a standard procedure. Anthropometric measurements were done according to CSTF (*Canadian Standardized Test of Fitness*) [31]. It is a standardized list of measurements which is conducted according to a standardized procedure.

VO_2max was estimated using continuous progressive submaximal test on Astrand cycle-ergometer [32].

The test started by measurement of heart rate (HR, in beats/min) and arterial blood pressure (BP, in mm Hg) at rest, after 5 minutes of subject's complete relaxation in sitting position. Heart rate was measured by stethoscope applied on the front chest wall, at the projection of heart apex.

Considering the fact that our subjects were young and apparently healthy, we decided to set the initial workload at 100 W (600 kP/min). After adjusting appropriate height of the seat, subjects started pedaling at the rate of 50 rpm (which was controlled on the speedometer), for exactly 6 minutes. The workload was increased by 50 W every six minutes. Heart rate was measured during the second half of each minute. Reference value was calculated by multiplying heart rates in the second half of the minute by two, whereas BP was registered at the middle of each six-minute period.

The test was interrupted at the end of any six-minute period in which HR value was 130-140 beats/minute and the steady state was established (steady state: difference in HR in two consecutive measurements less than 5 beats/minute).

Mean HR value in steady-state was used for determination of absolute VO_2max. Using this value, Astrand's and Rhyming's nomograms, and with correction factor for the age of subjects, we calculated kontrolisan na brzinometru - 50 okretaja u minuti) u toku šest minuta. Opterećenje je povećavano za 50W na kraju svakog šestominutnog perioda. U drugoj polovini svakog minuta merena je srčana frekvencija. Referentna vrednost dobijana je tako što je broj srčanih otkucaja u poslednjih 30 sekundi svakog minuta pomnožen sa dva. Na polovini svakog šestominutnog perioda merena je vrednost arterijskog krvnog pritiska.

Test je prekidan na kraju bilo kog šestominutnog perioda ako je dostignuta vrednost srčane frekvencije između 130 i 140 min^{-1} u stacionarnom stanju (*steady state*), tj. da se izmerene vrednosti u dva poslednja merenja razlikuju za manje od 5 udara u minutu, što je znak ulaska u stacionarno stanje. Prosečna vrednost srčane frekvencije ostvarene u stacionarnom stanju korišćena je za očitavanje maksimalne potrošnje kiseonika iz nomograma.

Za izračunavanje maksimalne potrošnje kiseonika korišćena je vrednost srčane frekvencije u stabilnom stanju. Pomoću ove vrednosti i nomograma Astranda i Rhyminga, uz korekciju za godine starosti, izračunavali smo vrednosti apsolutne potrošnje kiseonika ($mL \cdot min^{-1}$). Relativnu potrošnju kiseonika izračunali smo kao apsolutnu potrošnju kiseonika izraženu na kilogram telesne mase ispitanika ($mL \cdot min^{-1} \cdot kg^{-1}$), a deljenjem ove vrednosti sa 3,5 dobili smo vrednost u MET-ima.

Jedan sat po završetku prvog testa započeto je ispitivanje na step klupici. U ergometrijskom steptestu koristili smo opterećenje (W) od 12 kJ, budući da se radi o zdravoj, mladoj populaciji. U prethodnim istraživanjima utvrđeno je da je rad od 12kJ (200W), prema načinu obezbeđenja energije, aerobni rad. Visinu klupice (h) odredili smo prema telesnoj masi (TM) ispitanika po formuli

$h = W / 2TM \cdot g \cdot n$,

(W = 12 kJ, n = broj penjanja u minuti, tj. 25 min^{-1}; g = 9,81 m/s). Tabela u prilogu. Visina klupice se podešava jednostavnim podizanjem drvene prečage koja klizi po graduisanoj metalnoj šini. Test traje 6 minuta. Ritam penjanja kontrolisali smo upotrebom metronoma. Odmah po završetku testa ispitanik seda na klupicu. Srčanu frekvencu merili smo u

Tabela 1. Vrednosti telesne mase - BW (kg), telesne visine - BH (cm) i indeksa telesne mase - BMI ($kg \cdot m^{-2}$) u grupi sportista i nesportista

