HIIT VS MODERATE INTENSITY ENDURANCE TRAINING: IMPACT ON AEROBIC PARAMETERS IN YOUNG ADULT MEN

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Abstract
The purpose of this study was to compare the effectiveness of high-intensity interval training such as Billat 30s-30s training (HIIT) vs moderate intensity endurance training (CT+HIIT) on aerobic parameters in young adults men. The study involved 40 young adults men (20,15±0,56 years) who were randomly divided into the two training groups: Billat 30s working at 100% of vVO_2max and 30s recovery of 50% of vVO_2max (HIIT; N=20); and the moderate intensity endurance training (CT+HIIT; N=20). The training programs have lasted 4 weeks, three times per week. The measurement was carried out at two time points at Cosmed treadmill (model T 150) gas analysers (Quark b2) breath-by-breath method. Participants were tested for each of the following parameters: relative maximum oxygen consumption (rVO_{2max}); absolute maximum oxygen consumption (aVO_{2max}); minimum speed that athletes run when they reach VO_{2max} (vVO_2) and maximum heart rate (HR_{max}). To determine difference between effect of trainings, we used a Mixed factorial analysis of variance. Results indicated there was effect from time in rVO_{2max}, aVO_{2max} and vVO_{2max} ($p<0,05$) and effect from group in variable vVO_{2max} ($p<0,05$). There was a significant effect interaction group x time in rVO_{2max} and vVO_{2max}. In conclusion HIIT and CT+HIIT both elicit significant improvements in the aerobic parameters after 4 weeks. However, HIIT was more effective for improving rVO_{2max} and vVO_{2max} than CT+HIIT in healthy, young adults.

Key words: *VO_{2max}, HR_{max}, interval training, continous training.*

Introduction

Coaches and athletes in training most commonly used two methods: high-intensity interval training (HIIT) and continuous training (CT) (Upadhyay & Sandhu, 2016). HIIT involves repeating maximal and/or submaximal sprints for short and/or long periods, separated by recovery periods, which may be passive or active period of rest (Germano, et al., 2015). HIIT due to its potential brings benefits to healthy and sick individuals, and athletes, through several neuromuscular, molecular, metabolic and cardiorespiratory adaptations. CT represent running, brisk walking or cycling at low to moderate intensity (Donnelly, et al., 2009). The relative impact of HIIT versus CT has been debated for decades among athletes, coaches and sports scientists (Seiler & Tonnessen, 2009). In 1986 Astrand and Rodahl have set important but unsolvable question „Which type of trainings (CT vs HIIT) is most effecitve ?" The answer is still being searched for. However, athletes and coaches used both methods based on their experience, imagination and beliefs, and this often can prevent athletes to achieve top results. Several studies (Berthoin, Baquet, Dupont, Blondel, & Mucci, 2003; Tardieu-Berger, Thevenet, Zouhal, & Prioux, 2004; Thevenet, Tardieu-Berger, Berthoin, & Prioux, 2007) have examined the effects of CT or HIIT (i.e. at velocities equal or greater than the velocity at which maximal oxygen consumption (VO_{2max}) is achieved) during puberty on VO_{2max} and/or HR, as well as in adulthood (Billat, Flechet, Petit, Muriaux, & Koralsztein, 1999; Rozenek, Funato, Kubo, Hoshikawa, & Matsuo, 2007). CT and HIIT both elicit large improvements in VO_{2max} of healthy, young to middle-aged adults, but gain in VO_{2max} is greater following in HIIT (Hottenrott, Ludyga, & Schulze, 2012; Hazell, Hamilton, Oliver, & Lemon, 2014; Milanović, Sporiš, & Woeston, 2015). In active young male after 6 sessions HIIT improved VO_{2max} for 6,8% (Astorino, Allen, Roberson, & Jurancich, 2012). In sedentary male adults after 8-week 3 time/weeks HIIT improved VO_{2max} for 22,5% while CT improved for 10% (Matsuo, et al., 2014). In recreational male 42 years HIIT after 12 weeks VO_{2max} improved by 18,6% vs CT improved only for 7,1% (Hottenrott, et al., 2012). It can be noted that depending on the age and fitness level of the subjects as well as the duration of the activities intensity activity of the training improvements of VO_{2max} from 4 to 46% have been reported (Hottenrott, et al., 2012). One of the most popular HIIT for improvement VO_{2max} is training Veroniqe Billat. Veronique recommends using interval training consisting of brief high intensity repetitive runs (30s) alternating with periods of rest (30s) as efficient in improving VO_{2max} in athletes (Billat, et al., 2000). The early study (Billat, et al., 2000) in healthy subjects has shown that intermittent exercise (30s exercise at 100% vVO_2max, separated by 30s rest) achieved better results in VO_{2max} than continuous training at 50%vVO_2max. Combination of this two metods (CT+HIIT) on aerobic parameters are limited in the literature. Roxburgh, Nolan, Weatherwax, & Dalleck (2014) investigate effect 12 week HIIT+CT on VO_{2max} in sedentary participants (36,3 ± 6,9 yrs) with moderate risk of cardiovascular disease. Their (Roxburgh et al., 2014) results show that VO_{2max}

