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Original Article

Effect of high-intensity interval training vs. moderate-intensity continuous training in young trained cyclists

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Abstract
Purpose: The aim of this study was to determine the effect of high intensity interval training (HIIT) vs moderate- intensity continuous training (MICT) on VO_{2max} and anaerobic power in trained young cyclists in short period. **Methods:** Eighteen cyclists (between 15 and 20 years, n= 7 women, n= 11 men) were included in this study (age:17.50 years, height: 173.22 cm, body mass: 63.38 kg and body-mass index: 20.95 kg/m^2). The cyclists were randomly divided into two groups. The training group (G_{HIIT}, n= 9) participated in high intensity interval training two times per week for 6 weeks, while the Control Group (G_{CON}, n= 9) completed moderate intensity continuous training (MICT). The training' HR was conducted at 80%-95% HR_{max} for the first four weeks. In the last two weeks, the training' HR was increased to %100 $HR_{max.}$ The height, body mass, body fat %, aerobic and anaerobic power were measured. The maximal oxygen consumption (VO_{2max}) was measured using a portable metabolic analyzer and, the traditional VO_{2max} test followed a standard incremental design. Anaerobic capacity was evaluated by Wingate Anaerobic Test (WAnT) in 30sec. **Results:** There was no significant difference in body fat %, body mass, BMI, $power_{peak}$, $power_{mean}$, and $power_{min}$ between G_{HIIT} and G_{CON} at the end of the training program ($p>0.05$). However, there was a significant difference in VO_{2max} ($p= 0.001$) between G_{HIIT} and G_{CON} at the end of training ($p<0.05$). **Conclusion:** The high intensity interval training occurred a significant increase in VO_{2max}. Anaerobic power improved but this result was not significant. Nevertheless, HIIT may use to improve in VO_{2max} in young trained cyclists in short period.
Keywords: Anaerobic power, Aerobic Power, Cyclist, HIIT, VO_2max

Introduction

High Intensity Interval Training (HIIT), involves the alternation of short and intense anaerobic periods with short periods of aerobic recovery, and is proper to many sports (Agostino, 2019). Also, this method is recommended for improving aerobic and anaerobic capacity within a short period. Although cycling is an endurance sport, aerobic capacity is not enough to be good cyclists (Faria et al., 2005). In addition to aerobic power, anaerobic power also contributes on performance in cyclists. As a result, cycling clearly dominates aerobic and anaerobic capacities.

Cyclists have to exhibit each of their aerobic and anaerobic capacities in a sequence that they do not know in a competition (Faria et al.,2005). Even so, a standard training criterion has not yet been established on interval duration-rest and, the relationship between load and rest is unclear (When et al.,2019). There are many studies on sports such as soccer (Faude et al.,2014; Ferrete et al.,2014; Meckel et al.,2014; Paul et al.,2018), (Fernandez-Fernandez et al.,2017), cross country ski (Sandbakk et al.,2013), surfing (Farley et al.,2016) at the different interval duration and intensity. HIIT also, is an effective method to improve aerobic capacity in female with sedentary lifestyle and one of the exercise methods recommended for someone who doesn't have much leisure time (Syamsudin et al.,2021).

Despite all these researches, the results of studies comparing the effects of high intensity interval training and moderate intensity training on aerobic and anaerobic power in young trained cyclists are unclear. Moreover, it is difficult to place high and low loads consecutively in long cycling workouts and, the contribution of traditional cycling training on performance may not be at the expected level and time. Short HIIT duration is considered as less than 30s, the medium-HIIT duration is considered as 30s-2min, and long-HIIT duration is considered as 2-4min (When et al., 2019). When this classification is examined, it is seen that the load and rest periods used in the studies vary and are arranged in different intervals. In these studies, short and medium or long intervals were generally used based on heart rate or sport-specific functions. In fact, the short duration is not recommended as it does not allow the heart rate to be reached (Laursen & Buchheit, 2019). On the other hand, trained athletes have lower HRrest than untrained individuals (Aubert et al.,2003). Therefore, the increase in heart rate is lower in trained-individuals compared to untrained at the same exercise intensity. Although, it is difficult to achieve improving in the performance of trained athletes (Costill et al.,1991), cyclists must increase

