Comparison of Rowing Performance Improvements Following Various High-Intensity Interval Trainings

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Abstract

Akca, F and Aras, D. Comparison of rowing performance improvements following various high-intensity interval trainings. *J Strength Cond Res* 29(8): 2249–2254, 2015—The purpose of this study was to examine the effects of high-intensity interval training (HIT) and supramaximal interval training (SMIT) on indoor rowing performance; 20 male lightweight collegiate rowers (age = 21.77 ± 2.35 years, height = 178.4 ± 6 cm, body mass = 69.6 ± 3.1 kg) participated in this study. Baseline testing involved a 2,000-m time trial and incremental exercise test to determine $\dot{V}O_2$peak, peak power output (PPO), and power at 4 mmol·L^{-1} blood lactate threshold. After the baseline tests, participants were allocated to SMIT or HIT intervention groups, which they performed 8 times over a 4-week period (2 times per week, 2 days apart). The SMIT involved 10 × 30-second intervals at 150% of the PPO with 4-minute rest. The HIT involved 8 × 2.5-minute intervals at 90% of the PPO with 3-minute rest. Of note, 5.7 and 5 seconds of improvements were observed in 2,000-m performance after SMIT and HIT interventions, respectively. Of note, 2,000-m time trial performance, 2,000-m power, PPO, relative, and absolute $\dot{V}O_2$peak were significantly improved after both training interventions. However, the differences between the groups were not significant. As a result, 4 weeks of SMIT improves 2,000-m rowing ergometer performance and related physiological variables in a similar fashion with HIT in collegiate rowers.

Key Words ergometer, 2,000-m time trial, endurance, peak power output, $\dot{V}O_2$peak, supramaximal interval training

Introduction

Competitive rowing is a sport that requires highly developed aerobic and anaerobic capacities. The energy needed for a 2,000-m ergometer rowing was estimated to be 65–75% aerobic and 25–35% anaerobic (10). Anaerobic power is specifically crucial during the initial sprint and final phases of the competition and characteristically ensures 20–30% of the energy requirement of a 2,000-m race (25,31). A 2,000-m rowing ergometer time trial is the most common measure of rowing performance and has become an important selection tool for national rowing organizations (31). By testing rowers individually through competition-length time trials on ergometers, coaches are able to evaluate each athlete's ranking on the team in a controlled environment. When comparing on-water to simulated rowing methodologies, only slight disparities in physiological responses exist (19,20).

High-intensity interval training (HIT) and supramaximal interval training (SMIT) are both considered to be commonly used performance enhancing methods in individual and team sport training programs. High-intensity interval training involves work at the speed or work rate corresponds to the 90–100% of velocity at $\dot{V}O_2$max. Work-rest ratios applied during HIT sessions vary from 1:1 to 2:1. Supramaximal interval training involves the work at intensities greater than 100% of $\dot{V}O_2$max, often with work-rest ratios from 1:3 to 1:9 (2,11).

Greater improvements after HIT intervention compared with traditional continuous training on rowing time trial performance were reported in previous studies (8,9). Additionally, several studies demonstrated some benefits on $\dot{V}O_2$peak and short-term power output after SMIT (11,26). However, to the best of our knowledge, no single study has examined the effects of SMIT on rowing time trial performance. Thus, the aim of this study is to compare the effects of 4 weeks of HIT and SMIT interventions on 2,000-m rowing time trial performance and the parameters related to rowing performance such as peak power output (PPO), $\dot{V}O_2$peak, and power at 4 mmol·L^{-1} lactate level.

Methods

Experimental Approach to the Problem

To compare the effectiveness of different training regimens on indoor rowing performance, lightweight collegiate rowers were tested for 2,000-m time trial and maximal incremental exercise performances initially. After the baseline measures, subjects were matched according to their PPO

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value obtained from the incremental exercise test and then randomly assigned into 2 different training regimens as HIT and SMIT for 4 weeks (2 sessions per week for 4 weeks, 2 days between sessions, 8 sessions total). The time between the end of pretesting and beginning of the training was 48 hours. After 4 weeks of training, all baseline measures were retested at week 5 to compare the improvements in 2,000-m time trial test. Posttesting was employed after the completion of training interventions with 48 hours of rest before the tests. Training interventions were conducted in the last mesocycle of the specific preparation period of the squad's yearly training plan, when all athletes performed rowing ergometer exercises regularly.