had improved by 10,1%. Since other papers mostly show population with cardiovascular disease, we were interested to compare the impact of a 4 week (3 day per week) intervention consisting of either Billat 30s-30s (HIIT) or CT combined with a HIIT (CT+HIIT) on aerobic parameters in young health male without cardiovascular disease. It was hypothesized that there would be significant differences in the change in aerobic parameters as measured by VO_{2max}, vVO_{2max} and HR_{max} between groups. The aim of this study is to compare the effects among Billat 30s-30s (HIIT) and Moderate intensity endurance training (CT+HIIT) on aerobic parameters in adolescent's men.

Methods

Subjects

Forty physical active young adults male (20,15±0,56 years) randomly divided into the two training groups: Billat 30s working at 100% of vVO_2max and 30s recovery of 50% of vVO_2max (HIIT; N=20); and the moderate intensity endurance training (CT+HIIT; N=20). They training four weeks, three time per weeks. All participants were halthy without diagnosed metabolic or cardiovascular disease and they are students of the second year Faculty of sport and physical education in Novi Sad. Experimental protocol and associated risks had been explained both verbally and in writing to all the subjects before they provided their written consent. The study was according to the Helsinki Declaration.

Procedures

Each participant completed testing. On the first visit the participant performed a maximal incremental treadmill test to asses' aerobic parameters. For all participants testing was conducted in the morning (from 8AM; temperature of 22-23ºC and relative humidity of 40–60%) and completed the same day. After 4 weeks the testing was repeated in similar conditions. The participants were asked to follow their normal diet, to abstain from exercise activity for 48 h before each test and caffeine drinks on the day of the study, and to have sufficient rest the night before the study. All participants had the experience of running on a treadmill. Testing was conducted in Diagnostic center Faculty of Sport and Physical Education University of Novi Sad.

Before the testing, all subjects were given a detailed explanation of the test protocol. All the participants, regardless of the group assignment, were tested for each of the following parameters: aVO_{2max} (l/min) - maximal oxygen consumption in absolute units; rVO_{2max} (ml/kg/min) - maximal oxygen consumption in relative units; vVO_{2max} (km/h) - the minimum speed that athletes run when they reach VO_2max, maintaining this speed must be constant for 1 minute; HR_{max} (bpm) – maximal heart rate.

Protocol of VO_{2max} and vVO_{2max} determination

VO_{2max} test- Participants started walking at the speed of 5 km/h for 2 min (warm-up) on the treadmill (COSMED-model T-150). After the warm up, subject performed a progressive incremental speed treadmill test to determine VO_{2max}. After 2 min the speed on the treadmill increased to 7 km/h, then after 30s it increased to the speed of 7,5 km/h. After every 30s, the treadmill speed increases by 0,5 km/h. Oxygen consumption was collected and analyzed using an online breath-by-breath gas collected system (Quark b2). The highest 15s values for VO_2 recorded as VO_{2max}. Values for heart rate (HR) from the 15s period when VO_{2max} was reached were recorded as the maximal heart rate (HR_{max}). Before test the machine was calibrated. However, in order to check whether the participants has reached their maximum in the test, we used the following criteria (Vučetić & Šetija, 2004)

1. VO_{2max} has reached a peak and still is not growing;
2. HR_{max} is within the range of 10 beats as compared to the provided for maximum frequency for the age of the test;
3. Reaching maximum respiratory quotient (RQ_{max}) during the exhaustion is greater than 1.10.

vVO_{2max} - the velocity at VO_{2max} is established by incremental test in which oxygen consumption is measured whilst increasing the speed in an incremental manner. As the speed is increased oxygen consumption increases linearly until the point at which oxygen consumption is at its maximum. vVO_{2max} is defined as the lowest running speed maintained for more than 1 minute that elicited VO_{2max} (Billat & Koralsztein, 1996).