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their performance with various training methods. When compared to moderate-intensity aerobic training, HIIT, is preferred primarily due to it is effective in on aerobic and anaerobic capacity a short time (Tabata et al.,1996; Rodas et al.,2000; Roxburgh et al.,2014). There are few traditional training methods to improve endurance and anaerobic power. But, not clear that which method is effective in short term for young and trained athletes. This research aimed to compare these two training methods in young cyclist to increase VO_{2max} and anaerobic power and, to determine which method is more effective for increasing the athletes' VO_{2max} and anaerobic power. The aim of this study was to determine the effect of high intensity interval training (HIIT) on VO_{2max} and anaerobic power in trained young cyclists in short period.

Materials & Methods

Participants: Twenty participants were recruited from Local Cycle Sports Clubs in Canakkale, Turkey. The subjects were required to be involved in regular cycling training or cycling competition for a minimum of 1 years and to be achieving a minimum of 4 hours of endurance cycling training per week. A health screening was requested from participants to make sure they had no any cardiovascular or respiratory disease or symptoms. Two cyclists dropped out because of unrelated to the research at post-test period. Thus, two subjects were excluded in all statistical analyses. Eighteen cyclists, aged between 15 and 20 years, who had at least a one year of competitive cycling experience and had performed training with their team for a minimum of one hour three times a week, (n=7 women, n=11 men, age:17.50 years, height: 173.22 cm, body mass: 63.38 kg and BMI: 20.95 kg/m^2, VO_{2max}: 51.17 $ml.kg.dk^{1}$) completed this study. The cyclists were separated to two groups randomly. G_{HIIT} (n=9, three women) was included in high intensity interval training (HIIT) for six weeks additionally their continuous cycling training. G_{CON} continued moderate intensity continuous training (MICT) that a minimum of one hour three times a week in the 2019-2020 season. The study was carried out in accordance with the Helsinki Declaration and approved by Canakkale Onsekiz Mart University, Medical Faculty, Clinical Research Ethics Committee (Date: 25.07.2019, number: 18920478-050.01.04-E1900104110). All participants provided written informed consent. Informed consent was obtained from the legal guardians for participants who under 18 years included in this study.

Experimental Protocol: Participants visited the laboratory in three times. During the first visit, cyclist was informed about all tests and procedures. The laboratory, test environment and equipment were introduced to all participants. During the second visit, cyclists performed a maximal incremental exercise test for the determination of maximal oxygen uptake. During the last visit, subjects performed maximal power output test. Participants were asked to avoid from alcohol, caffeine, and other drugs 24 h before testing, and to avoid eating for 1 h before test days. No athletes were smokers. Also, athletes were asked not to perform any exhaustive exercise in the 48 h before test days. Tests were separated by at 2-5 days to allow to recovery. All tests were completed at the same time of day.

