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Original Article

Effects of high intensity interval training on peak aerobic power output and time trial performance in Thai amateur cyclists

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Abstract

The purpose of this study was to investigate the effects of high-intensity interval training (HIT) on peak aerobic power output (PAP) and time trial (TT) performance of Thai amateur cyclists. Twenty-nine male amateur cyclists were randomly allocated to one of two groups, a moderate-intensity continuous training (MICT) group (n = 14) and a HIT group (n = 15). All subjects performed an incremental exercise test to exhaustion and a 30 km TT to determine the PAP, lactate turnpoint (LTP) and endurance performance before (pre-test) and after the six-week training period (post-test). The HIT group completed ten intervals of 2 min at 120% of LTP with 4 min of rest between intervals, 3 times a week. The MICT group completed three sessions per week of 60 min cycling at 60-75% of the maximum heart rate. Both the HIT and MICT groups also completed one session per week of 120-minute continuous training at 60% LTP. The HIT and MIT training programs were six weeks in duration. Both PAP and performance in the 30 km TT were improved post training in the HIT group ($p<0.05$), but not the MICT group ($p>0.05$). The present study suggests that a HIT program was more effective at improving PAP and TT performance of Thai amateur cyclists compared to conventional MICT program.

Keywords: exercise training, aerobic fitness, time trial, cycling, endurance performance

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1. Introduction

High-intensity interval training (HIT) comprises repeated intense exercise bouts separated by passive or active recovery. It is well documented that both HIT and moderate-intensity continuous training (MICT) can improve endurance performance in sedentary or recreationally-active individuals (Christensen, 2016; Daussin *et al*., 2008; Granata, 2016; Mc-Kay, 2009). This improvement in endurance performance following HIT and MICT is accompanied by enhanced central cardiovascular function and peripheral oxidative metabolism which improves peak oxygen uptake and aerobic power output (PAP), and the lactate thresholds (Christensen, 2016; Daussin *et al*., 2008; Granata, 2016; McKay, 2009).

In individuals who are already well-trained, there is limited evidence to support further improvements in endurance performance, or some of its physiological correlates, with MICT (Laursen & Jenkins, 2002), while the efficacy of HIT to improve these variables is controversial. Although there is some evidence to suggest that replacing some high-volume MICT with HIT can elicit further improvements in endurance performance in trained runners (Bangsbo, 2009) and rowers (Ní Chéilleachair, 2017), the efficacy of HIT to improve endurance cycling performance of trained cyclists is equivocal (Paquette, 2017). Stepto *et al*. (1999) reported an improvement in PAP and 40 km cycling time trial (TT) performance of trained cyclists following three weeks of HIT comprising two sessions/week of 6×4 min-intervals at 85% PAP interspersed with 1.5 min recovery or 12×30 s intervals at 175% PAP interspersed with 4.5 min recovery. Similarly, Paquette *et al*. (2017) demonstrated that six weeks of HIT comprising three sessions/week of 1-7 min-intervals at 85% PAP interspersed with 30-210 s recovery and with a work:rest ratio of 2:1 in all sessions, improved PAP, peak oxygen uptake, and endurance performance of trained cyclists. However, three weeks of HIT comprising two sessions/week of 4×8 min-intervals at 80% PAP interspersed with 1 min-recovery, 12×2 min intervals at 90% PAP interspersed with 3 min-recovery or 12×1 min intervals at 100% PAP interspersed with 4 min-recovery did not improve PAP or 40 km TT performance (Stepto *et al*., 1999). Currently, there are many people interested in cycling for health benefits, recreational physical activity and physical performance. In particular, in amateur cyclists, defined as cyclists with a cycling experience of more than one year, cycling at least three days per week and for at least 20 minutes per session (Haskell, 2007), there is an emerging population of interest. In addition, these individuals have participated in some competitions, but not of professional racing standard. However, despite the large growth in amateur cyclists, there is no information about the ergogenic potential of HIT in Thai amateur cyclists. Therefore, further research is required to assess the ergogenic potential of HIT training, particularly when work intervals are submaximal relative to lactate turnpoint (LTP) and PAP, in amateur cyclists. This information will help optimize training recommendations and performance potential in this population.