Training programs

Training programs were conducted in May, 2014. Each group was trained on the tartan track 4 weeks, 3 day per week, and at the same time and with the same conditions**.** After initial mesurement participant's randomization was divided in two groups.

The first group is Billat 30s-30s (HIIT; N=20). This method of training invented Veroniqa Billat (Billat, Binsse, Petit, & Koralsztein, 1998). In the beginning of training participant used 15 minutes of warm-up (running at low intensity - running at 40-50% VO_{2max}). Then they used Billat 30s-30s. Billat method consist running intervals of work with 30s to 100% of vVO_{2max} with rest intervals from 30s to 50% of vVO_2max (Billat, et al., 1998). It is necessary to maintain that pattern as long as possible. For example, a runner who had vVO_2max 16 km/h (4,4 m/s) could run 133,2m for 30s to 100% of vVO2max and half distance of 66 m in 30s, to achieve 50% of vVO_{2max}. The second group is Moderate intensity endurance training (CT+HIIT; N=20) according to the programs in Table 1. This type of training consists of continuous and high-intensity interval training. The intensity of exercise is determined by the duration of running. The period of rest was limited by the heart rate. It is necessary to make the heart rate reaches 120 bpm. When most of the group reached the heart rate of 120 bpm, participants started running. In the periods of rest, they were walking with passive recovery periods.

Table 1. Description of the training program for Moderate intensity endurance training (CT+HIIT)

Week	Traning day	Distance (m)	Intensity (Time of running)
I	Monday	1600 x 1	7min±5s
	Wednesday	800 x 2	3:15min±5s
	Friday	400 x 4	1,17min±3s
II	Monday	300 x 6	52s±2,5s
	Wednesday	200 x 8	33s±2s
	Friday	100 x 10	16,5s±1s
III	Monday	100 x 10	16,5s±1s
	Wednesday	200 x 8	33s±2s
	Friday	300 x 6	52s±2,5s
IV	Monday	400 x 4	1,17min±3s
	Wednesday	800 x 2	3:15min±5s
	Friday	1600 x 1	7min±5s

All training sessions were supervised by trained exercise instructors who had finished bachelor or master studies of Faculty of Sport and Physical Education in Novi Sad.

Statistical Analysis

Data analysis was performed using the Statistical Package for the Social Sciences (v20,0, SPSS Inc., Chicago, IL, USA). Effects of different methods on aerobic parameters determined Mixed factorial design analysis of variance. Post-hoc Bonferroni test was used to determine differences among the groups. Paired-Simple T-test was used to determine the difference between the initial and final measuring of each group specifically for a particular variable. The Kolmogorov-Smirnov tests showed that data were normally distributed, and no violation of homogeneity of variance was found using Levene's test. The statistical significance was set at $p<0,05$.

Results

There are no statistic significant differences between groups for all parameters (rVO_{2max}, aVO_{2max}, vVO_{2max} and HR_{max}) in initial measurement ($p>0,05$). After 4 weeks of training participants in HIIT group showed higher enhancement in rVO_{2max} (10,80% vs 7,09%) then participants in CT+HIIT group (Table 2). At the end of the training programs HIIT group showed greater increase in the vVO_{2max} as compared to the CT+HIIT group that were 5,75% and 0,09% respectively (Table 2).

Table 2. Results of aerobic parameters in young adults men after 4 weeks different trainings intervention expressed in M±SD

Varibale	HIIT (N=20)		CT+HIIT(N=20)	
	in	fin	in	fin
rVO_2max(ml/kg/min)	49.03±4.31	54.37±4.63†*	48.61±5.15	52.06±5.63†
aVO_2ma (l/min)	3.81±0.59	4.22±0.67†	3.64±0.55	3.91±0.72†
vVO_2max(km/h)	15.16±0.59	16.03±0.67†*	14.43±0.55	14.56±0.63
HRmax (bpm)	190.73±6.35	194.13±9.47	190.33±6.34	192.86±8.01