Anthropometric Measurements: Body composition parameters included weight, height, body-mass index (BMI), body fat %. All participants were asked to wear light clothing on the measurement days to ensure more reliable results. Height was measurement with a statiometer (the nearest 0.1 cm, SECA 225, SECA, Hamburg, Germany). Body weight and fat % were measured with Body Composition Analyzer (TANITA, TBF-310 GS, Tokyo, Japan). **The maximal oxygen consumption measurements:** The maximal oxygen consumption (VO_{2max}) was measured using portable FitMate™ metabolic analyzer (Cosmed, Rome, Italy). Test protocol was determined on analyzer software and the data was entered for each participant. Prior to starting test, subjects were fitted with a facemask that was used for all measurements. The traditional VO_{2max} test followed a standard incremental design. The test started at 50 W and increased by 25 W every 3 min until the cyclist reached volitional exhaustion or cadence dropped below 80 RPM (Monark® Ergomedic 894 E, Monark, Sweden). The test was stopped when athletes could not continue anymore and reached its maximum level or steady state. HR was monitored by HR monitor (Polar RS800CX- Electro, Kempele, Finland) and was recorded during the last 15 s of the third minute. The Borg Scale (6-20) was used at each stage of test. **The anaerobic power measurements:** The Wingate Anaerobic Test (WAnT) was an all-out 30-s cycling performed on a cycle ergometer (Monark® Ergomedic 894 E, Monark, Sweden). The body weight was measured to adjustment test load. Anaerobic test software was started via computer and the data was entered for each participant. The warm-up protocol was applied for 5 min at 60-70 W work load and 60-70 rpm pedal speed. After the warm-up protocol, the participants were given a 5-minute passive rest. The test was started after the weight corresponding to 7.5% of cyclists' body mass obtained before the start of the test for each participant was placed as the external resistance. The cyclists reached the highest pedal speed in the shortest possible time without load. When the pedals' speed reached 150 rpm, the load was landed and the test was started. Verbal support was given to cyclists to cycle at top speed for 30 seconds. At the end of the test, a 2-3minute cool-down was applied, which included pedaling at a medium level (25-100W). Before each test, the cycle ergometer was adjusted to reproduce the position of the subjects.

Training Intervention: The cyclists in Control group trained 2 days/ per week, for 60-20 min moderate-intensity continuous training. HIIT session started with a 10 min warm-up and completed with a 5 min cool-down (Table 1) in HIIT Group. The training' HR was conducted at 80%- 95% HR_{max} for the first four weeks. In the last two weeks, the training' HR was increased to %100 $HR_{max.}$

Table1. HIIT session load and progression

Weeks	Days/per week	Intensity	Number & duration of intervals	Number of sets	Duration & intensity of rests
1-Week	3	HR_{max} 80-95%	30 s at 80-85% 30 s at 90-95%	5	60s rest-work at 50% [1:1]
2-Week	3	HR_{max} 80-95%	30 s at 80-85% 30 s at 90-95%	5	60s rest-work at 50% [1:1]
3-Week	3	HR_{max} 80-95%	30 s at 80-85% 30 s at 90-95%	5	60s rest-work at 50% [1:1]
4-Week	3	HR_{max} 80-95%	30 s at 80-85% 30 s at 90-95%	5	60s rest-work at 50% [1:1]
5-Week	3	HR_{max} 80-100%	30 s at 80-85% 30 s at 90-100%	5	60s rest-work at 50% [1:1]
6-Week	3	HR_{max} 80-100%	30 s at 80-85% 30 s at 90-100%	5	60s rest-work at 50% [1:1]
Totally	6 weeks, 18 days, 54 HIIT session				

Statistical Analyses: Mean SD (standard deviation) were calculated for all parameters. The level of statistical significance was set at $p \leq 0.05$ for all tests. The Shapiro-Wilk test was used to verify normal data distribution, Levene's test was used to determine the variance equality. The comparisons between G_{HIIT} and G_{CON} for all variables were used by the Mann-Whitney U test. The Wilcoxon test was used to analyze variables within groups. Effect size was calculated and presented as small (0.2), medium (0.5), and large (0.8). All analysis was using SPSS 26.0 software (SPSS, Chicago, USA).

Results

There was no statistically different in height (p = 0.753), BMI (p = 0.112), body fat % (p= 0.596), VO_{2max}, (p= 0.122), $power_{peak}$, (p= 0.070), $power_{mean}$, (p= 0.310) and $power_{min}$ (p= 0.453), between G_{HIIT} and G_{CON} at the baseline (p>0.05). But there was a significant difference in body weight (p= 0.024), between two groups (p<0.05, Table 2).