The purpose of this study was to assess the effect of HIT on endurance performance, PAP and the lactate turnpoint in a group of competitive amateur Thai cyclists and to compare these responses to conventional MICT training as a control condition. It was hypothesized that HIT, but not MICT, would improve endurance performance, PAP and the lactate turnpoint.

2. Materials and Methods

2.1 Participants

Twenty-nine Thai male cyclists were recruited from the Bangkok and surrounding areas. Participants had been training 6-8 h/week, with three to four training sessions/week for at least six months prior to entry into the study. Participants were all amateur Thai competitive road cyclists and had previously taken part in at least one cycling competition event. Sample size was calculated based on the study of Rønnestad (2014). At an alpha value of 0.05 and a statistical power of 80%, the sample size estimated was 14 subjects for each group. Participants provided written, informed consent to take part in the study, which was approved by the Naresuan University Ethics Committee (Naresuan University, Phitsanulok, Thailand) in accordance with the Declaration of Helsinki.

2.2 Procedures

The amateur trained cyclists were pair-matched into two matched groups, MICT (n=14) and HIT (n=15), based on their baseline LTP and PAP. Both groups underwent a six week-training period comprising four sessions per week. All exercise training sessions were performed on the cyclist's own bike in both groups. At least 24 h recovery separated training sessions. A flow chart of experimental protocol is illustrated in Figure 1.

2.3 Exercise testing

Exercise tests were performed before (pre-training) and after (post-training) the 6-week intervention period. Pre-testing was completed two weeks before intervention start. Post-testing was initiated 3-4 days after the last training session for all subjects and completed within 10 days of the final training session. On test days, subjects were instructed to report to the laboratory in a rested state, having completed no strenuous exercise within the previous 24 hours and having abstained from food for the preceding three hours. They were also instructed to have avoided caffeine and alcohol consumption within 12 and 24 hours of the test, respectively. The subjects were familiar with the experimental procedures used in the study. Testing was conducted at the same time of day (± 2 hours) for each subject.

Participants completed an incremental cycle test to determine lactate turn point (LTP) and peak aerobic power output (PAP). The CompuTrainer was used in ergometer mode and fitted with the participant's own bike. Following tyre-pressure checks (120 psi, 8.27 bar) and a 10-min light warm-up, the CompuTrainer was calibrated to 3.5 lb (1.59 kg), in line with the manufacturer's instruction, permitting an accurate power output reading up to 500 W. The test started at 100 W and increased by 30 W every three minutes until volitional exhaustion, with the cadence remaining self-selected but the speed was held above 14 mph (22.5 km/h) to ensure accurate measurements of power output (Neal *et al*., 2013). Thirty seconds before the end of each 3-min stage, a

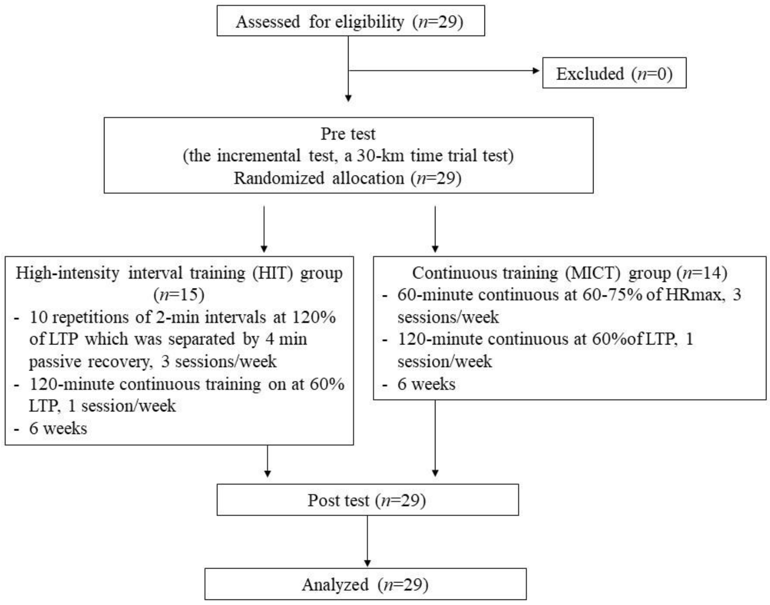

Figure 1. Flow chart of experimental protocol.

