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ACUTE PHYSIOLOGICAL RESPONSES DURING HIGH INTENSITY INTERVAL TRAINING AND CONTINUOUS EXERCISE TRAINING

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Clinical Exercise Physiology

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We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology.

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ABSTRACT

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The aim of this study was to investigate the correlation between improvements in aerobic and anaerobic power with various acute physiological responses, including blood lactate accumulation (HLa), percent heart rate reserve (%HRR), Rating of Perceived Exertion (RPE), session RPE (sRPE), and the training impulse (TRIMP) during high intensity interval training (HIIT) compared to moderate intensity interval training and continuous training. Fifty-five subjects aged 18 to 29 completed a pre and post VO_{2max} and Wingate test on the cycle ergometer. Subjects completed 24 sessions of either a steady-state exercise control at 90% of the power output (PO) at the ventilatory threshold (VT), a Meyer interval protocol with 30:60 seconds exercise-to-rest ratio at 100% of peak power output (PPO), or a Tabata interval protocol with 20:10 seconds exercise-to-rest ratio at 170% of VO_{2max}. During the 8-week training period, HLa, sPRE, %HRR, and TRIMP all followed the study's initial design and the overall relative intensity remained stable. Despite the fact that the Tabata HIIT had the highest average power (403.7 ± 108.60 W), average RPE (7.5 ± 0.83), average sRPE (6.85 ± 1.04), average %HRR (83.1 ± 8.02 %), average HLa accumulation (11.5 ± 2.80 mmol/L), and highest percentage of training time spent in Zone 3 (67.7 ± 16.18 %), it was not associated with significantly greater increases in aerobic or anaerobic capacity when compared to the steady-state control and the Meyer HIIT. These data support the fact that Tabata interval training, despite being associated with higher HLa, %HRR and RPE, elicits similar improvements in anaerobic and aerobic capaicty when compared to steady-state exercise and Meyer HIIT that averaged approximately 90% of the intensity at VT.

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But, most importantly I would like to thank my grandfater, Adie Daniel Harbin, Jr. Each year on my birthday my grandfather would buy me a new book as a present. Although what I really wanted was the American Girl Doll named Kristen, the fact that he instead gave me books every year showed how highly he regarded education. His love for education was passed on to me. I only wish that he was still alive today so that I could give him a copy of my thesis in return for everything he has given me.

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INTRODUCTION

The purpose of the Surgeon General's report in 1996 was to emphasize that physical activity reduces the risk of premature mortality and that benefits from exercise are achievable through moderate activity performed at least 30 minutes on most days of the week (US department of Heath and Human Services [USDHSS], 1996). In the 2008 Physical Activity Guidelines for Americans, the minimum amount of exercise required for substantial health benefits was revised to either 150 minutes at a moderate intensity or 75 minutes at a vigorous intensity per week (USDHHS, 2008). However, recent studies have shown that increased health benefits do not necessarily correlate with longer durations of physical activity (Sperlich et al., 2010). Instead, exercising at higher intensities for shorter durations are associated with decreased risk of mortality and have the potential to promote similar health benefits in significantly less time (Lee, Hsieh, and Paffenbarger, 1995; Sperlich et al., 2010).

The trend toward high interval intensity training (HIIT) emerged as an alternative to high volume training (HVT). There are two basic variants of HIIT. One is named after Japanese researcher Izumi Tabata and uses very short duration, very high intensity exercise. The other, named after the German researcher Katherina Meyer, is a less intense HIIT protocol compared to Tabata. Tabata high intensity intervals characteristically last four minutes and consist of eight repetitions of very intense exercise (170% of VO_{2max}) maintained for 20 seconds with 10 seconds of rest (Tabata et al., 1996). Tabata et al. determined that this high intensity protocol increased both VO_{2max} (7 ml/kg/min) and anaerobic capacity (28%). Meyer intervals are characteristically 30 seconds at an intensity of approximately 100% of VO_{2max} and 60 seconds at 25% of VO_{2max} (Meyer et al., 1990). Meyer et al. (1990) used this protocol in patients following coronary bypass surgery and with chronic heart failure patients. In chronic heart failure patients, they discovered that maximal work rate had doubled and the cardiac stress lowered following high intensity training. The main purpose of this study was to compare two different HIIT protocols (using Meyer and Tabata intervals) to a steady-state exercise control group and evaluate differences in anaerobic and aerobic improvement. In order to document which exercise intensity might correlate with a better response to training, blood lactate accumulation (HLa), % heart rate reserve (%HRR), Rating of Perceived Exertion (RPE), session RPE (sRPE), and the training impulse (TRIMP) was used to better understand how training variations might influence training outcomes.

Blood lactate accumulation (HLa)

Blood lactate is produced continuously as an alternative to pyruvate oxidation. In steady-state exercise below 50 to 60% of maximum oxygen uptake (VO_{2max}), the oxidative energy supply is established within about five minutes of exercise and HLa production and elimination are balanced at relatively low concentrations (Billat, 1996; Gosh, 2004). During a progressive exercise test in which the resistance on a cycle ergometer is increased at regular intervals, the rate of pulmonary minute ventilation (VE) will increase linearly for the first part of the test. The ventilatory threshold (VT), which is when the VE increases non-linearly with an incremental increase in workload, will typically occur around 50 to 60% of the peak power output (PPO). Near the VT, the combination of a non-linear increase in CO_2 production, increased end tidal oxygen, abrupt increased F_EO_2 and an increase in HLa are collectively associated with the lactate threshold (LT) (Gosh, 2004). This breakpoint where HLa accumulates disproportionately with oxygen consumption is designated as the lactate threshold (LT) and represents a shift from aerobic metabolism to anaerobic metabolism with greater intensity. Elevated HLa during HIIT indicates greater exertion and provides a good estimate for exercise effectiveness with the indication that more time spent exercising above the LT/VT. Since more time is spent exercising above the anaerobic threshold during higher intensity, HLa correlates with intensity and is a suitable parameter representing exercise training intensity.

Session RPE

In addition to analyzing HLa to assess HIIT, sRPE is closely linked to exercise intensity and an effective indicator of exercise intensity. Foster et al. (1995) found a moderate correlation between average percent HR and sRPE when studying the effect cross-training has on improved running performance (R=0.65). Through evaluating the relationship of the sRPE to the percentage of time spent below, between and above HLa transition zones during 30-minute training sessions, Foster et al. (1995) observed a good correspondence between session RPE and HR response. This collectively asserts that sRPE provides approximately the same information regarding relative training intensity as continuously monitoring HR.

TRIMP score

Another acute physiological training indicator is summating the time spent in different HR defined zones into a TRIMP score. Exercising in Zone 1, which is located below the VT, is characterized with light intensity exercise. Zone 2 is associated with moderate intensity and is located in between the VT and the respiratory compensation threshold (RCT). The RCT is characterized by the onset of hyperventilation. High intensity is associated with exercising above the RCT and is designated as Zone 3. Foster et al. (2001) concluded that calculating a TRIMP score from five different HR zones was highly consistent with sRPE, and thus, is a good indicator of exercise intensity with varying modalities ranging from cycling to playing collegiate-level basketball.

Percent heart rate reserve (%HRR)

Percent heart rate reserve, in addition to sRPE, HLa, and TRIMP scores, is another good indicator of HIIT intensity. This marker goes back to the primary works of Karvonen et al. (1957) who observed that, in order to cause an increase in VO_{2max} and decrease the working HR (WR), training must be intense and more than 60% of the available range from rest to the maximum attainable by running (Karvonen et al., 1957). More recently, Iellamo et al. (2013) studied the effect different intensities had on thirty-six heart failure patients that had a left ventricular ejection fraction less than 40%. This twelve week study used interval training on treadmill at 75-80 %HRR with active rest periods at 45-50 %HRR and continuous training at a moderate intensity at 45-60 %HRR. Both training groups had decreased blood pressure, decreased daytime diastolic blood pressure, increased in VO_{2peak}, and increase anaerobic threshold. The HIIT training at 75-80% of HRR significantly improved insulin sensitivity, evidenced by reduction though decreasing HOMA scores. In a study that evaluated hypertensive males, interval training at 60-79 %HRR resulted in a greater increase in VO_{2max} compared to the continuous training group and sedentary control (Lamina, 2009).