Table 2. All variables of G_{HIIT} and G_{CON} at baseline and the end of the training

	G_{HIIT} (n=9)				G_{CON} (n=9)					
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**z**	**p**
Baseline										
Height,m	172.56	5.56	160.00	178.00	173.89	5.13	162.00	180.00	-0.315	0.753
Body weight,kg	59.33	9.32	45.00	78.00	67.44	4.97	58.00	73.00	-2.256	0.024
BMI,kg/m^2	20.07	2.56	17.70	25.00	21.83	2.59	17.70	27.30	-1.590	0.112
Body fat %	12.16	5.80	3.50	19.00	13.77	4.10	9.60	21.00	-0.530	0.596
VO_{2max}, ml.kg.dk^{-1}	53.30	5.88	42.80	62.50	49.05	5.08	42.30	56.40	-1.545	0.122
$Power_{peak}$,W	628.76	98.99	384.35	717.66	555.27	129.28	403.67	841.22	-1.811	0.070
$Power_{mean}$,W	480.39	89.45	260.65	586.11	435.44	114.08	287.16	643.00	-1.015	0.310
$Power_{min}$,W	305.11	95.34	99.25	429.24	269.79	141.69	86.58	445.83	-0.751	0.453
Post										
Body weight,kg	60.43	9.00	47.60	78.00	68.00	4.60	60.00	73.00	-2.121	0.034
BMI,kg/m^2	20.16	2.35	17.60	24.10	22.71	2.90	18.00	27.20	-1.811	0.070
Body fat %	11.81	5.01	4.00	18.00	13.98	3.97	9.60	21.00	-0.796	0.426
VO_{2max}, ml.kg.dk^{-1}	59.42	4.26	51.70	65.30	49.23	5.22	45.20	57.10	-3.223	0.001
$Power_{peak}$,W	631.75	195.17	245.15	961.62	554.81	160.76	400.20	875.93	-1.369	0.171
$Power_{mean}$,W	486.54	153.41	162.73	735.01	431.40	111.94	314.31	613.01	-1.192	0.233
$Power_{min}$,W	312.01	106.88	123.60	490.16	277.92	103.42	87.40	430.81	-0.662	0.508

There was no significant difference in BMI (p= 0.070), body fat% (p= 0.426), $power_{peak}$ (p= 0.171), $power_{mean}$ (p= 0.233), $power_{min}$ (p= 0.508) between G_{HIIT} and G_{CON} (p>0.05). There was a significant difference in VO_{2max} (p= 0.001) and body weight (p= 0.034) between G_{HIIT} and G_{CON} at the end of the training period (p<0.05, Table 2).

Table 3. Within group values and differences

G_{HIIT} Baseline (n=9)					**G_{HIIT} Post**					
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**z**	**p**
Body weight, kg	59.33	9.32	45.00	78.00	60.43	9.00	47.60	78.00	-1.992	0.046
BMI,kg/m^2	20.07	2.56	17.70	25.00	20.16	2.35	17.60	24.10	-0.561	0.574
Body fat %	12.16	5.80	3.50	19.00	11.81	5.01	4.00	18.00	-1.014	0.310
VO_{2max}, ml.kg.dk^{-1}	53.30	5.88	42.80	62.50	59.42	4.26	51.70	65.30	-2.666	0.008
$Power_{peak}$,W	628.76	98.99	384.35	717.66	631.75	195.17	245.15	961.62	-0.338	0.735
$Power_{mean}$,W	480.39	89.45	260.65	586.11	486.54	153.41	162.73	735.01	-0.507	0.612
$Power_{min}$,W	305.11	95.34	99.25	429.24	312.01	106.88	123.60	490.16	0.000	1.000
G_{CON} Baseline (n=9)					**G_{CON} Post**					
Body weight,kg	67.44	4.97	58.00	73.00	68.00	4.60	60.00	73.00	-1.418	0.156
BMI,kg/m^2	21.83	2.59	17.70	27.30	22.71	2.90	18.00	27.20	-1.065	0.287
Body fat %	13.77	4.10	9.60	21.00	13.98	3.97	9.60	21.00	-0.593	0.553
VO_{2max}, ml.kg.dk^{-1}	49.05	5.08	42.30	56.40	49.23	5.22	45.20	57.10	-0.535	0.593
$Power_{peak}$,W	555.27	129.28	403.67	841.22	554.81	160.76	400.20	875.93	-0.420	0.674
$Power_{mean}$,W	435.44	114.08	287.16	643.00	431.40	111.94	314.31	613.01	0.000	1.000
$Power_{min}$,W	269.79	141.69	86.58	445.83	277.92	103.42	87.40	430.81	-0.533	0.594

