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Communication

Effects of 3-Week Work-Matched High-Intensity Intermittent Cycling Training with Different Cadences on VO_2max in University Athletes

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Abstract: The aim of this study was to clarify effects of 3-week work-matched high-intensity intermittent cycling training (HIICT) with different cadences on VO2max in university athletes. Eighteen university athletes performed HIICT with either 60 rpm (n = 9) or 120 rpm (n = 9). HIICT consisted of eight sets of 20-s exercise with a 10-s passive rest between each sets. The initial training intensity was set at 135% of VO2 max and was decreased by 5% every two sets. Athletes in both groups performed 9 sessions of HIICT during 3-week. The total work-load and achievement rate of the work load calculated before experiments in each group were used for analysis. VO2max was measured pre and post-training. After 3-week of training, no significant differences in the total work-load and achievement rate of the work load were found between the two groups. VO2max similarly increased in both groups from pre to post training (p = 0.016), with no significant differences between the groups (p = 0.680). These results suggest that cadence during HIICT is not training variable affecting effect of VO2max.

Keywords: aerobic capacity, graded-exercise test, total work-load

1. Introduction

High intensity intermittent (or interval) training (HIIT) is considered as time-efficient exercise strategy, because HIIT has superior effect for improving VO_2max in less time than low-moderate intensity continuous exercise [1, 2]. In addition, HIIT can increases VO_2max in a short-period (2-4-week) [3, 4, 5, 6, 7, 8, 9]. Since the total time of training is often limited for athletes, it is important to detect the more effective HIIT methodology for increasing the VO_2max in a short-period.

HIIT with the use of cycle ergometer is considered a safe method of training. In previous studies, various training modes of, such as cycling, running, aquatic treadmill running, jump rope, swimming and kettlebell training, have been attempted [10]. The results showed that the stress on the anterior cruciate ligament was lower during cycling exercise [11, 12]. In addition, cycling exercise was found associated with less eccentric contraction phases that cause muscle damage as compared to running [13]. Thus, HIIT by using cycle ergometer can increased VO_2max more safely.

Cadence during work-matched high-intensity intermittent cycling training (HIICT) may be a training variable that affects chronic effect of VO_2max under relative intensity (e.g. %VO_2max) and exercise time matched condition. The work-load during cycling exercise is a product of load (kp) and cadence (rpm). Therefore, HIICT can be performed either with high load / low cadence or with low load / high cadence under work-load and exercise time matched conditions [14]. Many previous studies reported that oxygen uptake (VO_2) during work-matched cycling exercise increases more significantly in high cadence cycling than low cadence cycling (35-110 rpm) due to elevated internal work-load of active muscles [15-20]. Thus, work-matched cycling exercise with high cadence may be higher actual intensity than cycling exercise with low cadence even though the relative intensity (e.g. %VO_2max) is same. Matsuo et al. reported that high-intensity interval training improves VO_2 max more significantly than moderate-intensity training due to an increase in left ventricular mass and stroke volume [21]. Therefore, it can be speculated that HIICT with high cadence can improve VO_2max more significantly than HIICT with low cadence. Paton et al. reported that high-intensity interval training with low cadence significantly improved VO_2max compared to high cadence in male cyclists [22]. However, work-load was not matched in this study. Since the work-load affects chronic effect of VO_2max [23], the effect of the difference in cadence on VO_2max should be examined under work-matched conditions.

The aim of this study was to examine whether 3-week work-matched HIICT with high cadence (120 rpm) can significantly improve VO_2max compared to HIICT with low cadence (60 rpm) in university athletes.