From the research conducted thus far comparing to continuous exercise, it has been concluded that: 1) HIIT is correlated with increased HLa accumulation, 2) sRPE, %HRR, and TRIMP scores are good indicators of exercise intensity, 3) higher intensity seems increase both anaerobic and aerobic capacity. The purpose of this study is to, by means of evaluating exercise intensity through several acute physiological training parameters, help determine which type of HIIT (Tabata or Meyer) is more effective for improving functional capacity compared to steady-state exercise.

METHODS

Subjects

Descriptive characterists of the subjects are summarized in Table 1. Prior to this study, approval from the University of Wisconsin-LaCrosse Institutional Review Board for the Protection of Human Subjects was obtained. To identify any ineligible subjects with health problems that would contraindicate participation, all subjects were screened with the Physical Activity Readiness Questionnaire (PAR-Q). Sixty-five untrained and sedentary to moderately physically active undergraduate students provided written informed consent (Appendix A) to participate in this 8-week training study. Expecting more dropouts in the Tabata group, 20 subjects were randomly assigned for steady-state, 20 for Meyer HIIT, and 25 for Tabata HIIT. Ten subjects discontinued training due to illness unrelated to this study and analysis was performed on the 55 subjects who completed the entire protocol.

Table 1. Descriptive characteristics of the subject population

	Steady-state	Tabata HIIT	Meyer HIIT
Age (yrs)			
Males	19.5 ±1.38	20.3 ± 2.14	19.3 ± 1.26
Females	19.6 ± 2.94	19.5 ± 1.16	19.9 ± 2.77
Height (cm)			
Males	181.5 ± 8.94	174.6 ± 6.08	179.3 ± 10.69
Females	164.8 ± 4.87	168.6 ± 3.93	164.9 ± 4.85
Weight (kg)			
Males	94.3 ± 7.22	81.0 ± 13.85	76.4 ± 12.47
Females	68.6 ± 15.12	68.2 ± 14.04	71.9 ± 18.55

Protocol

Each subject performed a pre and post incremental exercise test and Wingate Anaerobic Test (WANT) on a cycle ergometer. The incremental exercise test measured VO_{2max}, VT, HR response, HR max, and RCT, while the Wingate test was used to determine relative change in peak power (PP) and mean anaerobic power (MP). Subjects completed their Wingate and VO_{2max} tests at approximately the same time of the day with 24 hours of rest between the two exercise tests to ensure optimal performance. All subjects wore a Polar HR monitor (Polar Vantage XL, Lake Success, NY) during training. After completion of the initial VO_{2max} and Wingate test, subjects were randomly assigned to either the moderate intensity steady-state control group, the moderate intensity Meyer HIIT group, or the high intensity Tabata HIIT group.

The steady-state exercise training involved a 5-minute warm-up, 20 minutes of sustained exercise at 90% of VT, and a 5-minute cool-down. The warm-up and cool-down protocols were identical, with the first two minutes at 25 W, the third minute at 50 W, the forth minute at 75 W, and the fifth minute at 25 W. Blood lactate measurements were taken from a fingertip once a week during the last minute of the workout and subjects rated their RPE from 0 to 10 using the category ratio Borg scale in the middle of the steady-state exercise (Borg, 1998). The final sRPE was measured at the end of the five-minute cool-down. Heart rate response was recorded once a week during the continuous 20 minutes of cycling at 90% of VT, which excluded the HR response during the warm-up and cool-down. Determining the %HRR and TRIMP score was done after downloading the HR response to a computer.

Using the same warm-up and cool down as the steady-state group, the Meyer intervals consisted of 13 repetitions of 30 seconds at 100% PPO from the VO_2max test and 60 seconds at an active recovery, with the net PO the same as during steady-state training. Tabata intervals consisted of the same warm-up and cool down as steady-state, eight repetitions of 20 seconds at 170% PPO of VO_{2max}, and 10 seconds at rest. Blood lactate measurements for both Tabata and Meyer HIIT were taken once a week for each subject during the last interval of the workout. Rate of Perceived Exertion was measured during the last interval and the sRPE was measured at the end of the five-minute cool-down of every training session. The recorded HR response excluded the five minute warm-up and cool-down for both HIIT groups. All subjects exercised three times a week and completed a total of 24 training sessions.

Statistical Analysis

Descriptive statics were used to characterize the results of the relative change in aerobic PPO, relative change in anaerobic PP, and relative change in anaerobic MP.

TRIMP scores were calculated by multiplying the summated time spent in Zones 1 through Zone 3 by the duration of the time in each zone. Maximal HR during the VO_{2max} test and average HR during training were used to calculate %HRR, with resting HR assumed to be 70 beats per minute.

RESULTS

With a porportionally similar increase in the average PO during training between steady-state, Meyer HIIT, and Tabata HIIT, the results in Figure 1 indicate that HLa, sPRE, %HRR, and TRIMP all followed the study's initial design and remained relatively stable. The Tabata group not only generated the highest average power of 403.7 ± 108.60 W, but also had the highest average %HRR and HLa (Table 2). Regardless of elevated exercise HR, RPE, and HLa, Figure 1 depicts that the average power, HLa, RPE, %HRR, and TRIMP were not statistically different between the three training groups.

In Figure 2 it can been seen that the relative change in PPO during the VO_{2max} test was not associated with the absolute PO (R^2=0.01709) or TRIMP (R^2=0.06651) during training, but was moderately related to measures of relative intensity including %HRR (R^2=0.18127), HLa (R^2= 0.11128) and RPE (R^2=0.07852). Relative change in anaerobic PP (Figure 3) and relative change in anaerobic MP (Figure 4) similarly did not have any significant differences between the three exercise groups in regards to %HRR, HLa, RPE and TRIMP. Thus, although subjects in the Tabata group were exercising at a higher intensity and RPE, there were no detected significant differences suggesting improved anaerobic capacity. The relationship between acute physiological varaiables with improvement in aerobic and anerobic power was not significantly different between HIIT or moderate continuous exercise in this 8-week training study.

Table 2. Group averages of generated Watts, %HRR, HLa, sRPE, RPE, TRIMP, and % of the training time spent in Zones 1, 2, and 3.

	Steady-State	Meyer HIIT	Tabata HIIT
Power (Watts)	130.8 ± 41.71	118.1 ± 30.21	403.7 ± 108.60
%HRR	75.6 ± 8.99	75.3 ± 13.26	83.1 ± 8.02
HLa (mmol/L)	5.5 ± 2.48	8.3 ± 2.05	11.5 ± 2.80
sRPE	4.3 ± 0.94	5.4 ± 1.17	6.9 ± 1.04
RPE	3.7 ± 0.66	5.9 ± 0.97	7.5 ± 0.83
TRIMP	40.8 ± 4.05	41.4 ± 7.68	10.6 ± 0.62
% in Zone 1	12.8 ± 12.04	20.9 ± 17.97	10.1 ± 5.64
% in Zone 2	70.3 ± 15.84	41.5 ± 22.68	22.1 ± 14.42
% in Zone 3	16.8 ± 13.86	37.6 ± 27.07	67.7 ± 16.18