Legend: in – initially measurement; fin – final measurement; rVO_{2max} -maximal oxygen consumption in relative units; aVO_{2max} (l/min) - maximal oxygen consumption in absolute units; vVO_{2max} (km/h) - the minimum speed that athletes run when they reach VO_2max; HR_{max} (bpm) – maximal heart rate; *significant difference between HIIT and CT+HIIT group ($p<0,05$); † significant difference between in and fin ($p<0,05$)

Discussion

The study investigated the effect of a high-intensity interval training such as Billat 30s-30s training (HIIT) vs moderate intensity endurance training (CT+HIIT) on aerobic parameters in young adult men. A significant improvement in aerobic parameters was observed in both training programs. However, HIIT achived greater improvements in aerobic parameters than CT+HIIT in young adult men. It initial measurement that there was no significant difference between groups (HIIT vs CT+HIIT) in the aerobic parameters ($p>0,05$) (Table 2). Therefore, it is assumed that participants have the same chance in improving aerobic parameters, according to initial measurement and the duration of the training programs (4 week, three times per week). In initial measurement participants achieved 49,03 ml/kg/min in HIIT group and 48,61 ml/kg/min in CT+HIIT group, which classifies as "good" and "high" aerobic capacity according to World Health Organization. This result indicated that our participants achieve good aerobic capacity, which justifies by selecting a sample (physical active young male). Certain changes in rVO_{2max} were evident after trainings (HIIT vs CT+HIIT). This might be due to the increases in oxygen delivery as well as improved oxygen utilization by active muscles through greater capillarization and mitochondrial density (Hottenrott et al., 2012). After 4 weeks HIIT achieved an increase in rVO_{2max} for 5,34±0,32ml/kg/min, aVO_{2max} for 1,04±0,08 l/min and vVO_{2max} for 0,87±0,08 km/h. There were no statistical significant changes in HR_{max} (Table 2). In CT+HIIT after 4 weeks of training we can observe the improvement only in vVO_{2max} for 0,13±0,08 km/h while in other parameters: rVO_{2max}, aVO_{2max} and HR_{max} there were no statistical significant changes between initial and final measurement (Table 2). However, when analyzing the effect of group x time, a statistically significant difference between effects in HIIT vs CT+HIIT in rVO_{2max} and vVO_{2max} can be observed (Table 2). HIIT improved rVO_{2max} for 10,8% while CT+HIIT only 7,09% in young adults male. Esfarjania & Laursen (2007) considered that HIIT requires a higher oxygen delivery which leads to

greater adaptations of the oxygen delivery system (e.g. through increased stroke volume and cardiac output) which leads to an increase in VO_{2max}. On the other side CT+HIIT consist combinations continuous aerobic training and high-intensity interval training, where continuous training consist low-intenstiy which achieves a low adaptations of the oxygen delivery system, that will not lead to incrasing in rVO_{2max}. Upadhyay & Sandhu (2016) used the same training protocol (Billat 30s-30s) and got which resulted in improved rVO_{2max} for 13,87% after 3 weeks, and after 6 weeks for 20,5% in young adult's health male. In physically active women (21 years) after 7 weeks of HIIT (Billat 30s-30s) increased VO_{2max} by 5% (Burke, Thayer, & Belcamino, 1994). The differences in improving VO_{2max} between results are in the physiological difference between male and female. The similar results (increased by 5,5%) came onlz after 8 weeks of Bilat 15s-15s obtained Helgerud et al. (2007) in football players. Helgerud et al. (2007) used a different training protocol and different population than participants in this paper. Billat training (15s-15s; 30s-30s; 60s-60s) allows the participants to stay longer at VO_{2max} during active rest, and does not allow the decline of lactate which helps the improvement of VO_{2max} (Billat et al., 2000). Also, this type of training improved lactate threshold and running economy (Billat et al., 1999) which affects positively on improving VO_{2max}. Active recovery has shown to result in a faster clearance rate of lactic acid, making it the preferred form of recovery when compared to a passive form of recovery (Garner, 2016). However, HIIT (Billat 30s-30s) consists of active and short periods of rest (30s) which does not allow complete removal of lactate from the body (Billat, et al., 2001) that can improve running at lactate threshold. During the present study of HIIT the duration of exercise recoveries were of 30s, the recovery bouts were either run at an intensity of 50% of vVO_{2max} while CT+HIIT using long passive period of rest were about 3-5min. In vVO_{2max} significant greater benefits were achieved by HIIT (5,75%) where as in CT+HIIT (0,09%) group ($p<0,05$). Billat et al. (1999); Millet et al. (2003) used efforts in VO_{2max} alternating with active pause (50% of vVO_{2max}) allows an increase in vVO_{2max}. The improvement of vVO_2max can be affected by the length of running at high speed (Noakes, Myburgh, & Schall, 1990*)*. The variable HRmax did not change significantly after 4 weeks of trainings (Table 3). Similar results, but on soccer players were obtained by Dupont, Akakpo, & Berthoin (2004). The limitation of this study is the number of variables that were analyzed. We analyzed only a few aerobic parameters, but we must not ignore other aerobic parameters such as: lactate threshold, running economy, utilization of energy substrates and type of muscle fiber. It is also important to note that within this study the factors that determine VO_{2max} not monitored: cardiac output, O_2 delivery and O_2 utilization. However, these factors depend on other factor, so that the analysis of VO_{2max} after training programs is a very complex process.