Table 1. *Values of body weight - BW (kg), body height - BH (cm) and body mass index - BMI (kg÷m/s2) in athletes and nonathletes*

	X	SD	CV(%)	Min	Max	p
BW (kg)	[1]75,20	10,25	14	62,40	112,10	0,05
	[2]69,05	8,49	12	54,60	87,40	
BH (cm)	[1]181,01	0,0812	4	167,00	202,00	0,05
	[2]178,53	0,0631	4	167,00	191,50	
BMI	[1]22,930	6,221	27	20,080	30,570	0,05
	[2]21,695	2,771	13	18,270	29,720	

[1] grupa I - sportisti; [2] grupa II - nesportisti

[1] group I - athletes; [2] group II - nonathletes

absolute value of maximal oxygen consumption. Relative VO_2max was calculated by dividing absolute VO_2max by body mass of tested person. The results in metabolic equivalents (METTs), were found when relative VO_2max was divided by 3.5.

One hour after finishing the Astrand test, our subjects performed the test on a step-bench. For this test, we used an initial workload (W) of 12 kJ, since subjects were young and apparently healthy. During previous investigations we found that work of 12 kJ (200 W) is aerobic work. Height of the bench (h) was determined according to body mass

$h = W/2TM \cdot g \cdot n$;

(W =12 kJ; n = 25 steps/min; g = 9.81 m/s) (Table 1). The hight of the bench was easily adjusted to subjects height by moving wooden bench on a graduated metal scale. The test lasted 6 minutes. Rhythm was determined and controlled by a metronome. Immediately after finishing the test, subjects had to sit down on the bench. Heart rate was measured from 15th to 30th second of the recovery period by putting stethoscope on spot that is projection of heart apex. Values of absolute VO_2max were calculated according to nomogram, based on workload (W) and HR measured in recovery period (15 seconds) (Nomogram).

Results

There was no statistically significant difference in body height (BH) ($p > 0.05$) between groups of subjects involved in our investigation, but differences in body mass (BM) and body mass index (BMI) were considerable ($p < 0.05$) (Table 1).

Values of absolute VO_2max, relative VO_2max and METT values, calculated by Astrand test and steptest [30) are statisticaly highly significantly different ($p < 0.001$) in groups of athletes and non-athletes (Table 2).

Tabela 2. Vrednosti maksimalne kiseoničke potrošnje VO_2 max: apsolutne ($mL \cdot min^{-1}$), relativne ($mL \cdot min^{-1} \cdot kg^{-1}$) i izražene u jedinicama metaboličkog ekvivalenta (MET) u grupi sportista i nesportista dobijene upotrebom Astrandovog testa

Table 2. *Values of maximal oxygen consumption - VO_2max; absolute ($mL \cdot min^{-1}$), relative ($mL \cdot min^{-1} \cdot kg^{-1}$) and metabolic equivalents (MET) in athletes and nonathеletes, acquired by Astrand test*

VO_2max	X	SD	p
apsolutna	[a] 3503,8	781,3	< 0,001
absolute	[b] 2569,9	471,3	
relativna	[a] 46,587	8,344	< 0,001
relative	[b] 37,638	7,629	
MET	[a] 13,311	2,384	< 0,001
	[b] 10,754	2,180	

[a] vrednosti za sportiste, n = 38; [b] vrednosti za nesportiste, n = 38

[a] values for athletes, n = 38; [b] values for nonathletes, n = 38

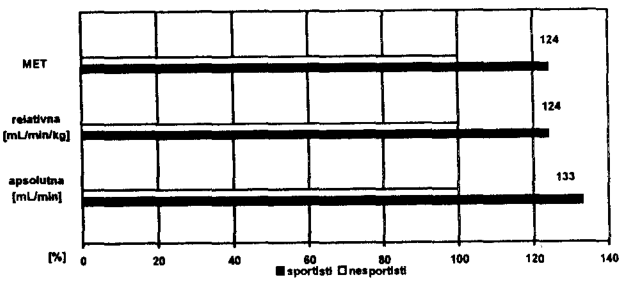
intervalu od 15 do 30 sekunde (broj udara/15 sekundi) prislanjanjem stetoskopa na grudi u projekciji vrha srca. Predviđene vrednosti VO_2max (apsolutne) očitavali smo prema nomogramu, u odnosu na opterećenje (W) i 15-sekundnu srčanu frekvencu.