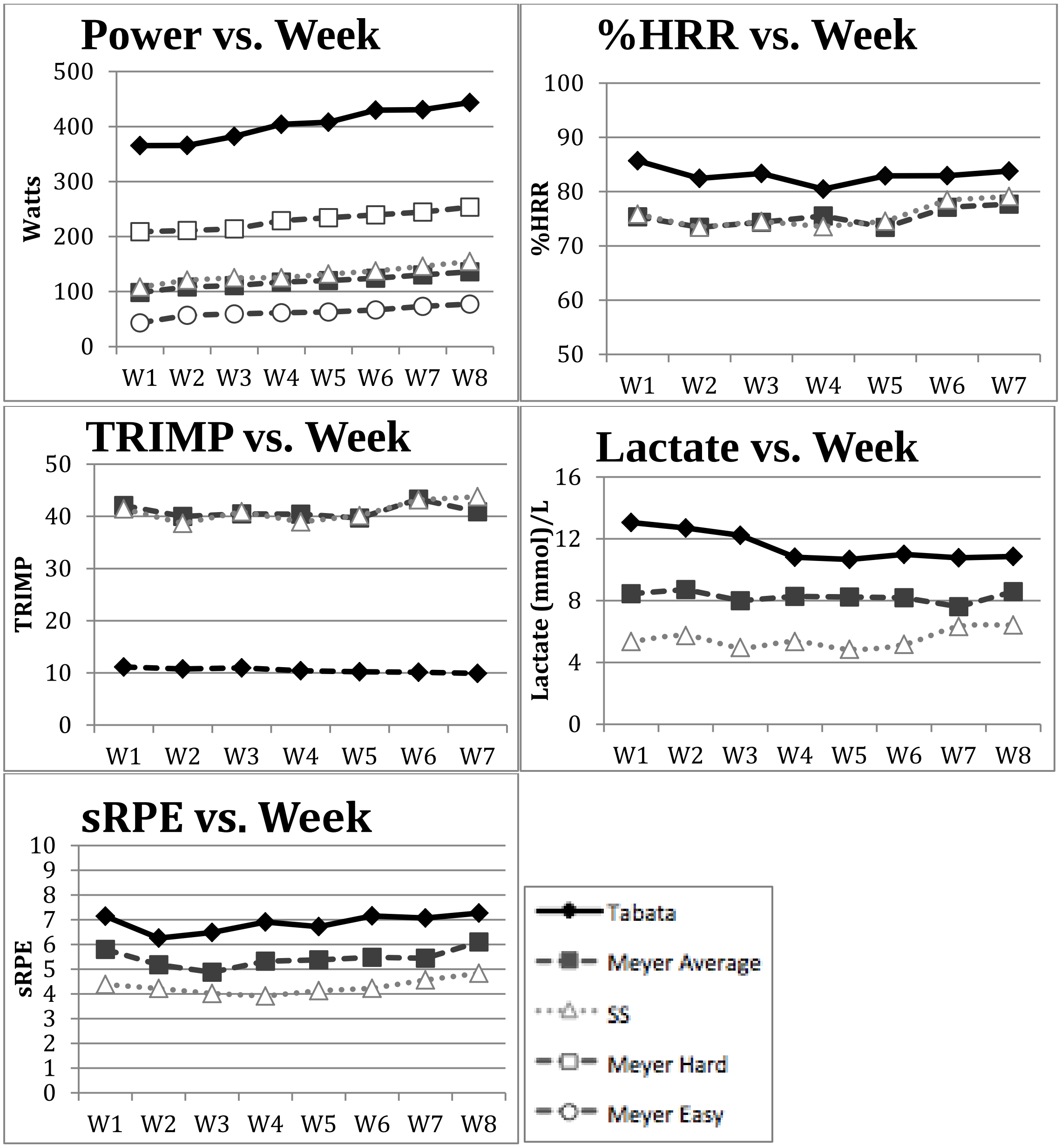

Figure 1. Weekly averages in power (Watts), %HRR, HLa (mmol/L), sRPE and TRIMP during the eight week training session for Tabata HIIT, Meyer HIIT, and steady-state. Note: both average Watts on the hard and easy interval were plotted for Meyer HIIT.

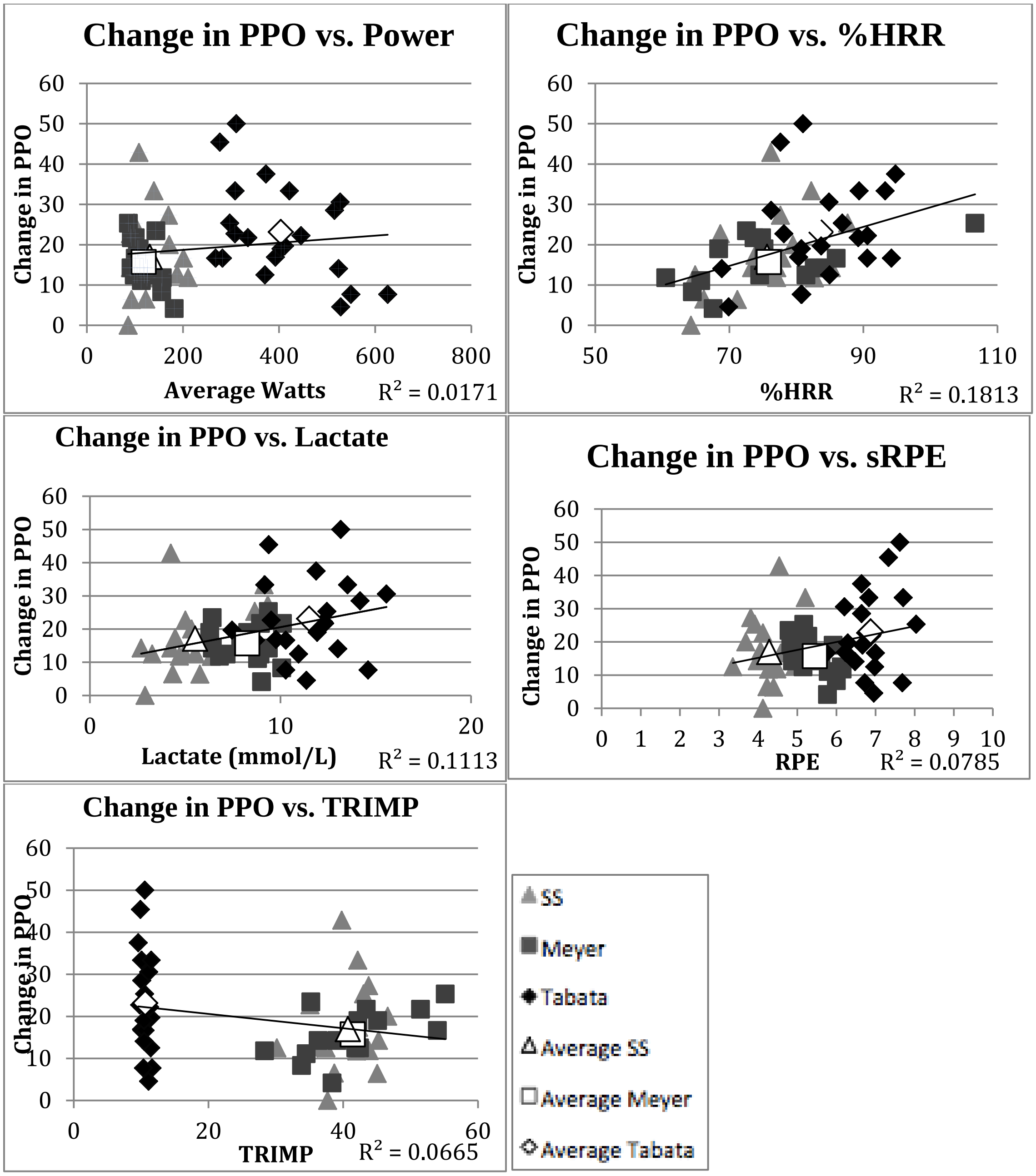

Figure 2. Tabata HIIT, Meyer HIIT, and steady-state group averages as well as individual data for relative change in PPO versus power (Watts), %HRR, HLa (mmol/L), RPE, and TRIMP.