2. Materials and Methods

2.1 Experimental design

Participants were assigned to one of the two experiments groups, according to their work-load of HIICT calculated based on pre-training VO_2max. One group of participants performed HIICT with 60 rpm (n = 9, age : 20.1 ± 0.8 years, height : 174.6 ± 4.8 cm, body weight : 65.4 ± 3.9 kg) and the other group of participants performed HIICT with 120 rpm (n = 9, age : 20.0 ± 1.0 years, height : 173.2 ± 5.3 cm, body weight : 64.4 ± 6.3 kg). HIICT was performed 9 sessions during 3-week in both groups and performed at least twice per week in order not to bias the number of sessions per week. In both groups, training load was increased by 2.5% for every 3 sessions. All training sessions were supervised by investigators with expert knowledge about HIICT. VO_2max measurement during the graded-exercise test using a cycle ergometer was carried out pre and post-training. All measurements for each participant were performed at approximately the same time of day (± 2.5 h) to take into consideration the circadian rhythm.

2.2 Participants

Twenty one Japanese male university athletes were initially recruited. Three participants could not complete the training due to injuries not related the experiment. Thus, the data of eighteen participants were used for further analysis. All participants practiced exercise more than two times per week and belonged to the university volleyball team (n = 8), soccer team (n = 3), soft tennis team (n = 3), ultimate team (n = 2), badminton team (n = 1) and sailing team (n = 1). They did not habitually performed any physical training, except for practice for each competition ; furthermore, all participants did not performed resistance training for the lower extremities more than twice per week during the past six months and cycling training for a competitive race. All participants were informed about the potential risks of experiments and provided written consent to participate before the experiments. This study was approved by the Ethics Committee of Faculty of Education, Hokkaido University (Approval number : 17-24).

2.3 VO_2max

The graded-exercise test was performed to determine the VO_2max and the relative intensity of HIICT using a cycle ergometer (Powermax-VII, Combi Wellness, Tokyo, Japan). The test was begun at 60 W, followed by 30 W increases every 3 minutes until each participants could not maintain a cadence of 60 rpm. The cadence during the test was controlled by metronome and was displayed on a screen. During the test, the VO_2 was measured every 10s using mixing chamber methods with a

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respiratory gas analyzer (VO2000, S&ME Co. Ltd., Tokyo, Japan) throughout the test and the peak value was defined as VO_2max [24-26].

2.4 High Intensity Intermittent Cycling Training

In all training sessions, HIICT was performed by using a cycle ergometer (Powermax-VII, Combi Wellness, Tokyo, Japan) following a warming up at 90 W for 10 minutes and a rest period of 3 minutes. The initial training intensity of HIICT was set at 135% of VO_2max and was decreased by 5% every two sets and consisted of eight sets of 20-s pedaling with a 10-s passive rest between each set. This protocol was conducted according to the results of our pilot study that was based on previous studies [3, 27-28]. Participants were instructed to maintain a cadence of either 60 rpm or 120 rpm that was controlled by the value displayed on the screen and a metronome during each session. After HIICT, participants performed cool down cycling at 90 W for 5 minutes in all training sessions. The total work-load and achievement rate of the work-load calculated before experiments for each group were used analysis. The cadence was decided to be insufficient if the work-load for 3-week did not reach 90% of the workload calculated before the experiments and the data were excluded from the analysis. The average value of the absolute load of HIICT during the training period was shown in Table 1.

Table. 1 Average value of absolute load of high-intensity intermittent cycling training throughout training period

Group	Session	1-2 set (kp)	3-4 set (kp)	5-6 set (kp)	7-8 set (kp)
60 rpm	**1-3 session**	**6.2 ± 0.4**	**5.9 ± 0.4**	**5.7 ± 0.4**	**5.4 ± 0.4**
	4-6 session	**6.3 ± 0.4**	**6.1 ± 0.4**	**5.8 ± 0.4**	**5.5 ± 0.4**
	7-9 session	**6.5 ± 0.4**	**6.2 ± 0.4**	**6.0 ± 0.4**	**5.7 ± 0.4**
120 rpm	**1-3 session**	**3.1 ± 0.2**	**2.9 ± 0.2**	**2.8 ± 0.2**	**2.7 ± 0.2**
	4-6 session	**3.1 ± 0.2**	**3.0 ± 0.2**	**2.9 ± 0.2**	**2.8 ± 0.2**
	7-9 session	**3.2 ± 0.2**	**3.1 ± 0.2**	**3.0 ± 0.2**	**2.8 ± 0.2**