Participants were asked to refrain from any food intake for 3 hours before the measurements and to avoid caffeine and alcohol intake and strenuous exercise for 48 hours before tests. All participants reported that they have not consumed any nutritional or ergogenic supplements, excluding multivitamin pills for the previous 6-week period, and the same routine was followed during the training intervention period. Participants were also instructed to keep a diary of dietary intake on the day before the baseline tests, and the same dietary intake was replicated on the postintervention test (8,9). Tests were conducted approximately at the same time of the day (±1 hour) for each participant, and rowers used the same ergometer during the tests.

Participants were asked to keep a training diary during the whole study time. Training diaries consisted of the type of training, duration, heart rate (HR), and distance or mean power (where appropriate) of each training. Intensity ratings of each training session were provided by the participants themselves using CR10 Borg's Scale (4) for rating of perceived exertion (RPE). To quantify the amount of total training that was completed in both HIT and SMIT interventions, this study used a method focusing on the session RPE. The session RPE method provided a mechanism for quantifying the exercise intensity component and was reported as a reliable tool for rowers and other athletic populations (7). To calculate training amounts and loads using session RPE method, the RPE of each training session was multiplied by the duration (minutes) of the session. Participants were the part of the same squad which performs the same training program, thus only difference in training between the groups was the ergometer protocol they were undertaking twice a week.

Subjects

Twenty male, national level, lightweight collegiate rowers (age = 21.77 ± 2.35 years, height = 178.4 ± 6 cm, body mass = 69.6 ± 3.1 kg, sport age = 4.3 ± 2.4 years, $\dot{V}O_2$peak = 56.6 ± 5.7 $ml \cdot kg^{-1} \cdot min^{-1}$) voluntarily participated in the study. The study was approved by the Institutional Human Research Ethics Committee. Before the tests, participants were provided with a sheet that contained information about the study design and any possible risks, and they signed written informed consent forms to participate in this study.

Procedures

2,000-m Time Trial Test. An air-braked rowing ergometer (model D; Concept II, Morrisville, VT, USA) was used for rowing performance measures. Drag factor settings of the ergometers were adjusted to 135 as recommended by Amateur Rowing Association for lightweight men rowers (28). For the time trial test, participants were asked to perform an all-out 2,000 m on ergometer. Heart rate was recorded with a telemetric HR monitor throughout the test (s610i; Polar Electro Oy, Kempele, Finland). Completion time, stroke rate, HR, and average power outputs were recorded immediately after the test for the whole test and each 500-m splits separately. Test-retest reliability of 2,000-m rowing ergometer time trial was previously reported with a coefficient of variation (CV) of 1% (17,29).

Incremental Exercise Test. To determine the metabolic responses to loading, incremental rowing ergometer test recommended by Australian Institute of Sport (AIS) was executed (13). The test protocol was discontinuous with progressive 4-minute increments, consisting of 6 submaximal stages and a final (seventh) maximal stage. The stages were separated by l-minute recovery intervals during which blood samples for lactate analyses were taken. The work intensity for the submaximal stages was determined individually based on each participant's best time during 2,000-m time trial test. The average 500-m pace of the 2,000-m maximal test time plus 4 seconds was calculated to give the pace (per 500 m) that the participant was required to maintain during the sixth stage of the test. Successive amounts of 6 seconds per 500 m were added to calculate the required pace for the earlier work intensity. The final (seventh) stage was performed with 4-minute maximal effort.

Gas exchange during the test was measured breath by breath with a gas analysis system (Oxycon Mobile, Jaeger GmbH, Hoechberg, Germany). Heart rate was recorded during test using heart rate belt (Polar Electro OY, Kempele, Finland). Blood lactate concentrations were measured using an automated lactate analyzer (YSI Sport 1500, Yellow Springs, OH, USA). Before tests, lactate and gas analyzers were calibrated according to manufacturers' instructions.