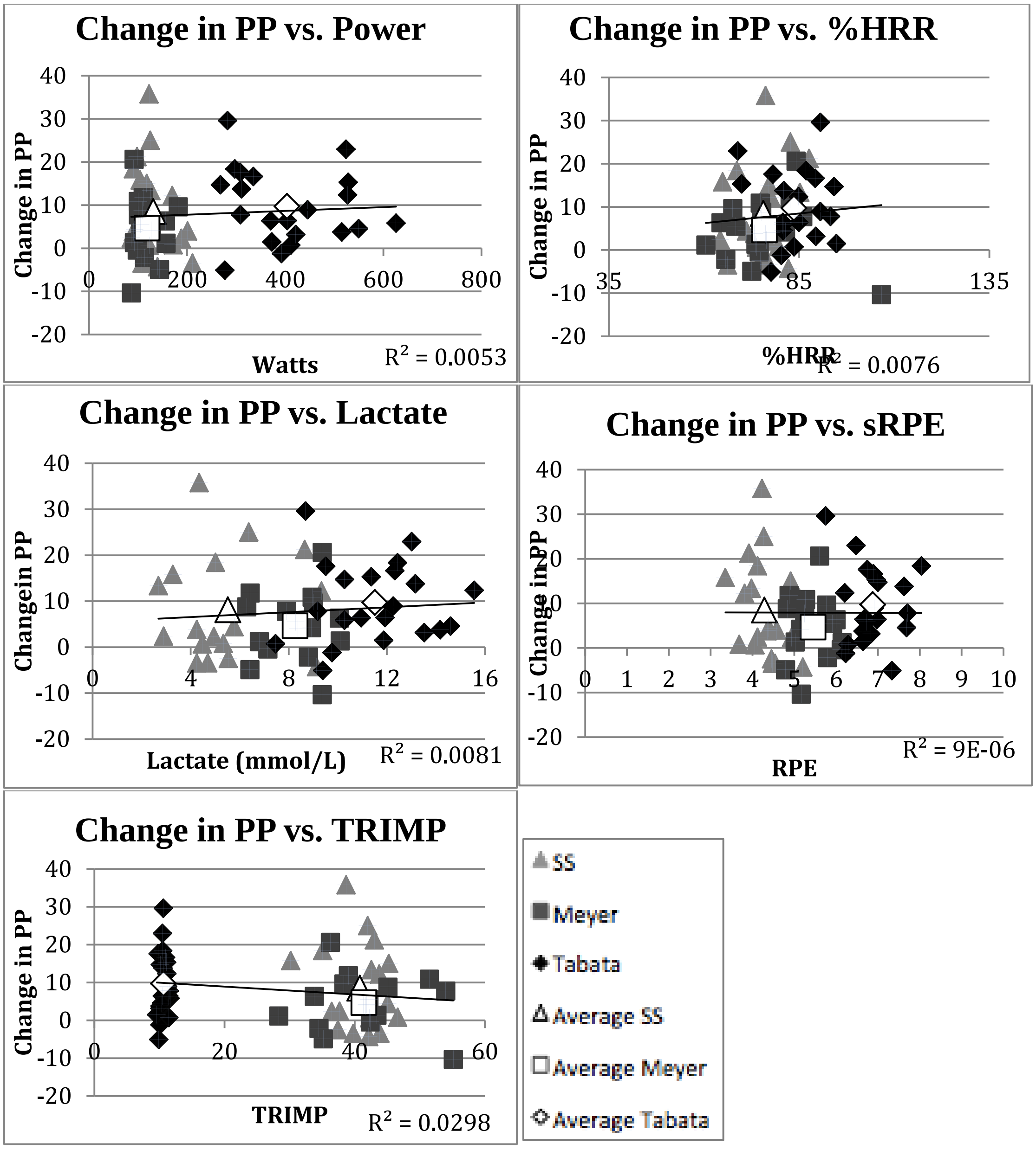

Figure 3. Tabata HIIT, Meyer HIIT, and steady-state group averages as well as individual data for relative change in PP versus power (Watts), %HRR, HLa (mmol/L), RPE, and TRIMP.

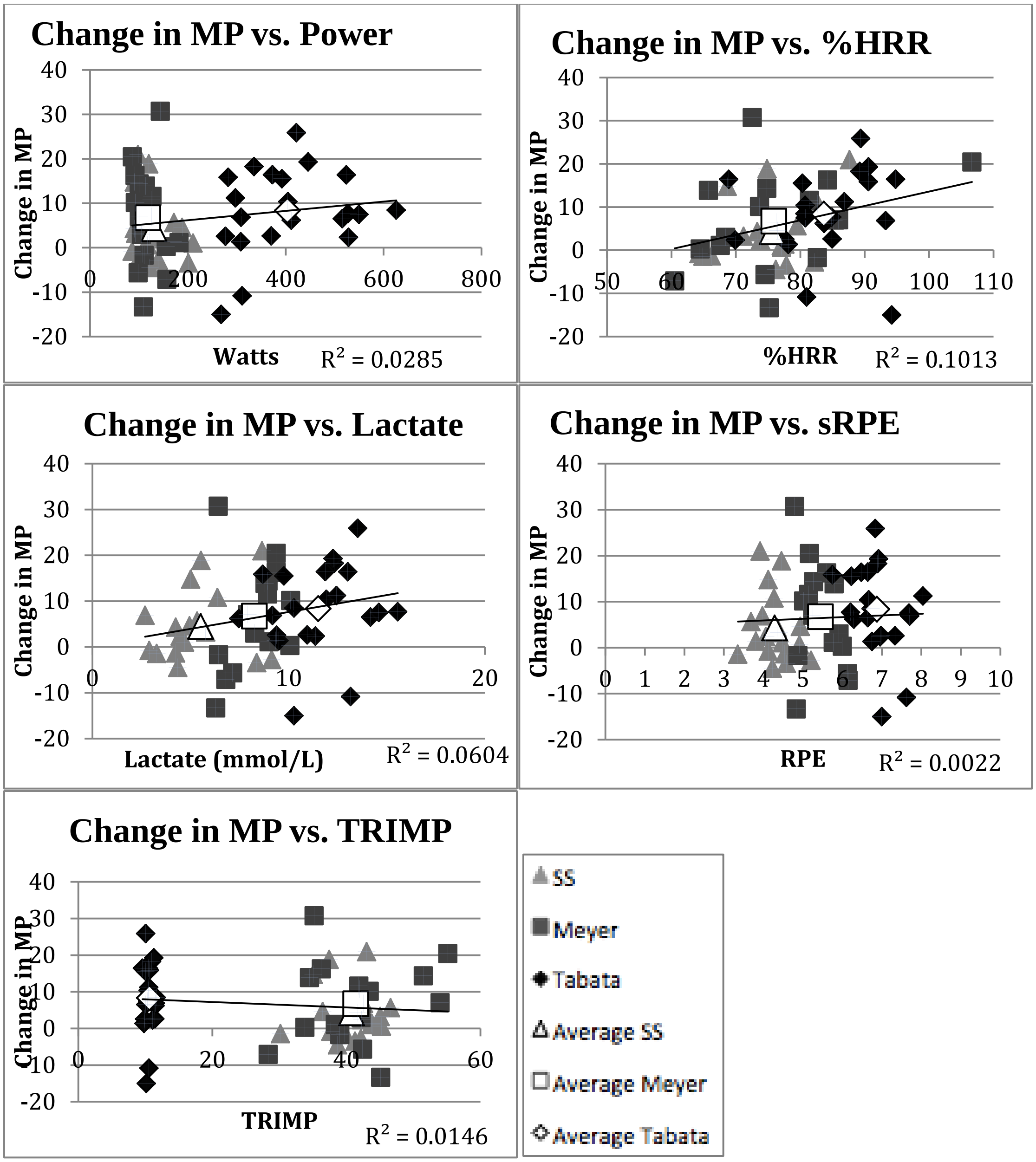

Figure 4. Tabata HIIT, Meyer HIIT, and steady-state group averages as well as individual data for relative change in MP versus power (Watts), %HRR, HLa (mmol/L), RPE, and TRIMP.

DISCUSSION

The aim of this study was to examine if HIIT (Tabata or Meyer) would result in a better response to training than steady-state training. During the eight weeks of training, the workload was increased proportionally among the three groups to ensure that HR, TRIMP, HLa, and RPE remained relatively constant. Tabata had the highest average HLa, RPE, %HRR, generated power, and highest percentage of time spent in Zone 3 (Table 2). However, there were not any statistically significant correlations on improvement in both aerobic and anaerobic capacity when compared to both interval groups and steady-state exercise.

Astrand and Rodahl (1986) studied the effect of interval training has on HLa. Astrand et al. (1986) observed a situation in which a subject could accomplish a fixed amount of work over the duration of one hour at a load of 175 W. When exercising continuously at this relatively light intensity, the HLa level was only 1.3 mmol/L. Doubling the power output to 350 W, the exercise could be only maintained for nine minutes. When performing intermittent exercise of three minutes at 350 W and three minutes at rest, the HLa level increased to 12.3 mmol/L, but could be sustained for an hour (Astrand et al., 1986). Sperlich et al. (2010) studied the effect HIIT on competitive swimmers aged 9 to 11 and observed an increase in the rate of HLa accumulation by 20.1% in the HIIT training group. Rozenek et al. (2007) evaluated the physiological responses of 12 men who were randomized into three different interval training programs that consisted of 15 seconds of work at 100% vVO_{2max} with 15 seconds of recovery

(15/15 trial), 30 seconds of work at 100 at 100% vVO_{2max} with 15 seconds of recovery (30/15 trial), or 60 seconds of work at vVO_{2max} with 15 seconds of recovery (60/15 trial). These interval exercises progressively doubled the work to rest ratio of 1:1, 2:1, and 4:1. The highest HLa concentration, 12.5 mmol/L, was with the 4:1 interval, while the lowest was with the shorter 1:1 interval.