capillary blood sample was obtained for blood lactate concentration analysis using a microassay (Lactate Scout; LS, SensLab GmbH, Germany). The LTP was determined as the second delineation point in the relationship between blood lactate concentration and power output, as applied previously (Midgley, 2006).

On a separate day, at least two days following the incremental test to exhaustion, a 30-km time trial (TT) was performed. Each participant brought his bike into the laboratory at the same time of day and set it up on the CompuTrainer. Following tyre checks and a 10-min light warm-up, the CompuTrainer was calibrated to 3.5 lb (1.59 kg). Participants were then instructed to complete a 30-km TT as fast as possible. The only data that the participants could see during the test was distance completed. Completion time and mean power output were recorded.

2.4 Exercise training

2.4.1 Continuous training (MICT) group

The MICT group completed three sessions per week of 60 min cycling at 60-75% of the maximum heart rate (HRmax), which was set based on the HR data from initial incremental exercise testing. In addition, participants completed one 120-minute session of continuous exercise at 60%of lactate turn point (LTP). The MICT group completed cycling on the road or on the CompuTrainer. The MICT group's sessions were monitored from heart rate (HR) recordings (Garmin Heart Rate Monitor HRM Strap with ANT^+ Compatibility, U.S.A.).

2.4.2 High-intensity interval training (HIT) group

The HIT group performed 10×2-min intervals, separated by 4-min passive recovery, at an exercise intensity corresponding to 120% of LTP three times/week, and one 120-minute session of continuous training at 60% LTP per week. All cyclists were instructed to perform each HIT session with the aim to produce the highest possible mean power output across the intervals. This allowed mean power output of each HIT session to be used as an indicator of performance level. The cyclists in the HIT group were equipped with a power meter (Garmin power meter, U.S.A.) to monitor the power output during the HIT sessions. The HIT group completed cycling on the road or on the CompuTrainer.

2.5 Data analysis

The results are expressed as mean±SD. Shapiro-Wilk test was used to determine normal distribution of data. Pre- and post-intervention measurements within the sample group were compared using paired Students t-tests. Independent Students t-tests were performed to test for any differences in relative changes between the groups using the SPSS program version 23 (SPSS Inc., Chicago, Illinois, U.S.A.). Statistical significance was accepted as $P < 0.05$.

3. Results

The physical characteristics were not significantly different between the MICT (age 30±4 years, height 1.73±0.08 m, body mass 68±9 kg) and HIT groups (age 30±4 years, height 1.72±0.07 m, body mass 68±7 kg). There were no differences in cycling experience between the MICT and HIT groups (2.1±1.1 and 2.8±1.1 years, respectively). Training adherence was 100% for the MICT and HIT groups. The mean total amount of work completed during the training sessions was 19.8±4.0 kJ for HIT.

Compared to pre-training values, LTP power (pre: 207±42, post: 229±44 W) and PAP (pre: 260±42, post: 282±45 W) were significantly increased in the HIT group (p<0.05, Table 1). There were no pre- to post-training changes in LTP power (pre: 205±31, post: 205±31 W) or PAP (pre: 253±30, post: 254±26 W) for the MICT group (p>0.05, Table 1). The mean power output (pre: 187±35, post: 206±36 W) and completion time (pre: 55.9±4.1, post: 54.4±4.1 min) for the 30-km TT were improved post-training in the HIT group (p<0.05, Table 1). However, there were no pre- to post-training differences in mean power output and endurance time for the 30-km TT in the MICT group (p>0.05, Table 1).