Rezultati

Antropometrijska merenja pokazuju da ne postoji statistički značajna razlika u telesnoj visini (BH) ispitanika ($p > 0,05$), ali da postoje statistički značajne razlike ($p < 0,05$) u telesnoj masi (BW) i indeksu telesne mase (BMI) (tabela 1).

Primenom Astrandovog testa kao i primenom modifikovanog step-testa [30] vrednosti apsolutne maksimalne potrošnje kiseonika - VO_2max ($mL \cdot min^{-1}$) i vrednosti relativne maksimalne potrošnje kiseonika - VO_2max ($mL \cdot min^{-1} \cdot kg^{-1}$), kao i vrednosti izražene u jedinicama metaboličkog ekvivalenta (MET) pokazuju statistički visokoznačajne razlike ($p < 0,001$) između grupe sportista i nesportista (tabela 2).

Na grafikonu 1 dato je procentualno poređenje vrednosti VO_2max. Vrednosti izmerene u grupi nesportista uzete su kao 100%.



Grafikon 1. Odnos vrednosti maksimalne kiseoničke potrošnje: izražene u jedinicama metaboličkog ekvivalenta (MET), relativne ($mL \cdot min^{-1} \cdot kg^{-1}$) i apsolutne ($mL \cdot min^{-1}$) u grupi sportista i nesportista dobijene primenom modifikovanog step-testa (po Vanovićevoj)

Fig. 1. *Comparison of VO_2max values: metabolic equivalent (MET), relative ($mL \cdot min^{-1} \cdot kg^{-1}$) and absolute ($mL \cdot min^{-1}$) in athletes and nonatheletes obtained by using a modified step-test (modified by Vanović)*

Vrednost apsolutne potrošnje kiseonika VO_2max dobijene upotrebom modifikovanog step-testa u grupi sportista iznosi 3294,9±653,4 ml min^{-1} (raspon od 3001 do 4415 $mL \cdot min^{-1}$), dok u grupi adolescenata koji se ne bave sportom aktivno iznosi 2471,8±353,6 mL min^{-1}. Razlika je statistički visokoznačajna ($p<0,001$). Vrednost relativne maksimalne potrošnje kiseonika ($mL \cdot min^{-1} \cdot kg^{-1}$) takođe pokazuje statistički visokosignifikantne razlike, kao i vrednost izražena u jedinicama metaboličkog ekvivalenta (MET).

Poređenjem izračunatih vrednosti za VO_2max u Astrandovom i modifikovanom step-testu (grafikon 2), nisu dobijene značajne razlike, u obe grupe: sportisti (3503,8±781,3 prema 3294,9±653,4 $mL \cdot min^{-1}$

Figure 1 shows a comparison of VO_2max values (%). Those in nonathletes were taken as reference values (as 100%).

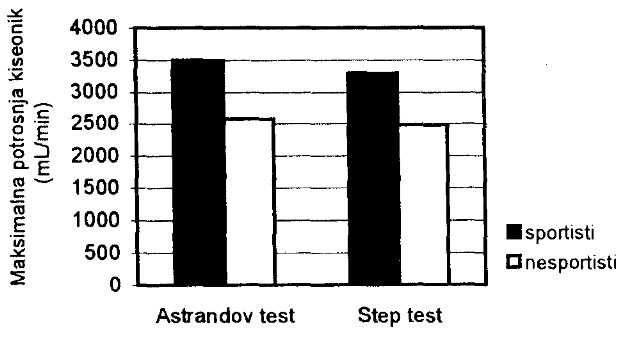
Absolute VO_2max values acquired using a modified step-test in the group of athletes were 3,294.9 ±653.4 $mL \cdot min^{-1}$ (3001-4415 $mL \cdot min^{-1}$) and 2,471.8±353.6 $mL \cdot min^{-1}$ in the group of nonathlete adolescents. Those values differed significantly ($p < 0.001$). Values of relative VO_2max ($mL \cdot min^{-1} . kg^{-1}$) and METT-values also showed statistically significant differences.