In regard to RPE, Green et al. (2009) observed that sRPE was not affected by exercise duration, but instead, is more responsive to exercise intensity. While running on the treadmill with the intensity clamped at 70% VO_{2max}, sRPE was compared during durations of 20 minutes, 30 minutes and 40 minutes. Green et al. (2009) concluded that, since no observable differences in sRPE were detected for different durations of exercises, with the intensity clamped at 70% VO_{2max} workload, exercise duration had minimal influence on sRPE. Acute physiological responses to training including the HR, RPE and HLa all did not differ significantly among trials. The similar metabolic loads further support the assertion that intensity is a stronger mediator of session RPE compared to duration. In addition to duration, different exercise modalities do not effect sRPE (Green et al., 2011).

Foster et al. (2001) concluded that sRPE is a valid method of quantifying exercise training. In a 2-part design, subjects performed a cycle ergometer incremental test and either played basketball or did an interval cycle exercise. The first part of the study used subjects that were 12 well-trained, recreation-level cyclists, while the second part consisted of 14 collegiate-level basketball players. Despite using different subjects, the results indicated that sRPE is a valid marker of quantifying exercise intensity in a broad range of exercise modalities. From this study, correlation between sRPE and HLa suggests that RPE is a good indicator of work intensity (Seiler et al., 2011; Rozenek et al., 2007; Foster et al., 1995; Foster et al., 2001).

Gossenlin et al. (2012) found similar results to this current study. High intensity intervals performed at approximately 90% of VO_{2max} was no more physiologically taxing than steady-state exercise at 70% VO_{2max}. Consisting of a 3-week training period, subjects participated in five different 10-minute exercise protocols with varying work-to-rest periods that were 30/30, 60/30, 90/30, or 60/60. Although peak VO_2, mean VO_2, RPE, HR and HLa were the highest in the 90/30 exercise protocol, the total energy expenditure was the lowest in both the 90/30 and the 60/30 protocol with little to no change in aerobic capacity.

Similar results regarding the lack of difference between HIIT and moderate intensity exercise in trained athletes were observed in a 5-month training study by Esteve-Lanao et al. (2007). One exercise group had a total percentage distribution of 80/10/10 in Zones 1, 2, and 3 respectively, the other group's distribution averaged in 65/25/10. Despite significant differences for the percent training time in Zone 1, there was no difference in total TRIMP score or weekly TRIMP scores. Performance time during a 10.4 kilometer cross-country race were significantly improved in both groups, but the exercise group with more time spent in Zone 1 had a greater improvement (-157 ± 13 seconds) compared to Zone 2 (-121.5 ± 7.1 seconds). Thus, higher intensities of exercise can be associated with smaller gains in performance (Gosselin et al., 2012; Esteve-Lanao et al., 2012).

On the contrary, Jakeman, Adamson, and Babarj (2012) found that, in a 3-week study, six sessions (approximately four hours a week) of cycling at 100 revolutions per minute with 6-second sprints against 7.5% of body weight resulted in improved aerobic performance and delayed HLa. After the 3-week training periods, exercising with 6-second sprints against 7.5% of body weight produced an attenuation of HLa accumulation by 17%, a 6% increase in generated PP, and a 11% reduction in the time for a 10 kilometer trial by 10%. Laursen et al. (2002) evaluated three different HIIT regimens on 38 highly trained cyclists and triathletes for four weeks. Cyclists either participated in a control group, a HIIT group of eight intervals at their VO_{2peak} power output (P_{max}) with duration equal to 60% of time to exhaustion (T_{max}), a HIIT of eight intervals at Pmax with a recovery time equal to 65% of max HR (HR_{max}), or a HIIT group of 12 30-second bouts at 175% PPO with a four and a half minute of recovery. All the 3 HIIT groups had significant improvements in a 40 kilometer time trial compared to the control, as it was the 60% of T_{max} as the interval duration elicited the most consistent improvements in endurance performance, peak power output, and VO_{2peak} (Laursen et al., 2002)

Technical constraints of the current study include the limitations of the 8-week training period, as it is predicted that greater fitness benefits from interval training would have been observed if the duration were increased. It is also noteworthy that, although the goal of recruiting 65 subjects was initially met, 10 subjects quit due to illness unrelated to this study and, out of those 10 subjects; six were assigned to the Meyer HIIT group. Thus, the fact that the Meyer and steady-state group were comparable in average intensity (%HRR and TRIMP) (Table 2) could possibly be a result from a lack of statistical power compared to steady-state or Tabata. Furthermore, the 170% of PPO of Tabata may have been underperformed in subjects if the cadence was not maintained at

90 revolutions per minute. And in regards to HLa; this study took one measurement per week for each subject at either the end of the last interval in Tabata or Meyer or during the last minute of steady-state exercise. Although this was done for practicality, it could potentially have resulted in slightly depressed values since HLa concentrations continues to increase after cessation of exercise.

Further research of training responses and the effect different HIIT protocols has on aerobic and anaerobic fitness could be done in studies with more subjects and a training period longer than eight weeks. It would also be interesting to evaluate if greater fitness is associated with HIIT in cardiovascular patients compared to untrained, apparently healthy college students. Additionally, future studies should investigate the concentration of HLa during exercise and also into recovery, as only HLa measurements were taken during the last minute of exercise in this current study.

In conclusion, the results from this 8-week training study do not support significant improvements in anaerobic or aerobic fitness from Tabata training despite having elevated average RPE, generated power, HLa, and %HRR. Improvements in anaerobic and aerobic fitness from the Tabata HIIT were achieved in a fifth the time as both the Meyer HIIT and continuous exercise.

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APPENDIX A

INFORMED CONSENT

Title: Acute physiological responses during high intensity interval training and continuous exercise training.

Principal Investigator: Michelle M. Harbin

Purpose:

This study will, by means of measuring blood lactate accumulation (HLa), session Rating of Perceived Exertion (sRPE), percent heart rate reserve (%HRR), and training impulse scores (TRIMP), determine the effectiveness of Meyer and Tabata high intensity interval training (HIIT) compared to continuous exercise. Other parameters assessed by colleagues include post-exercise hypotension, exercise enjoyment, improvement in aerobic capacity, and improvement in anaerobic capacity. Data collection will approximately begin September 1, 2013 and will last to November 25, 2013.

Procedure:

Procedures include 1) a pre and post VO_{2max} test, 2) a pre and post Wingate test, 3) completion of eight weeks (24 training sessions) of either a high-intensity Tabata HIIT, a moderate-intensity Meyer HIIT, or moderate-intensity steady-state exercise 4) measuring HLa, %HRR and TRIMP once a week, 5) measuring sRPE for every training session, 6) measuring blood pressure once a week, and 6) completion of an exercise enjoyment form once a week.

The steady-state training group will have a moderate intensity of cycling for 20 minutes at 90% of the ventilatory threshold (VT). The Meyer HIIT consists of 13 repetitions of 30 seconds at 100% PPO and a 60 seconds recovery period at 25% PPO. Tabata intervals are eight repetitions of 20 seconds at 170% the PO at VO_{2max} and 10 seconds of rest. All training groups will consists of a 5-minute warm-up and cool-down with the first two minutes set at 25 W, the third minute at 50 W, the fourth minute at 75 W, and the last minute at 25 W.

In regard to HLa measurements, only one sample will be taken during each training session once a week. The steady-state training group will have HLa measurements taken in the last minute of steady-state exercise. Both the Meyer HIIT and the Tabata HIIT will have HLa measurements taken during the last interval. Taking weekly HLa measurements is the only invasive procedure during this study and requires a finger prick to draw blood samples.

All subjects will wear a Polar heart rate monitor and respond to questions regarding their perceived exertion on a scale from zero to ten. The Training Impulse score and %HRR will be calculated for each subject once a week. Light intensity is designated as Zone 1 (below the VT), moderate intensity is Zone 2 (above the VT but blow the respiratory compensation threshold (RCT)), and high intensity in Zone 3 (above the RCT). Also, the subjects will fill out an exercise enjoyment form once a week.

Goal:

The goal of this study is to recruit 60 subjects and randomly assign the subjects evenly among the three training groups. The main objective is to recruit sedentarily to moderately physically active University of Wisconsin at LaCrosse (UW-L) undergraduate students from the ages of 18 to 30. Additionally, the subjects will complete of a PAR-Q questionnaire. Athletes or intensively physically active UW-L students will be excluded from this study.