$\dot{V}O_2$peak was determined by averaging the 4 highest consecutive oxygen consumption value recorded during the last stage of the test. Mean power output in the last stage of the incremental test was deemed as PPO and was used to determine the work intensity at which each participant would row during the HIT and the SMIT sessions. As recommended by AIS (13), the 4 $mmol \cdot L^{-1}$ fixed blood lactate concentration method was used to determine anaerobic threshold. Values at the fixed blood lactate concentration of 4 $mmol \cdot L^{-1}$ were determined using a software package (Lactate-E, v2.0; National University of Galway, Galway, Ireland) (27).

High-Intensity Interval Training Protocol. The HIT protocol used in this study was adapted from the study of Driller et al. (8). The group completed 8 sessions in 4 weeks (2 sessions per week, 2 days between each session). Each participant rowed at 90% of their individual PPO determined during 2,000-m time trial test, for 2.5 minutes per set, and completed 8 sets per training. Participants were instructed to continue rowing at 40% of their PPO for 3 minutes for recovery. Intensity of the recovery period was chosen so as to promote the efficient rate of lactate removal and rapid HR recovery. Each session lasted approximately 45 minutes.

Supramaximal Interval Training Protocol. The SMIT group completed 8 sessions in 4 weeks (2 sessions per week, 2 days between each session). Each training consisted of 10 sets of 30-second efforts with the velocity of 150% of the PPO determined by an incremental exercise test. Various work-rest ratios from 1:3 to 1:9 were suggested for SMIT trainings in the literature. To match the exercise duration with the HIT intervention, work-rest ratio was selected as 1:8, and participants were instructed to continue rowing at 40% of their PPO for 4 minutes for recovery (2,5,11) Intensity of the recovery period was chosen to promote the efficient rate of lactate removal and rapid HR recovery. Each session lasted approximately 45 minutes.

Statistical Analyses

Results of the measured variables (2,000-m time, 2,000-m power, $\dot{V}O_2$peak, PPO, and 4 mmol·L^{-1} power) and percent changes of the same variables were compared using paired *t*-tests for each training regimen, and independent *t*-tests were used to analyze training diary data, using the SPSS (version 20.0; SPSS, Inc., Chicago, IL, USA) with a statistical significance of $p \leq 0.05$. Standardized changes in mean of each measure were used to assess magnitudes of effects and provide the likelihood of the true effects being practically positive, trivial, and negative by dividing the changes by the smallest worthwhile change. The mean effects of training and their 90% confidence limits were estimated using a Microsoft Excel Spreadsheet (3). The likelihoods were set as <1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely or probably not; 25–75%, possibly or maybe; 75–95%, likely or probably; 95–99%, very likely; >99%, almost certainly. To summarize, likelihood values between 0 and 25% were deemed as negative, 25–75% were deemed as trivial, and >75% were deemed as positive effect in the table that is presented in the Results section. Measures of reliability known as CV were used as the smallest worthwhile change of each variable (16). Coefficient of variation for the mean power during 2,000-m time trial was reported as 2%, the CV reported for time to complete a 2,000-m time trial in the same study was 1% (29). The CVs for $\dot{V}O_2$peak, 4 mmol·L^{-1} power output, and PPO were reported as 2.2, 1, and 2%, respectively. All of these CV values were halved for each variable and used as the smallest worthwhile change in this study. Thus, the worthwhile change was accepted as 1% for 2,000-m power, 0.5% for 2,000-m time, 1.1% for $\dot{V}O_2$peak, 0.5% for 4 mmol·L^{-1} power, and 1% for PPO, respectively (8).