There was no significant difference in BMI (p= 0.574), body fat % (p= 0.310), $power_{peak}$ (p= 0.735), $power_{mean}$ (p= 0.612), $power_{min}$ (p= 1.000) between the baseline and post-training period in G_{HIIT} (p>0.05). There was a significant difference in body mass (p= 0.046) and VO_{2max} (p= 0.008) between the baseline and post-training period in G_{HIIT} (p<0.05). There was no significant difference in weight (p= 0.156), BMI (p= 0.287), body fat % (p= 0.553), VO_{2max} (p= 0.593), $power_{peak}$ (p= 0.674), $power_{mean}$ (p= 1.000), $power_{min}$ (p= 0.594) between the baseline and post-training period in G_{CON} (p>0.05) (Table 3).

Table 4. Effect size data

	Post training				**Cohen's**	**Effect size**
	G_{HIIT} Mean SD		**G_{CON} Mean SD**		**d**	**r**
VO_{2max}, ml.kg.dk^{-1}	59.42 ± 4.26		49.23 ± 5.22		2.20	0.74
$Power_{peak}$,W	631.75 195.17	±	554.81 160.76	±	0.43	0.21
$Power_{mean}$,W	486.54 153.41	±	431.40 111.94	±	0.41	0.20
$Power_{min}$,W	312.01 106.88	±	277.92 103.42	±	0.33	0.16

The high intensity interval training affected on VO_{2max} in six weeks. HIIT improved the other parameters, $power_{power}$, $power_{mean}$, and $power_{min}$ respectively. HIIT provided an increase 3,64% in VO_{2max}, 2,26% in $power_{min}$, 1,28% in $power_{mean}$ and 0,47% in $power_{peak}$ (Table 4).

Discussion

The aerobic and anaerobic responses to high-intensity interval training vs moderate-intensity continuous training (MICT) in young trained cyclists were examined in this study. The findings were as follows: i) An increase in both VO_{2max} and anaerobic power in G_{HIIT}, ii) A significant difference between G_{HIIT} and G_{CON} inVO_{2max} after training, iii) An increase in mean VO_{2max} in HIIT Group, iv) An increase in $power_{mean}$ in HIIT Group.

At the baseline, there was no significant difference in BMI, body fat %, VO_{2max}, $power_{peak}$, $power_{mean}$, $power_{min}$ between G_{HIIT} and G_{CON} (p >0.05). Whereas, body weight was statistically different between two groups (p<0.05). This difference in body weight was probably due to muscle mass because there was no

significant difference in body fat % at the baseline (Table 3). Moreover, body fat % was decreased while body weight was increased in G_{HIIT} in the post training. However, in G_{CON}, weight and body fat % were increased in the post training. Finally, there was no significant difference in body mass between two groups in the post training period.