Risks:

Minimal discomfort will be associated HLa measurements, as this is the only invasive procedure and consists of a finger prick. Side effects from interval training include overtraining, fatigue, syncope, possible muscle loss, muscle craps, nausea, and possible musculoskeletal injuries. To minimize risks from HIIT and steady-state exercise, all procedures will be conducted with UW-L exercise physiology graduate students who are CPR and ACLS certified. Not only is this study under the direction of Dr. Carl Foster, subjects will also be screened prior to training for research exclusion.

Benefits:

Participation in this study will increase the understanding of the effectiveness of HIIT by means of measuring the acute physiological training responses. Subjects will not receive monetary incentives to participate in this study. But, to aid in promoting participation, undergraduate students enrolled in select exercise sport science classes at UW-L may receive extra credit. Not only will this study give subjects insight to alternative forms of interval training, but will also help improve their understanding of how acute physiological responses can differ with varying intensities.

Confidentiality:

The principle investigator will ensure individual data will be kept private. Data will be collected and released only among the research staff and the thesis committee for the purpose of statistical analysis. Only average data (no personal information) will be published or presented to ensure confidentiality.

Compensation:

UW-L will not pay for expenses incurred because of side effects caused by the study procedures.

Voluntary Participation and Withdrawal:

Your decision to participate in this study is voluntary and withdrawal from this study will not be penalized. If you choose to not participate in this study, you may continue to exercise using Tabata or Meyer HIIT protocols at your own risk.

Statement of Consent:

I, _______________________________________, give my informed consent to be a subject this is study to help further determine the effectiveness of Meyer and Tabata HIIT though the assessment acute physiological responses. Specifically, HLa accumulation, %HRR, TRIMP, and sRPE will be evaluated to determine exercise effectiveness. I have been notified by the principle investigator that this study is under the direction of Carl Foster, whom is a former president of ACSM and a professor for the Department of Exercise and Sport Science at the University of Wisconsin at LaCrosse. I consent to the publication, presentation, and other release of summary data where my identity is blinded.

I have read and understand this consent form. Participation in this study requires that I will perform two incremental max tests, two Wingate tests, and complete 24 exercise sessions. I have been informed that I will be assigned to either a continuous exercise group, Meyer HIIT group, or Tabata HIIT group. I have also been informed that, other than fatigue, muscle sourness, nausea, and possible syncope, there are no major risks associated with HIIT. There will only be minor discomfort with the finger prick for drawing HLa once a week. Furthermore, I have been informed that there are no monetary benefits associated with participation and that I have the option of either declining to participate or withdrawing from this study, as neither will result in any penalties. Regardless, educational benefits that I would not have achieved otherwise include the knowledge of my VO_{2max} and conceptualizing how RPE, %HRR, TRIMP, and HLa is related with exercise intensity. Other benefits include free exercise testing and, after completion of this 8-week training study, my contribution to science will assist the on-going research of the effectiveness of HIIT.

______________________________ ______________

Participant Signature Date

______________________________ ______________

Signature of Researcher obtaining consent Date

_______________________________________ has completely read and signed the consent form. The subject has informed me that he/she has no questions that have not been answered by the researcher. The subject understands the consent form and the consent is willingly given. I believe that the subject understands the risks and benefits from participation and I am writing my name as a witness.

____________________________________ ________________

Witness Signature Date

APPENDIX B

REVIEW OF THE LITTERATURE

REVIEW OF THE LITERATURE

The purpose of this paper is to review the literature evaluating the effect high intensity interval training (HIIT) has on relative improvement in anaerobic and aerobic capacity when compared to high volume training (HVT). In particular, the parameters of interest for evaluating the effectiveness of exercise intensity are blood lactate concentration (HLa), percent heart rate reserve (%HRR), Training Impulse (TRIMP), Rating of Perceived Exertion (RPE), and session RPE (sRPE).

Introduction

Although physical activity at moderate intensity, such as continuous running, biking, or walking will enhance health and lower the relative risk of developing coronary heart disease, hypertension, type II diabetes mellitus, colon cancer, and premature mortality, vigorous exercise has a stronger correlation with lower risk of mortality than continuous exercise at a moderate intensity (Lee, Hsieh, and Paffenbarger (1995). The results from the Harvard Alumni Health Study observed that those who expended more than 6300 kJ/week or more in vigorous exercise had 0.75 to 0.87 times the risk a dying compared to men that expended less than 630 kJ/week (Lee et. al, 1995). Additionally, mortality continued to decline in men that had a weekly total energy expenditure at 14,700 kJ (Lee et al., 1995).

Furthermore, research has shown that doubling the volume of physical activity at a moderate intensity does not correlate with increased competition performance or health (Sperlich et al., 2010). Meyer, Lehmann, Sunder, Keul, and Weidmann (1990) observed that three and a half weeks of interval training improved both aerobic and anaerobic capacity more than continuous exercise at a moderate intensity in patients following coronary bypass surgery. The 24 participants in this study had undergone coronary bypass surgery at least 26 days before the start of the training period and were randomly assigned to be in either a continuous or interval training group. The results from Meyer et al. (1990) showed that, although there were no changes in either blood pressure, rate-pressure product, circulating concentration of either glucose or catecholamine, there was a significant higher rate of lactate. The average value of HLa was 2.4 mmol/L for continuous exercise and 3.7 mmol/L for interval exercise (Meyer et al., 1990). Furthermore, interval training led to an increase in patients' physical performance by 45 W, while the continuous exercise control group only increased by 20 W. Interval training resulted in increased physical performance (+0.63 W/kg vs. +0.26 W/kg), lower resting HR (-9 beats/minute vs. -4 beats/minute), lower rate-pressure product at rest (-1675 vs. -291), lower rate-pressure product at 75 W (-2810 vs. -735), and lower lactate at 75 W (-0.83 mmol/L vs. -0.33 mmol/l). These results support that improvement in physical performance specific to cardiac bypass surgery patients is related to the intensity rather than the total amount of work.

While it is evident that both HIIT and continuous exercise at a moderate intensity will enhance health, it is unclear what alternative types of intervals and intensity will promote greater health benefits in significantly less time compared to continuous exercise at a moderate intensity. Tabata is a specific type of HIIT protocol that is characteristically four minutes in duration and consists of eight repetitions of intense exercise maintained at 170% peak power output (PPO) for 20 seconds with 10 seconds of rest between each bout (Tabata et al, 1996). Tabata et al. (1996) observed that this high intensity protocol increased VO_{2max} by 7 ml/kg/minutes and increased anaerobic power by 28% in six weeks. Characteristic of Meyer high intensity intervals are thirty seconds at high intensity (100% VO_{2max}) and sixty seconds at an active rest (25% VO_{2max}). Meyer et al. (1997) employed this protocol at an intensity of 50% of maximum work rate achieved during a special *steep ramp* test, which is close to the power output at VO_{2max}. Using patients with congestive heart failure as subjects, they demonstrated that this protocol of interval training is correlated with significantly increased physical performance and increased effectiveness in economizing cardiac function.

Assessment of Interval Training: Blood Lactate Accumulation

Blood lactate is continuously produced at rest; the production of it is in balance with removal. Whereas significantly elevated HLa levels may indicate ischemia or hypoxia, HLa accumulation is essentially a normal response to physical exertion. The formation of lactic acid occurs in skeletal muscles and is the outcome of glycogenolytic and glycolytic pathways. Lactate accumulation has the potential to limit performance time ranging from 30 seconds to 15 minutes (Billat, 1996).

The metabolic reaction to longer lasting dynamic exercises can be of two different basic types; either loads that can be maintained for a long time at steady-state where pyruvate is oxidized with aerobic metabolic processes, or loads that require an additional net formation of lactate (and thus accumulation of protons) to maintain power output. Accumulation of HLa results when the rate of production is greater than its removal in non-steady-state conditions. During a progressive exercise test where the resistance on a cycle ergometer is continually increased, HLa will have a non-linear pattern of accumulation with increases in power output (PO) and oxygen consumption (VO_2) (Brooks, 1985). The workload at which the accumulation of HLa demonstrations a non-linear trend and abruptly increases is known as the anaerobic or lactate threshold (LT) (Brooks, 1985). The anaerobic threshold and the ventilatory threshold (VT) are closely related, as the VT is defined as the work rate, or oxygen uptake, beyond which HLa accumulates more rapidly. The VT occurs at the highest maintained VO_2 without a substantial increase in HLa and represents the point at which circulating bicarbonate is destroyed by buffering protons that are created with HLa. This acts to defend the pH, but the destruction of bicarbonate liberates CO_2 that must be exhaled. This causes abrupt increase in VCO_2 relative to VO_2 and a sudden increase in ventilation, hence the term VT.