Values are mean ± SD

2.5 Statistical analyses

All data are presented as means and standard deviations (SD). Total work-load, achievement rate, baseline VO_2max levels in both study groups and percent change of VO_2max were analyzed using unpaired *t*-test. Moreover, the change in VO_2max and body weight from pre to post-training were analyzed by two-way (group × time) mixed-design analysis of variance (ANOVA ; between-participant factor : group, within-participant factor : time). A post hoc analysis was performed using the Bonferroni test. Statistical significance level was set at $P<0.05$. As indices of the effect size, Cohen's d (for unpaired t-test and post hoc comparisons) and partial η^2 (for ANOVA) were also calculated. SPSS Statistics (version 24.0 for Windows, SPSS Inc., Chicago, Ill., USA) was used for data analysis.

3. Results

All 18 participants who completed 9 training sessions exceeded 90% achievement rate of the work-load calculated before experiments. No significant differences in the baseline VO_2max levels was found between the groups (p = 0.967, Cohen's d = 0.020, 60 rpm : 59.2 ± 3.9 ml/kg/min, 120 rpm : 59.3 ± 5.5 ml/kg/min). The total work-load and achievement rate of the work load calculated before experiments in each group are shown in Table2. No significant differences in the total work-load and achievement rate of the work-load were found between the groups.

Table. 2. Comparisons of total work-load and achievement rate throughout training period

Title 1	60 rpm	120 rpm	P Value	Cohen's d
Total work load (W)	25234.7 ± 1572.8	24897.1 ± 1757.5	0.673	0.202
Achievement rate (%)	98.3 ± 1.0	97.9 ± 1.4	0.522	0.309

Values are mean ± SD

Main effect of time and interaction were not observed in body weight (main effect of time : p = 0.821, partial η^2 = 0.03, interaction : p = 0.821, partial η^2 = 0.03, 60 rpm pre-training : 65.4 ± 3.9kg, 60 rpm post-training : 65.4 ± 3.8kg, 120 rpm pre-training : 64.4 ± 6.3kg, 120 rpm post-training : 64.3 ± 5.9kg). The results of change of VO_2max from pre to post-training between groups are shown Figure. 1. The main effect of time was observed in VO_2max (p = 0.016, partial η^2 = 0.311). However, no interaction was observed (p = 0.680, partial η^2 = 0.011). No significant difference was detected in the relative change of VO_2max (p = 0.675, Cohen's d = 0.201, 60 rpm : 4.3 ± 6.2%, 120 rpm : 3.2 ± 5.5%). The average values of VO_2max were as follows: pre-training : 59.2 ± 3.9 ml/kg/min, post-training : 61.7 ± 4.4 ml/kg/min in the 60 rpm, and pre-training : 59.3 ± 5.5 ml/kg/min, post-training : 61.1 ± 6.1 ml/kg/min in the 120 rpm.

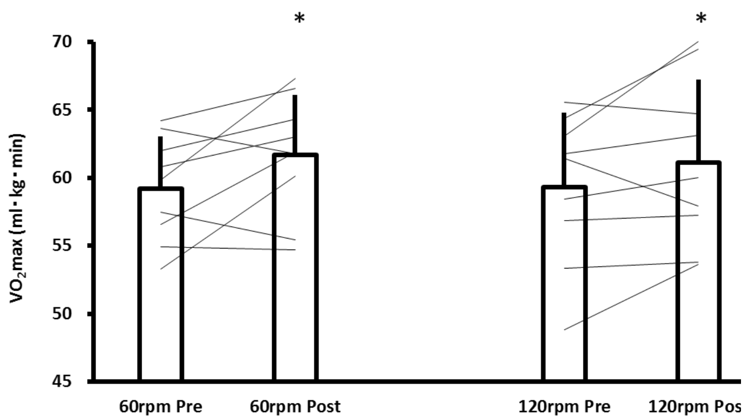

Figure 1. VO2max in 60rpm and 120rpm. Each line is the change for an individual subject. Bars are the average value in each subject. Values are mean ± SD, * P<0.05 vs Pre