VO_{2max} and anaerobic power improved after six weeks in young trained cyclists. The most significant increasing was determined in VO_{2max}. Maximal oxygen consumption increased from 53.30 ± 5.88 ml.kg.min^{-1} to 59.42 ± 4.26 ml.kg.min^{-1} to post training. The $Power_{mean}$ was 480.39 ± 89.45 W at the baseline, and increased to 486.54 ± 153.41 W in the post training. There was no significant difference between body mass, BMI, body fat %, VO_{2max}, $Power_{peak}$, $power_{mean}$ and $power_{min}$ between the baseline and after training in G_{CON} ($p > 0.05$, Table 3). After the training, there was no significant difference in $Power_{peak}$, $power_{mean}$, $power_{min}$ between G_{HIIT} and G_{CON} ($p > 0.05$), but there was a significant difference in VO_{2max} between the two groups ($p < 0.05$). This improvement in VO_{2max} was consistent with previous research results. Compared to traditional aerobic exercise, HIIT is preferred because it is effective in a short time, increases aerobic capacity and anaerobic capacity (Tabata et al.,1996; Rodas et al.,2000; Roxburgh et al.,2014). Rodas et al., (2000), evaluated the aerobic and anaerobic metabolic changes of a HIIT program that included a maximum intensity load of 15-30 s on the cycle ergometer with 45-30 s breaks after 2 weeks of daily exercise. In this study, significant increase was determined in VO_{2max} and $power_{peak.}$ The effect size of high intensity interval training method was large level on VO_{2max} in six weeks and, with HIIT method, an increase of 3,64% occurred in the VO_{2max} (Table 4). As well as, anaerobic power improved. However, this improvement was not significant. We did not include the mechanisms that responsible for the affecting factors on anaerobic power in this study. However, we have a few reasons that may explain this result. Firstly, it is believed that differences in rest time and intensity, as well as the duration of training in researches, may be effective. In the present study, [1:1], the load/rest form was used at 80-95% HR_{max}, as 5 x 60 s and 60 s rest. The second reason may be an inverse physiological pathway between the loads and Wingate 30s.

Secondly, in the previous study, it was found that the energy requirement depends on the competition feature during the Wingate test. It means that the energy supply to the sprinters is mainly provided by anaerobic metabolism. Therefore, the Wingate test may not be an appropriate anaerobic capacity test. However, it can be used as an exercise that stimulates both aerobic and anaerobic processes (Medbo & Tabata,1989). Physiologically, at the start of the sprint, both phosphagen and glycolytic systems are fully activated. Accelerated glycolysis, PCr cleavage, and oxidative metabolism provide approximately 50-55%, 23-29%, and 16-25% of the adenosine triphosphate (ATP) required for muscle working during a 30s sprint. For competitive cyclists, these facts form the basis of the sprint strategy. Finishing of a sprint too early will result in a gradual reduction in speed and a loss of first place. It means that PCr disruption begins at the start of intense exercise and reaches a maximum speed within 10 s. Then, the PCr' source stops contributing to the energy supply, as it decreases from 10 to 30 s. Beginner energy sources in young people may have revealed this difference. However, we did not detect changes in energy resources in the present study. The children represent higher oxidative capacity, low anaerobic and glycolytic capacities in muscle substrates, and enzyme activity levels (Kaczor et al.,2005). This limited glycolytic capacity and greater dependence on oxidative metabolism lead to relative and absolute decreasing performance in intense interval exercise. However, it is recommended as a reason for increased recovery (Falk & Dotan,2006).

Finally, in the present study, cyclists in the HIIT program had more improvement than the control group. In other words, six weeks were sufficient for an improvement in aerobic capacity, but it was not enough to gain in anaerobic output. Paul et al., (2018) noted that no significant difference between HIIT and continuous training groups in trained players in similar ages. Farley et al. (2016) compared HIIT and SIT in young surfing athletes and stated that aerobic gain from HIIT and anaerobic gain from SIT were higher. The researchers emphasized that the anaerobic gain that cannot be obtained with HIT can be obtained with SIT. These results were provided that SIT provides better development of anaerobic power in cyclists, as it affects the body movement and ground reaction force. Further research is needed to answer this question.

Conclusion

High-intensity interval training provided a significant increase in VO_{2max}. Anaerobic power improved but this result was not significant statistically. If the conditioners and trainers plan to increase VO_{2max}, the high-intensity interval training which characterized at 95% -80 % of HR_{max}, 60 s cycling: 60 s rest (1:1) will contribute to improving aerobic capacity in a short time. There was no occur health problem in young cyclists during the study.

The present study has some limitations. First, the training was conducted individually. Additionally, it was difficult to conduct in young-trained cyclists because of their continuous cycling training, school routine lessons, and exams. Therefore, we did not find time to measure another anaerobic performance test. However, we conducted this study successfully.

Conflict of interest: Authors state no conflict of interest.

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