Research has shown that LT typically occurs at 70% of the HRR in well-trained athletes and 50 to 60% HRR in untrained to sedentary individuals (Goodwin et al., 2007). The LT occurs in between 40% to 60% of VO_2max in untrained individuals. Exercising below the LT/VT is characterized as light and typically ranges from a perceived exertion of 10 to 13 on the Borg scale. High intensity exercise of a hard RPE of approximately 15 occurs above the VT and exercising at 85% of VO_2max will result in greater accumulations of HLa and quicker exhaustion and fatigue. Exercise effectiveness and training intensity is measurable by HLa accumulation; exercising above the lactate threshold indicates higher intensity exercise.

Astrand and Rodahl (1986) discussed how intermittent exercise, by means of introducing periods of more intensive muscular activity followed by periods of rest, simulates HLa accumulation. If one subject had to accomplish a fixed amount of work in the duration of one hour, it could be done with uninterrupted exercise at a load of 175 W. Doubling the workload to 350 W allowed the same amount of work of 635 kJ to be achieved in half the time, but would be impossible to sustain. Exercising at 350 W for nine minutes until exhaustion had a measured HLa concentration of 16.5 mmol/L. On the contrary, through intermittent exercise at 350 W for 30 seconds exercising and 30 seconds at rest, the subject could accomplish the fixed amount of work with moderate intensity. Continuous exercise at 175 W for one hour had the lowest HLa level at 1.3 mmol/L and intermittent exercise of three minutes at 175 W with three minutes of rest had a HLa of 13.2 mmol/L. Two-minute intervals at 175 W had a lower HLa level of 10.5 mmol/L, one-minute intervals were associated with a HLa concentration of 5.0 mmol/L, and thirty-second intervals had a HLa level of only 2.2 mmol/L. Overall, Astrand et al., (1986) demonstrated that longer activity periods of intermittent exercises are characterized as exhaustive and are correlated with elevated HLa concentrations, whereas short periods of work can be well tolerated.

More recent studies supported the concept that high volume continuous exercise performed at moderate intensity is not as efficient as HIIT with shorter time durations on the basis of HLa. Rozenek, Funato, Kubo, Hoshikawa, and Matsuo (2007) evaluated the physiological responses of twelve men who were randomized into either interval training that consisted of 15 seconds of work at 100% vVO_2max with 15 seconds of recovery (15/15 trial), 30 seconds of work at 100 at 100% vVO_2max with 15 seconds of recovery (30/15 trial), or 60 seconds of work at vVO_2max with 15 seconds of recovery (60/15 trial). These trials had a work to rest ratio of 1:1, 2:1, and 4:1 and, since all subjects were able to complete the 15/15 trial with minimal difficultly, the observations indicated that light to moderate intensity was associated with a work to rest ratio of 1:1. The 15/15 trial had the lowest HLa of 7.3 mmol/L (Rozenek et al, 2007). The highest HLa concentration at 12.5 mmol/L was seen with the 60/15 trial. However, this value was not statistically different from the 12.1 mmol/L of peak HLa achieved during the 30/15 trial.

Research conducted by Sperlich et al. (2010) evaluated the effect of interval training on competitive swimmers aged 9 to 11. The length for HIIT was 30 minutes with the intensity set at 92% of personal best time. The duration was set at 60 minutes for HVT with intensity at 85% of personal best time. The data collected came from this five-week study and revealed a decrease in the rate of HLa by 30.1% with the HVT group (Sperlich et al., 2010). High intensity interval training had an increase in HLa by 20.1%, which was an approximate 3.5-fold higher HLa accumulation compared to HVT.

A seven-week study led by Seiler, Joranson, Olesen, and Hetlelid (2013) compared the physiological effects of interval training with varying work periods durations on 37 recreational cyclists. This was a controlled experiential trial with one steady-state exercise group using only low-intensity endurance training and three different HIIT groups at maximal tolerable intensity. The interval prescriptions varied in the work period duration, which were either at 4x16 minutes, 4x8 minutes, or 4x4 minutes. The HLa accumulated the most in the 4x4 minute training group at 13.2 mmol/L, while the lowest accumulation of HLa at 4.9 mmol/L was observed with the 4x16 minute training group (Seiler et al., 2011). The 4x8 minute training group had a HLa concentration of 9.6 mmol/L (Seiler et al., 2011). The perceived exertion for the entire training session was the highest in the 4x4 minute at 7.9 and the lowest in the 4x16 with 6.8. In this situation, the shorter interval increased HLa the most and had more time spent exercising above threshold.

Oliveira et al. (2011) evaluated a HIIT protocol that consisted of a three-minute run at VT2 following with eight sets of one-minute runs at maximal velocity (vMAX). A significant increase of HLa at approximately 231$\pm$197% was observed post interval training (2.8$\pm$0.9 mmol/L to 10.5$\pm$3.5 mmol/L). In elite rowers, Ingham, Carter, Whyte, and Doust (2008) found that higher peak HLa concentrations were observed at 9.0 mmol/L after 12 weeks of exercising at a moderate intensity. Moderate intensity consisted of 70% of the training duration spent below the LT and the remaining 30% halfway between the VO_2 at LT and VO_{2peak}. Low intensity, which consisted of 100% of the training duration below lactate threshold, was correlated with a lower accumulation of HLa at 6.3 mmol/L. In regard to moderately physically active to competitive athletes, HLa accumulation is a good indicator of high intensity (Oliveria et al., 2010; Ingham et al., 2010; Seiler et al., 2011; Sperlich et al., 2010, Astrand et al., 1986).

The severity of exercise can be quantified with higher HLa concentration. Elevated HLa levels during HIIT indicate greater exertion and provide a good estimate for exercise effectiveness, with the indication that more time is spent exercising above the LT/VT (Astrand et al., 1986; Meyer et al., 1990, Sperlich et al., 2010; Siler et al., 2011; Oliveira et al. 2010; Meyer et al., 1990, Ingham et al., 2008; Rozenek et al., 2007). Since the HIIT have noticeable increased HLa levels, the use of both aerobic and anaerobic production of ATP, with the probable recruit of both slow and fast twitch muscle fibers rather than just the slow twitch fibers that are recruited during low intensity continuous exercise, made it more effective than steady-state exercise.

Assessment of HIIT: sRPE

In conjunction with elevated HLa concentration; sRPE is another acute physiological training response that is a good indicator of exercise intensity. It is based on the fundamental understanding that athletes can inherently evaluate the physiological stress on their body during exercise. Session RPE was created to further simplify the objective measure of assessing training load (Foster et al., 1995).

Foster et al. (2001) experimentally showed that there is a correlation between sRPE and summated HR zones in both steady-state and interval training, which collectively demonstrated that sRPE is a credible indicator of exercise intensity. Green et al. (2009) evaluated how sRPE is not affected by exercise duration, but instead, is more responsive to exercise intensity. In this study, the sRPE of 10 subjects was compared among treadmill trials clamped at an intensity of 70% VO_2max with durations of 20 minutes, 30 minutes, and 40 minutes. Heart rate and acute RPE were analyzed every five minutes. Blood lactate concentration was recorded at rest and once every 10 minutes. In regard to acute physiological responses to training, HR and HLa concentration were not significantly different among trails, which further supports that exercise intensity is a stronger mediator of sRPE compared to duration. Green et al. (2009) concluded that, since no difference were detected for different durations of exercises clamped at 70% VO_2(max) workload, exercise intensity strongly influences session RPE and duration had minimal influence.