Compared values of VO_2max calculated using Astrand test and modified step-test (Figure 2), showed statistically insignificant differences (3,505.6± 784.7 vs. 3,294.9±653.4 $mL \cdot min^{-1}$; $p > 0.05$) and in the group of non-athletes (2,563.3±69.3 vs. 2,471.8±53.6 $mL \cdot min^{-1}$; $p > 0.05$).

Discussion

According to data published by Petrella and Wight who conducted a research in Canadian general practitioners, in spite of their positive attitude towards physical activity, doctors rarely prescribe physical activity to their patients. Lack of information in the area and lack of easy and reliable equipment [33] that can be used for determination of current physical status, are some of the reasons why medical doctors do not often prescribe this kind of therapy.

From physiological point of view, an ergometric assessment of aerobic capacity should be done by using a test or protocol, which: 1) Ensures dynamic, cyclic movements, which engages more than one muscle group. That is the only way to activate the cardiovascular system in a way which permits assessment of aerobic capacity; 2) Has the possibility to dose the amount of external (mechanical) work, which can be expressed in units of mechanical work [30].



Grafikon 2. Vrednosti za VO_2max dobijene upotrebom Astrandovog i modifikovanog ergometrijskog step-testa

Fig. 2. *Values of VO_2max obtained by Astrand and modified ergometer step-test*

za step-test; $p > 0,05$), nesportisti (2569,9 ± 471,3 prema 2471,8±353,6 mL · min^{-1}; $p > 0,05$).

Diskusija

Prema podacima koje iznose Petrella i Wight, u istraživanju sprovedenom na populaciji kanadskih lekara opšte medicine, uprkos pozitivnom odnosu prema fizičkoj aktivnosti u cilju unapređenja zdravlja, lekari retko "propisuju" doziranu fizičku aktivnost svojim pacijentima. Razlozi za to su brojni, a među glavnima jesu nedostatak znanja iz te oblasti i nedostatak jednostavne i pouzdane aparature [33] na osnovu koje bi se precizno, brzo, lako i bez velikih ulaganja "propisao" potreban stepen fizičke aktivnosti.

Sa fiziološkog stanovišta, ergometrijska procena aerobne sposobnosti podrazumeva: 1) da se u toku testa izvode dinamički ciklični pokreti koji angažuju velike mišićne grupe, jer se jedino tako kardiovaskularni sistem aktivira na način koji omogućava procenu aerobne sposobnosti; 2) da se količina spoljašnjeg (mehaničkog) rada može kontrolisati (dozirati) i izraziti u jedinicama mehaničkog rada [30].

Kao što je navedeno u uvodnim razmatranjima, submaksimalni laboratorijski ergometrijski testovi zadovoljavaju ove uslove. Ali kad test treba primeniti kod većeg broja osoba, za relativno kratko vreme ili u terenskim uslovima, step-klupica je ergometar izbora.

Uopšteno, testovi koji se izvode na step-klupici (tzv. step-testovi) su zdravstveno bezbedni jer ne zahtevaju maksimalna fizička naprezanja, jednostavni su za izvođenje, zahtevaju mali utrošak vremena, malu i ne specijalno obučenu ekipu, transportabilni su, imaju nisku cenu koštanja i skoro su nezamenjivi kod testiranja velikog broja ispitanika.

Osnovni nedostatak većine step-testova je što spoljašnji rad u step-testu nije jednak za sve ispitanike. Po osnovnom zakonu mehanike spoljašnji rad u step-testu jednak je proizvodu sile i pređenog puta. On tako direktno zavisi od visine klupice, brzine penjanja i u najvećoj meri od telesne mase ispitanika [30]. U postojećim step-testovima visina klupice je za sve ispitanike uglavnom ista. Zato je obavljeni mehanički rad za ispitanike različitih telesnih masa samo standardan (izvodi se na isti, tačno određen način), ali ne i standardizovan (isti u jedinicama rada).