Conclusion

After four week HIIT and CT+HIIT produced improvements in aerobic parameters. However, HIIT produces greater improvements in rVO_{2max} and vVO_{2max} than CT+HIIT. These results indicate that when high-intensity interval training is used with active periods of rest it is more effective for improving VO_{2max} than the combination continuous and high-intensity interval trainings with passive periods of rest in physical active and healthy adult population. Furthermore, the most effective training was interval training when running near the VO_{2max}, and in the period of rest when runners are still in VO_{2max}. This study contributes to growing body of evidence concerning the beneficial effects of higher-intensity exercise for improvement in VO_{2max} and vVO_{2max}, as well as potential benefits for cardiovascular health. This study illustrated short term improvements in aerobic parameters for all groups, but perhaps longer duration of training may result in a greater training effect on aerobic parameters in health population.

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HIIT VS TRENING IZDRŽLJIVOSTI SREDNJEG INTENZITETA: UTJECAJ NA AEROBNE PARAMETRE KOD MLADIH ODRASLIH MUŠKARACA

Sažetak

Cilj istraživanja bio je da usporedba učinaka visoko intenzivnog intervalnog treninga poput Billat 30s-30s (HIIT) naspram kombinacije kontinuiranog i visko intenzivnog intervalnog treninga (CT + HIIT) na aerobne parametre mladih muškaraca. Metode: Na uzorku od 40 ispitanika (dobi 20,15 ± 0,56 godina) studenta Fakulteta sporta i fizičkog vapistanja, Sveučilišta u Novom Sadu, primijenjena su dva modela vježbanja u trajanju od 4 tjedna (3 puta tjedno). Ispitanici randomizacije su podijeljeni u dvije grupe. Prva skupina primjenjivala je Billat 30s tračanja 100% od vVO2max i 30s odmora na 50% od vVO2max (HIIT; N = 20) dok je druga skupina primjenjivala Modificirani intenzivni trening izdržljivosti (CT + HIIT; N = 20). Testiranje je realizirano u dvije vremenske točke na Kosmed tredmilu (model T150). Registrirani su sljedeći parametri: relativna maksimalna potrošnja kisika (rVO2max); apsolutna maksimalna potrošnja kisika (aVO2max); minimalna brzina na kojoj sportaš dostiže VO2max (vVO2) i maksimalna srčana frekvencija (HRmax). Za obradu dobivenih rezultata korištena je Mix dizajn faktorska analiza varijance. Rezultati: Analiza dobivenih rezultata pokazala je da postoji statistički značajan učinak vremena kod rVO2max, aVO2max i vVO2max (p <0,05) dok efekt za grupu postoji samo kod vVO2max (p <0,05). Također se može uočiti statistički značajan učinak interakcije grupa x vrijeme kod rVO2max and vVO2max. U ostalim parametrima (aVO2max and HRmax) nema statistički značajnih učinaka između skupina (p> 0,05). Zaključak: Ova studija je pokazala da poslije 4 tjedna HIIT i CT + HIIT ostvaruju poboljšanje u aerobnim parametrima. Međutim, HIIT ostvaruje bolje rezultate u aerobnim rVO2max i vVO2max nego CT + HIIT kod muškaraca u adolescenciji.

***Ključne riječi**: VO2max, HRmax, intervalni trening, kontinuirani trening.*

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