In addition to assessing HLa, Seiler et al. (2013) assessed sRPE in three different HIIT groups and one HVT control. They observed the trend that higher RPE was associated with higher HLa. Not only was the HLa concentration the highest for the most intense 4x4 minute HIIT, it also had the highest session RPE at 7.9±0.8. The less intense 4x8 minute HIIT training not only had a lower HLa accumulation, but also a lower sRPE at 7.3±0.7. The least intense 4x16 minute HIIT group had the lowest HLa accumulation and lowest all bout RPE of 6.8±0.7 (Seiler et al., 2011). Rozenek et al. (2007) observed a similar correlation between sRPE and HLa levels. The 60/15 training group had, not only the highest HLa, but also was associated with the highest session RPE of 17.2 (Rozenek et al., 2007). The 15/15 trial had the least amount of HLa and, accordingly, was categorized at light intensity with a reported RPE of 13.4. Since higher session RPE indicates more relative time above the LT/VT, the consistent correlation between sRPE and HLa supports how RPE is a good indicator of work intensity (Seiler et al., 2011; Rozenek et al., 2007)

Session RPE is a good indicator of exercise intensity because it not only is independent of exercise duration, but it has a closer relation to exercise intensity instead than exercise modality. Green et al. (2011) studied seven men that participated in moderate intensity running at 75% VO_2max, low intensity running at 50% VO_2max, low intensity cycling trials at 50% VO_2max, and high intensity cycling at 75% VO_2max. In regard to the overall sPRE, cycling at 75% VO_2max had the highest RPE and was significantly higher than both cycling and running at 50% VO_2max (Green et al., 2011). There was no difference between cycling or running at 50% VO_2max, as this collectively indicates the sRPE responses are sensitive to higher exercise intensity and is not altered between different modes of exercise.

Ceci and Hssmen (1991) evaluated how using the 15-graded RPE scale can regulate exercise intensity by comparing three different RPE intensities while running on the outdoor track and on the treadmill. Two sessions were conducted of both outdoor running and treadmill running, as the subjects exercised according to three minutes at an RPE of 11, 11 minutes at an RPE of 13, and ended with five minutes of an intense exercise with an RPE of 15. The field tests were conducted on a 500 meter out-door track, as subjects ran one lap (500 meters) at a RPE of 11. After rest for one to two minutes, subjects repeated running one lap at with a RPE of 11. The following four laps (2000 meters) were regulated at an RPE of 13 and the last two laps (1000 meters) were regulated at an RPE of 15. The two different sessions did not have any significant differences in any of the variables and, in both the first session and the second session, there was an increasing trend of HLa accumulation with increasing RPE values. With exercising at an RPE of 15 on the field, this corresponded to the highest HLa concentration of 5.8 mmol/L in the first session and 6.42 mmol/L. Exercising at an RPE of 13 on the track had a HLa concentration of 4.07 mmol/L in the first session and 4.10 mmol/L in the second session. The lowest RPE at 11 had the lowest HLa concentration of 1.73 mmol/L in the first session and 2.23 mmol/L in the second session. Exercising on the treadmill displayed a similar trend of increasing HLa concentrations and increasing RPE except for the fact that treadmill had overall lower lactate accumulations. Exercising at a RPE of 11 on the treadmill had a lower peak lactate accumulation compared to running on the track at 1.73 mmol/L (Ceci et al., 1991). The peak lactate accumulation, which was 4.25 mmol/L was also lower exercising on the treadmill at a RPE 15 (Ceci et al., 1991). The correlating of accumulating lactate levels and increasing perceived exertion denote RPE as a good indicatory of high intensity.

Session RPE functions well in monitoring exercise intensity, as research indicates that interval training has higher RPE (Ceci et al., 1991; Rodríguez-Marroyo, 2012, Green et al., 2011; Foster et al, 2001, Rozenek et al., 2007; Seiler et al., 2011). The use of sRPE, since it is correlated with HLa and is independent of different exercise modalities and durations, is a good method that quantifies high intensity and indicates effective exercise.

Assessment of HIIT: TRIMP

TRIMP scores is another acute physiological training response used to measure the extent of how intense and effective HIIT is compared to HVT. Zone 1 is located below the LT/VT and is characterized with light intensity exercise. Zone 2 is associated with moderate intensity and is in between the LT/VT and the respiratory compensation threshold (RCT). The RCT is characterized by the onset of hyperventilation, as high intensity exercise is located above the RCT and is labeled as Zone 3.

Seiler and Kjerland (2006) studied eleven competitive junior cross-country skiers, as the results indicated that the athletes displayed a 75%-8%-17% training session distribution in Zones 1, 2, and 3 respectively. Thus, nationally competitive junior skiers adopted a polarized pattern, in which a majority of the training sessions were performed below the VT and a substantial amount of training session about the lactate accommodation zone. Esteve-Lanao, Foster, Seiler, and Lucia (2007) also experimentally depicted a polarized trend of training by evaluating two different training programs. This study assessed 12 sub-elite runners and randomly assigned them into either a training program that emphasized low intensity exercise below the VT, or in a training program that had moderate intensity exercise above the threshold. The results indicated that the athletes displayed a distribution of 80% in Zone 1, 12% in Zone 2, and 8% in Zone 3. Regardless, the magnitude of improvement on endurance performance was more significant with more time spent training in Zone 1 than Zone 2. The Zone 1 training group had decreased their time on the 10.4 kilometer cross-country race by 157$\pm$13 seconds, while the Zone 2 training group only decreased their by by 121.5$\pm$7.1 seconds.

A similar polarized pattern of training was depicted while studying 27 elite Norwegian rowers that won international medals (Fiskerstrand and Seiler, 2004). From the 1970s to the 1990s, there was a large increase in the total volume of training performed at low intensity where the HLa concentration was less than 2 mmol/L. And, along with a 20% increase in total training volume, rowers in the 1990s had a 12% higher VO_2max compared to athletes in the 1970s. Esteve-Lanao, San Juan, Earnest, Foster and Lucia (2005) also suggested that total training time spent at low intensities are associated with improved performance during highly intense endurance events. Eight sub-elite Spanish runners spent 71% of their time in low intensities in Zone 1, 21% in Zone 2, and the lowest time in Zone 3 at 8%. Regardless, there was a significant negative correlation between the total time spent in Zone 1 and performance time during the 10.130-kilometer cross-country run. Thus, this study suggests that there is a relationships between cumulative training spent at low intensities and endurance performance at high intensities.

After reviewing the literature on average time spent while exercising, studies show that a majority of athletes' training is not considered HIIT and a majority of training time is spent at light intensities below the LT/VT. And uniquely enough, increasing time spent at lower intensities is correlated with greater endurance performance and increased VO_2max (Fiskerstrand et al, 2004, Esteve-Lanao et al, 2007, Esteve-Lanao et al., 2005).

Assessment of HIIT: % HRR

Another good indicator of the effectiveness of HIIT training is %HRR, as this measures the difference between the resting and maximum HR of a given target intensity. Iellamo et al. (2013) studied the affect different intensities had on 36 patients with chronic heart failure (CHF) who had a left ventricular ejection fraction less than 40%. This 12-week study used interval training on a treadmill at 75-80% of HRR with active rest periods at 45-50% HRR and continuous training at a moderate intensity at 45-60% of HRR. The diastolic and systolic blood pressure decreased in both training groups, as both groups displayed significant increases in VO_{2peak}, increased anaerobic threshold, and decreased daytime diastolic blood pressure. High intensity interval training had significantly decreased HOMA, which indicates improved insulin reduction. In regard to a study that evaluated male essential hypertensive participants, interval training at 60-79% maximum heart rate resulted in a significant increase in VO_2max compared to the continuous training group at 60-79% HRR (Lamina, 2009). Compared to the sedentary control, both interval and continuous training had significant decreases in systolic and diastolic blood pressure, resting heart rate, rate-pressure product, pulse pressure, and mean arterial pressure.

Wisløff et al. (2007) found that aerobic interval training at 90 to 95% peak HR had greater benefits in regard to reversal of LV remodeling, aerobic capacity, and endothelial function. While, in the evaluation of a HIIT of 70% to 80% of HRR, of 25 men with left ventricular dysfunction after a myocardial infarction or coronary artery bypass graft, the results indicated that an increase in VO_2max by 23% after one month (Dubach et al., 1997). Mendes et al. (2013) evaluated 12 individuals that were diagnosed with type II diabetes. Subjects that underwent high-intensity interval training at 70% HRR while exercising on the treadmill had a significant lower blood glucose level compared to a control. Monitoring high intensity through %HRR is a good indicator of exercise effectiveness.

Conclusions

Previous studies confirm that acute physiological training responses, such as HLa and session RPE, are dependent on intensity. During higher interval training, elevated HLa and also higher session RPE are observed. Benefits at exercising at elevated heart rates and exercising above the respiratory compensation threshold in Zone 3 include greater increased aerobic capacity and anaerobic capacity. It is hoped that the results of this study are definitive in determining which HIIT protocol, Meyer or Tabata, will produce the greater changes in aerobic and anaerobic capacity.

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