Results

Table 1 presents the raw data that were collected before and after the exercise interventions. The clinical significance that SMIT had on performance and the chances that SMIT had a positive, negative, or trivial effect on performance are also given in Table 1. According to the *t*-test results, all values were significantly improved as a result of the 4-week training intervention compared with the pretest results in both groups ($p < 0.01$). However, none of the variables showed any practically significant difference between the SMIT and

Table 1. Two thousand-meter time trial and incremental exercise test performances before and after the training interventions and effect of supramaximal interval training (SMIT) relative to high-intensity interval training (HIT) and likelihoods of clinically substantial differences.*

	SMIT		HIT		Likelihood (%) of SMIT being positive/trivial/negative (compared with HIT)
Variable	Pre	Post	Pre	Post	
2,000-m time (s)	412 ± 7.7	406.3† ± 7.1	411.6 ± 7.5	406.6† ± 7	39/31/30
2,000-m power (W)	320 ± 24.6	335† ± 26.2	322 ± 25	334† ± 26	36/38/26
$\dot{V}O_2$peak (ml·kg^{-1}·min^{-1})	56.1 ± 5.5	59.2† ± 5.8	57 ± 5.7	59.8† ± 5.4	34/40/26
$\dot{V}O_2$peak (L·min^{-1})	4.08 ± 0.66	4.30† ± 0.61	4.10 ± 0.65	4.29† ± 0.63	32/39/29
PPO (W)	335 ± 24	353† ± 26	336 ± 20	351† ± 21	44/38/18
4 mmol·L^{-1} power (W)	238 ± 27	256† ± 28	240 ± 23	257† ± 22	45/41/14

*PPO = peak power output.
†$p \leq 0.05$ (between pre and post measurements of each group).

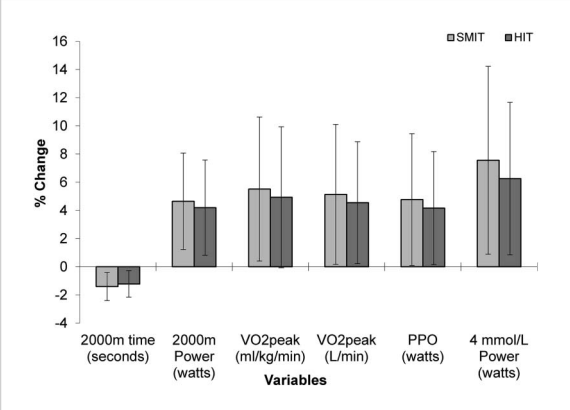

Figure 1. Changes as a percentage in measured variables after supramaximal interval training and high-intensity interval training interventions.

HIT groups. The likelihood that the SMIT was beneficial compared with the HIT group was ≥36% and ≥44% for the 2,000-m power and PPO variables, respectively. The results, determined for the 2,000-m time trial result, absolute $\dot{V}O_2$peak, and relative $\dot{V}O_2$peak were found to be ≥39%, ≥32%, and ≥34%, respectively.

As displayed in Figure 1, percentage improvements in 2,000-m time trial performance, 2,000-m power output, $\dot{V}O_2$peak, PPO, and 4 mmol·L^{-1} power values were similar and not significantly different between both groups ($p = 0.94$, $p = 0.93$, $p = 0.88$, $p = 0.91$, and $p = 0.95$, respectively).

According to the results of the training diary analysis, there were no significant differences ($p = 0.96$) in the total amount of the training performed between the groups during the whole study process (as identified by the session RPE method, SMIT = 8,813 ± 7,380; HIT = 8,477 ± 7,654).

Discussion

To the best of our knowledge, no previous study has compared the effects of SMIT and HIT on rowing performance. This study is the first that demonstrated the effects of SMIT on the performance of rowers showing that SMIT improves performance in a similar fashion with HIT in lightweight collegiate rowers.

The rowing performance differences after SMIT and HIT interventions were not statistically or practically significant. Regardless of training group, all values of the measured variables were significantly improved between pre- and posttest (Table 1). Besides, performance improvements as a percentage in 2,000-m time trial time, PPO, 2,000-m power, $\dot{V}O_2$peak, and 4 mmol·L^{-1} power were all similar for both training interventions (Figure 1).

Significant improvements in time trial performances were demonstrated in runners and cyclists after HIT (21). However, the research data in the literature on the effects of HIT on rowing performance are limited. Performance improvements of 3% were determined in 5 km (18) and 10 km (1) running times in middle- and long-distance runners after HIT intervention. In a study conducted on highly trained cyclists, improvements in 40-km time trial performance were reported to be between 4.4 and 5.8% after similar HIT protocols (23). It was found that performance enhancements related to rowing time trial performance may be associated with improvements in PPO, 4 mmol·L^{-1} power, and $\dot{V}O_2$peak values (19,33). These improvements were demonstrated also in this study for both training interventions.