Following the training intervention, power output at LTP (MICT: 205±31, HIT: 229±44 W) and PAP (MICT: 254±26, HIT: 282±45 W) were greater in the HIT group compared to the MICT group (p<0.05). However, there were no significant differences in the lactate concentration at the LTP, or average PO and time trial completion time between groups after training (p>0.05, Table 1).

Table 1. Changes in cycling performance from pre- to post-training in the HIT and the MICT groups.

Parameters	MICT group		HIT group	
	Pre	Post	Pre	Post
Incremental cycling test				
Work rate at LTP (W)	205±31	205±31	207±42	229±44*,#
PAP (W)	253±30	254±26	260±42	282±45*,#
Lactate concentration at LTP (mmol)	7.33±1.16	7.46±1.18	6.70±1.31	6.87±0.92
30 km time trial				
Average PO (W)	190±26	188±28	187±35	206±36*
Time trial completion time (min)	56.1± 3.1	56.2± 3.1	55.9±4.1	54.4±4.1*

Values are mean±SD. *Difference between pre and post (P < 0.05). #Difference between MICT and HIT after training (P<0.05). PAP = peak aerobic power output. LTP = lactate turnpoint. PO = power outptu.

4. Discussion

The principal findings of this study are consistent with our experimental hypothesis and revealed that six weeks of HIT was able to improve PAP and the power output at the LTP in a group of Thai amateur cyclists. There were no changes in these variables in a similar group of cyclists who completed conventional MICT. Average PO and time trial completion time were only improved post training relative to pre training in the HIT group, but there were no differences in these variables between the HIT and MICT groups post training. These results suggest that trained amateur cyclists are more likely to improve PAP, LTP and endurance cycling performance if they undertake a period of HIT compared to MICT.This might have implications for improving training recommendations and optimizing endurance performance in amateur cyclists.

In the present study, there was a 3%-improvement in the time required to complete a 30 km TT following HIT, compared to before HIT, in trained amateur cyclists. This improvement in endurance performance following HIT in the current study, where the interval work rate during the HIT protocol was set at 120% LTP (~80% PAP), and the work: rest ratio was 1:2, is consistent with the findings of Paquette *et al*. (2017) who reported improved endurance performance following six weeks of HIT comprising three weekly sessions of 1-7 min-intervals at 85% PAP interspersed with 30-210 s recovery (work:rest ratio of 2:1) in well trained cyclists. Our observations are also in accord with the findings of Stepto *et al*. (1999) who observed improved endurance performance in trained cyclists following three weeks of HIT comprising two weekly sessions of 6×4 min-intervals at 85% PAP (Stepto, 1999). Moreover, several other studies have reported enhanced PAP and cycling performance in trained cyclists after completing a HIT intervention employing a work: rest ratio of 2:1 (Driller, 2009; Laursen, 2002). However, our observations conflict with the findings of Stepto *et al*. (1999) who reported no improvement in endurance performance in trained cyclists following three weeks of HIT comprising two weekly sessions of 4×8 min-intervals at 80% PAP interspersed with a 1 min-recovery (work:rest ratio of 8:1), 12×2 min-intervals at 90% PAP interspersed with a 3 min-recovery (work:rest ratio of 2:3) or 12×1 min-intervals at 100% PAP interspersed with a 4 min-recovery (the work: rest ratio was 1: 4) (Stepto, 1999). These inter-study discrepancies might be linked to differences in the duration, intensity or volume of the training programs administered and the work-rest ratio may also play an important factor. Therefore, these training principles need to be carefully considered by trained cyclists to maximize the ergogenic potential of their training programs. The lack of an improvement in endurance performance following six weeks of MICT in the trained cyclists who participated in the current study is consistent with the notion that further adaptations in endurance performance are curtailed in endurance trained individuals with continued MICT, and that HIT is a better training strategy to elicit further performance gains in this population (Bangsbo, 2009; Laursen & Jenkins, 2002).