4. Discussion

To the best of author`s knowledge, this is the first study to examine whether 3-week work-matched HIICT with high cadence (120 rpm) significantly improves VO_2max in university athletes than low cadence (60 rpm). As a result of 3-week training, contrary to our hypothesis, VO_2max increased similarly between the 60 rpm and 120 rpm. These results suggest that cadence during 3-week work-matched HIICT is not training variable affecting effect of VO_2max in university athletes.

There are two possibilities as the reason why there was no significant difference in the effect on VO_2max between 60 rpm and 120 rpm in this study. As the first possibility, VO_2 response during HIICT in this study was similar between 60 rpm and 120rpm unlike different from previous studies. In many previous studies, VO_2 was higher during work-matched cycling exercise with high cadence than low cadence [15-20]. However, submaximal exercise intensity were used in these studies, while a much higher supramaximal intensity was used in this study. Recruitment of type II fiber increased in low cadence than high cadence at submaximal cycling [26, 27] and type II fiber is higher ATP consumption than type I fiber [28]. In this study, VO_2 responses might be similar between 60 rpm and 120 rpm due to the recruitment a more intense type II fibers than in previous studies by using supramaximal intensity. Future studies should to investigate in detail the acute VO_2 response during work-matched HIICT with different cadences.

As the second possibility, the workload affects VO_2max rather than exercise intensity. In this study, if VO_2 during HIICT with high cadence was higher than low cadence like many previous studies, HIICT with high cadence was higher in actual intensity than low cadence even though the relative intensity (e.g. %VO_2max) was the same. Matsuo et al. reported that high-intensity training improves VO_2 max more significantly than moderate-intensity training due to increased left ventricular mass and stroke volume [22]. On the other hands, Scribbans et al. [29] reported in their meta-analysis that increasing the exercise intensity above 60% VO_2max does not provide additional increases in VO_2max. In addition, Granata et al. [24] reported that VO_2max can be changed by manipulating the total work-load, not the relative intensity. Therefore, the similar chronic effect on VO_2max in this study might be related to the equal work-load in both groups.

In this study, the subjects had relatively high initial VO_2max levels (60 rpm : 59.2 ± 3.9 ml/kg/min, 120 rpm : 59.3 ± 5.5 ml/kg/min) as compared to previous studies, in which the increase in VO_2max was observed in a short training period (32.8 ml/kg/min - 57.3 ml/kg/min) [3-9]. Nevertheless, VO_2max significantly increased in both groups after 3-week. This implies that, for regularly trained athletes, the 3-week HIICT protocol used in this study appears to be an effective method to improve VO_2max in short-term regardless of cadences during HIICT.

5. Conclusions

This study examined whether 3-week work-matched HIICT with high cadence (120 rpm) significantly improves VO2max in university athletes compared to HIICT with low cadence (60 rpm). As a result of 3-week training, contrary to our hypothesis, VO2max similarly increased in 60 rpm and 120 rpm. These results suggest that cadence during 3-week work-matched HIICT is not training variable affecting short-term effect of VO2max in university athletes.

Author Contributions: N. T conceived, designed, and carried out all experiments, performed statistical analyses and wrote manuscript. K. T, K. S and M. M reviewed and provided feedback for approval of the final manuscript draft. All authors have read and approved the manuscript.

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Conflicts of Interest: The authors declare no conflicts of interest.

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