Improvements between 5 and 15% in $\dot{V}O_2$peak after various HIT interventions were reported in several studies (12,23,32). Similarly, 7% improvement in $\dot{V}O_2$peak was determined in runners, swimmers, and cyclists after HIT intervention (21). In a study conducted on highly trained runners using a similar HIT method, significant improvements of $\dot{V}O_2$peak around 5% were noted (32). Moreover, 8% improvement in $\dot{V}O_2$peak after 4 weeks of HIT was noted for highly trained cyclists (23). Improvements of about 5% in $\dot{V}O_2$peak were noted in this study after SMIT and HIT interventions. Although genetics and initial fitness level can be considered as important factors influencing improvements in $\dot{V}O_2$peak, training stimulus related to HIT and SMIT can also be labeled as a determining factor which contribute to a magnitude of the enhancement (22). The findings in various research (32) about the effectiveness of training at or close to the velocity corresponding to $\dot{V}O_2$peak are supported in this study when the improvements after the HIT intervention were taken into account. In a study that used similar SMIT intervention, the change in performance of 3,000-m running after SMIT was found greater compared with the one in continuous running (5). In the same study, after 6 weeks of training, improvements of about 6.2% for males and 10.5% for females were determined in 3,000-m running performance after SMIT intervention, and HIT intervention did not produce significantly greater improvement in endurance variables than SMIT. In addition, it has been established that SMIT enhances anaerobic variables significantly greater than HIT.

Lactate clearance rate at a given submaximal power output and ability to elicit less lactate with a higher work rate are important predictors of rowing performance because of the relationship between blood lactate levels and muscle respiratory capacity (19). Work output at 4 mmol·L^{-1} blood lactate level was established as an important predictor of rowing performance in several studies (6,19,30). Improvements of about 7.5 and 6.3% in power at 4 mmol·L^{-1} were observed after both SMIT and HIT interventions in this study, respectively.

The positive effects of HIT intervention on rowing time trial performance have been demonstrated in 2 studies (8,9). Of note, 7% improvement of $\dot{V}O_2$peak was reported after 4 weeks of HIT (8). In raw terms, 8-second (8) and 6-second (9) improvements have been reported in 2,000-m rowing time trial performance after the 4-week HIT intervention.

In this study, 2,000-m time trial performances were improved 5.7 seconds and 5 seconds after SMIT and HIT interventions, respectively. Similar to the findings of this study, the performance improvements that occurred after the 4-week HIT intervention have been found to be associated with the enhancements in the $\dot{V}O_2$peak values, PPO, and 4 $mmol \cdot L^{-1}$ power (8,9).

In the design of this study, 8 training sessions were completed for each training intervention. There are studies that report improvements by 3.5% in 40-km cycling time trial performance after 6, 8, and 12 HIT sessions (15,24). It seems that increasing the number of HIT sessions does not result in any further performance improvement in cycling performance. Besides, improvements in 40-km cycling time trial performance related to HIT intervention were reported to be completed after only 6 sessions (14). Also, whether the trend associated with the number of SMIT or HIT sessions into a rowing training program is similar still remains unanswered and may be an interesting area of future research. Furthermore, determining optimal number of the sets and rest intervals during SMIT is another factor to research on.

Practical Applications

In a practical perspective for rowing coaches, about 6-second improvement in 2,000-m time trial performance was observed after SMIT intervention, and also 5-second improvement was observed to be associated with HIT intervention. Improvement of about 6 seconds is equal to approximately a 2-boat length improvement in a single sculling race, and these improvements can be decisive factors in the race result. Both methods proved to be successful in improving rowing time trial performance, the benefits gained after SMIT intervention were similar compared with HIT intervention in lightweight collegiate rowers. It should be noted that these outcomes were observed in national level collegiate rowers. The question about the effects of SMIT on performances of elite level rowers remains to be unanswered. Furthermore, considering that this study is the first to show performance improvements after 4 weeks of SMIT intervention in rowers, more research is needed to determine the optimal volume and periodization of the SMIT interventions in a rowing training program.

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