The improvement in 30 km cycling TT performance after HIT in the current study was accompanied by increases in PAP (8%) and the power output at the LTP (10%).This observation supports the notion that PAP (Borszcz, 2017) and LTP (Midgley, 2006) are important determinants of endurance performance, a contention that is substantiated by the lack of concomitant changes in TT performance, PAP and LTP after MICT in the current study. Previous studies have also reported increased PAP (McKay, 2009) and LTP (Teixeira, 2017) following HIT. Our findings are also consistent with previous studies reporting greater improvements in power output at LTP and PAP following HIT compared to MICT (Buchheit & Laursen, 2013; Laursen, 2010). However, since we did not measure other key determinants of endurance performance, such as peak oxygen uptake, oxygen uptake kinetics and critical power, and since these variables have been reported to be enhanced following HIT (McKay, 2009; Vanhatalo, 2008), we cannot exclude the possibility that these variables might also have contributed to the ergogenic effect of HIT reported in the current study. A further limitation of our study was that we did not include a non-exercising control group to assess for potential changes in the outcome variables of this study over a 6 week-period. In addition, we acknowledge that since the total work done was not controlled and matched between the training groups that this might have impacted the findings of this study. This might explain, at least in part, why MICT did not alter physiological responses or performance in the current study. This observation is consistent with previous observations that physiological and performance adaptations to MICT are limited in already trained participants (Laursen & Jenkins, 2002). Improvements in 30 km-cycling TT performance and increases in PAP and the power output at the LTP after HIT in the current study are likely linked to improvements in both central cardiovascular function (Daussin *et al*., 2008; Esfandiari, 2014) and peripheral oxidative metabolism (Christensen, 2016; Daussin *et al*., 2008).

Through demonstrating that HIT evoked superior improvements in PAP and the power output at the LTP compared to MICT, and that TT performance was only enhanced pre-post training in the HIT group, the current study might help inform training recommendations for amateur-trained cyclists. Specifically, our results suggest that as aerobic fitness is enhanced, athletes need to consider incorporating HIT into the training program to limit a plateau in training adaptations and competitive performance.

5. Conclusions

Six weeks of HIT increased PAP and the power output at the LTP and improved cycling TT performance in a group of trained amateur Thai cyclists. These variables were not alerted when a similar group of subjects underwent a MICT intervention over the same time frame. Therefore, our results suggest by Thai amateur cyclists are more likely to improve endurance performance with HIT compared to MICT.

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References

Bangsbo, J., Gunnarsson, T. P., Wendell, J., Nybo, L., & Thomassen, M. (2009). Reduced volume and increased training intensity elevate muscle Na^{+}-K^{+} pump alpha2-subunit expression as well as short- and long-term work capacity in humans. *Journal of Applied Physiology, 107*(6), 1771-1780.

Borszcz, F. K., Tramontin, A. F., de Souza, K. M., Carminatti, L. J., & Costa, V. P. (2017). Physiological correlations with short, medium, and long cycling time-trial performance. *Research Quarterly for Exercise and Sport, 89*, 120-125.

Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. *Sports Medicine, 43* (5), 313-338.

Christensen, P. M., Jacobs, R. A., Bonne, T., Flück, D., Bangsbo, J., & Lundby, C. (2016). A short period of high-intensity interval training improves skeletal muscle mitochondrial function and pulmonary oxygen uptake kinetics. *Journal of Applied Physiology, 120*, 1319-1327.

Daussin, F. N., Zoll, J., Dufour, S. P., Ponsot, E., Lonsdorfer-Wolf, E., Doutreleau, S., . . . Richard, R. (2008). Effect of interval versus continuous training on cardiorespiratory and mitochondrial functions: relationship to aerobic performance improvements in sedentary subjects. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 295*(1), R264-R272.

Driller, M. W., Fell, J. W., Gregory, J. R., Shing, C. M., & Williams, A. D. (2009). The effects of high-intensity interval training in well-trained rowers. *International Journal of Sports Physiology and Performance, 4*(1), 110-21.