Pored toga, u većini testova procena aerobnih sposobnosti vrši se na osnovu frekvencije srčanog rada, a rezultat se izražava u bodovima ili indeksima. Iako pod određenim uslovima bodovi i indeksi mogu biti direktno proporcionalni aerobnoj sposobnosti, oni nisu brojčana (tačna) mera aerobne sposobnosti. Primer je najpoznatiji step-test, Harvardski step-test, osmišljen je još u II svetskom ratu, za potrebe selekcije u američkoj vojsci. Osim Harvardskog step-testa

As already mentioned, laboratory submaximal tests conducted on a step bench (so-called "step-tests") fulfill these demands. But, when there is a need to test large groups, for relatively short time period or outdoors, step-bench is to be used.

In general, step-tests are safe, since they are submaximal. They are easy to perform, last shortly, they require few and not specially trained staff, and step-benches are transportable. They are inexpensive. Those reasons make step-tests practically irreplaceable when there is a need of testing large groups of people.

Step-tests in general are not standardized because the basic condition of indirect assessment of aerobic capacity is not fulfilled - external work must be equal for all the subjects. External work in step-test, by the basic law of mechanics, depends on mechanical force and distance. It depends directly on the height of the bench, step rate and, mostly, on the body mass of the subjects [30]. In existing step-tests height of the bench is fixed and therefore the same for all subjects. Therefore mechanical work for persons with different body mass is standard (performed in the same way), but not standardized (equal in terms of mechanical work applied).

Besides that, in most tests assessment of aerobic capacity is based on heart rate, but results are expressed in points or indexes. Although under certain conditions points or indexes can be proportional to aerobic capacity, they are not its exact measure. The best example is the best-known step-test - Harvard step-test, (developed during the Second World War for the needs of US army). There are a number of other step tests and their modifications [30,34].

Having in mind all this we decided to make a simple step-test whose results could be expressed in units of maximum oxygen uptake and which would be more standardized.

Based on laws of mechanics and a mechanical model of step-test, we found that work (W) done during step-test is directly proportional to body mass (BM), gravitation (g), height of the bench (h) and step-rate (n), according to:

$W=2 \cdot BM \cdot g \cdot h \cdot n$.

External work is constant (12 kJ) as well as step-rate per minute (25 · min^{-1}), by changing the height of the bench, depending on body mass of the subject, it is possible to make work in step-test more standardized, step-test becomes ergometric.

Values of VO_2max obtained in step-test were compared to results of some other tests done in the same subjects (Bruce treadmill protocol, Astrand test on cycle-ergometer, Dobeln's test on cycle-ergometer) and it was found that values of individual coefficients of correlation range from 0.958 to 0.999[30]. This way we showed that the modified step test (according to Vanović) can be compared by accuracy with tests for direct measuring and indirect assessment of maximum oxygen uptake.

postoji čitav niz drugih step-testova i njihovih modifikacija [30,34].

Iz navedenih razloga odlučili smo da pristupimo izradi jednostavnog step-testa, u kome bi spoljašnji rad bio isti za sve ispitanike (standardizovan) i čiji bi se rezultat izražavao u jedinicama maksimalne potrošnje kiseonika.

Polazeći od zakona mehanike i mehaničkog modela step-testa, izračunali smo da je rad koji se vrši tokom step-testa (W) jednak dvostrukom proizvodu telesne mase (BW), ubrzanja koje potiče od gravitacije (g = 9,81 m/s), visine klupice (h) i broja penjanja na klupicu (n)

$W = 2 \cdot TM \cdot g \cdot h \cdot n.$

Ako odredimo spoljašnji rad kao konstantu (doziramo rad, W), odredimo broj penjanja u minuti (konstanta 25 puta u minuti), promenom visine klupice u odnosu na masu ispitanika, moguće je standardizovati rad u step-testu. Naj taj način step-test postaje ergometrijski.