Esfandiari, S., Sasson, Z., & Goodman, J. M. (2014). Short-term high-intensity interval and continuous moderate-intensity training improve maximal aerobic power and diastolic filling during exercise. *European Journal of Applied Physiology, 114*(2), 331-343.

Granata, C., Oliveira, R. S., Little, J. P., Renner, K., & Bishop, D. J. (2016). Mitochondrial adaptations to high-volume exercise training are rapidly reversed after a reduction in training volume in human skeletal muscle. *FASEB Journal, 30*, 3413-3423.

Haskell, W. L., Lee, I. M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., . . . Bauman, A. (2007). Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation, 116*, 1081-1093.

Hawley, J. A., Dennis, S. C., & Hopkins, W. G. (1999). Effects of different interval-training programs on cycling time-trial performance. *Medicine and Science in Sports and Exercise, 31*, 736–741.

Laursen, P. B. (2010). Training for intense exercise performance: High-intensity or high-volume training? *Scandinavian Journal of Medicine and Science in Sports, 20*(2), 1-10.

Laursen, P. B., Blanchard, M. A., & Jenkins, D. G. (2002). Acute high-intensity interval training improves Tvent and peak power output in highly trained males. *Canadian Journal of Applied Physiology, 27*(4), 336-348.

Laursen, P. B., & Jenkins, D. G. (2002). The scientific basis for high-intensity interval training: Optimising training programmes and maximising performance in highly trained endurance athletes. *Sports Medicine, 32*, 53-73.

McKay, B. R., Paterson, D. H., & Kowalchuk, J. M. (2009). Effect of short-term high-intensity interval training vs. continuous training on O_2 uptake kinetics, muscle deoxygenation, and exercise performance. *Journal of Applied Physiology, 107*, 128-138.

Midgley, A. W., Mc Naughton, L. R., & Wilkinson, M. (2006). The relationship between the lactate turnpoint and the time at VO_{2max} during a constant velocity run to exhaustion. *International Journal of Sports Medicine, 27*, 278-282.

Neal, C. M., Hunter, A. M., Brennan, L., O'Sullivan, A., Hamilton, D. L., De Vito, G., & Galloway, S. D. (2013). Six weeks of a polarized training-intensity distribution leads to greater physiological and performance adaptations than a threshold model in trained cyclists. *Journal of Applied Physiology, 114*, 461-471.

Ní Chéilleachair, N. J., Harrison, A. J., & Warrington, G. D. (2017). HIIT enhances endurance performance and aerobic characteristics more than high-volume training in trained rowers. *Journal of Sport Sciences, 35*, 1052-1058.

Paquette, M., Le Blanc, O., Lucas, S. J., Thibault, G., Bailey, D. M., & Brassard, P. (2017). Effects of submaximal and supramaximal interval training on determinants of endurance performance in endurance athletes. *Scandinavian Journal of Medicine and Science in Sports, 27*, 318–326.

Rønnestad, B. R., Hansen, J., & Ellefsen, S. (2014). Block periodization of high-intensity aerobic intervals provides superior training effects in trained cyclists. *Scandinavian Journal of Medicine and Science in Sports*, *24*(1), 34-42.

Stepto, N. K., Hawley, J. A., Dennis, S. C., & Hopkins, W. G. (1999). Effects of different interval-training programs on cycling time-trial performance. *Medicine and Science in Sports and Exercise, 31*, 736-741.

Teixeira, A. S., Arins, F. B., De Lucas, R. D., Carminatti, L. J., Dittrich, N., Nakamura, F. Y., & Guglielmo, L. G. A. (2017). Comparative effects of two interval shuttle-run training modes on physiological and performance adaptations in female professional futsal players. *Journal of Strength and Conditioning Research*, 33(5), 1416-1428. doi:10.1519/JSC.00000 00000002186

Vanhatalo, A., Doust, J. H., & Burnley, M. (2008). A 3-min all-out cycling test is sensitive to a change in critical power. *Medicine and Science in Sports and Exercise, 40*, 1693-1699.