Dobijene vrednosti VO_2max tokom step-testa poredili smo sa rezultatima nekoliko drugih testova, na istim ispitanicima (Bruceov test na tredmilu, Astrandov test na bicikl-ergometru, Dobelnov test na bicikl-ergometru) i pronašli da su vrednosti individualnih koeficijenata korelacije u obimu 0,958 - 0,999 (rezultati nisu prikazani) [30]. Na taj način smo pokazali da se novi ergometrijski step-test po preciznosti može meriti sa opšteprihvaćenim testovima za direktno i indirektno merenje maksimalne potrošnje kiseonika.

Na kraju, daćemo uporedni prikaz karakteristika Astrandovog indirektnog testa na bicikl-ergometru i novog step-testa - modifikacija po Vanovićevoj [30]. Za poređenje sa Astrandovim testom opredelili smo se jer je to najčešće korišćeni indirektni test, kako u populaciji sa zdravstvenim poremećajima, tako i u opštoj i sportskoj populaciji.

	Astrandov test *Astrand's test*	Modifikovani step-test/*Modified step-test*
Specifičnost/*Specificity*	++ *	
Osetljivost/*Sensitivity*	++	++
Preciznost/*Precision*	++	++
Tačnost/*Accuracy*	++	++
Pouzdanost/*Reliability*	++	++
Zdravstvena bezbednost *Health safety*	+++	+++
Obučenost kadrova *Staff training*	veća/*more*	manja/*less*
Jednostavnost/*Simplicity*	kompleksniji *more complex*	jednostavniji/*simple*
Laboratorija/*Laboratory*	neophodna *necessary*	nije neophodna *unnecessary*
Transportabilnost *Transportability*	komplikovana/*complicated*	jednostavna/*easy*
Mogućnost upotrebe na terenu/*outdoors use*	ne postoji/*no*	postoji/*yes*
Trajanje testiranja/*Lasting*	duže/*more*	kraće/*less*
Broj ispitanika na sat/*No of subjects tested in one hour*	mali/*few*	veliki/*many*
Izbor ispitanika/*Subject choice conditions*	samo ko zna da vozi bicikl *Pedaling skill*	opšta/*general*
Cena koštanja/*Cost*	veća/*more*	manja/*less*

* u odnosu na testove u kojima se direktno meri VO_2max, koje bismo označili sa +++/* *Compared to tests for direct measurements of VO_2max which would be marked +++*

Comparison of Astrand indirect submaximal test on cycle-ergometer and modified step-test is given above. We decided to compare our step-test to Astrand test, because it is widely used in indirect testing of different groups of people, with health problems, general population and physically active population - athletes.

Zaključak

Ne postoje statistički značajne razlike između vrednosti VO_2max u Astrandovom i modifikovanom step-testu. Zato se novi, modifikovani ergometrijski step-test može koristiti kao pouzdano sredstvo za brzu procenu maksimalne potrošnje kiseonika i kod fizički aktivnih ispitanika-sportista.

Razlike između Astrandovog i modifikovanog step-testa u zdravstvenoj bezbednosti, specifičnosti, osetljivosti, preciznosti, tačnosti, pouzdanosti jesu minimalne. Zbog prikazanih praktičnih prednosti, mi preporučujemo naš ergometrijski step-test (modifikacija po Vanovićevoj) kao pouzdano sredstvo za određivanje VO_2max.

Conclusion

There were no significant differences in the values of VO_2max comparied results of modified step-test and Astrand test. That is why our modified step-test can be used as a reliable tool for quick estimation of maximal oxygen uptake among physically active subjects.

Differences in Astrand test and modified step-test in terms of safety, sensitivity, accuracy and reliability are minimal. According to practical advantages, we are recommending our ergometric step-test (modification by Vanović) as a reliable protocol for estimation of VO_2max.

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Rad je primljen 10. VII 2001.
Prihvaćen za štampu 16. VII 2001.
BIBLID.0025-8105:(2001):LIV:11-12:522-529.