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A Comparison of the Effects of High-Resistance Cycle Training and Leg Press on the Wingate Anaerobic Test, Strength, and Time-Trial Performance

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A COMPARISON OF THE EFFECTS OF HIGH-RESISTANCE CYCLE TRAINING AND LEG PRESS ON THE WINGATE ANAEROBIC TEST, STRENGTH, AND TIME-TRIAL PERFORMANCE

by

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GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

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This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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As chair of the candidate's graduate committee, I have read the thesis of Aaron W. Stites in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

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The purpose of this study was to compare high-resistance cycle training (HRCT) with resistance training (RT), and their effects on Wingate anaerobic test watt max (W_{max}) and watt average (W_{ave}), strength (improvement in 1 repetition max [RM]), and time-trial performance. Twenty-five healthy college-age untrained male subjects were randomly assigned to the HRCT (n=10), RT (n=10), or control (n=5) group. All subjects completed pre and posttesting for the leg press (LP), 30 s Wingate anaerobic test, and 15-min time-trial. Subjects also completed familiarization tests prior to pretesting in the Wingate anaerobic test and 15-min time-trial. HRCT and RT subjects trained 2x/wk for 8 weeks with at least 48 hrs between training sessions. During each training session HRCT completed 4 x 30 sec efforts increasing resistance when >65 rotations per minute (rpm) could be maintained for the full training session. RT completed 3 x 10 repetitions of leg press with weight increasing 5 -10 lbs when all repetitions were completed during a training session.

ANOVA with Tukey post-hoc was used to determine if differences existed between the groups. Within group change was analyzed using paired T-test. Effect size was computed to determine meaningfulness of differences. HRCT and RT groups both showed statistical significance (p < 0.05) pre to posttesting in LP, Wingate anaerobic test W_{max} and W_{ave}, and 15-min time-trial. Control group also showed statistical significance (p < 0.05) pre to posttesting in LP and 15-min time-trial. Significant between group differences were noted between HRCT and control in Wingate anaerobic test W_{max} (p=0.03) and W_{ave} (p = 0.007) and 15-min time-trial (p = 0.003). There was a significant difference between RT and control on the 15-min time-trial (p = 0.008). When comparing HRCT and RT no statistical difference was seen in LP, Wingate anaerobic test W_{max} and W_{ave}, and 15-min time-trial. High-resistance cycle training and RT resulted in similar strength gains. However, HRCT showed greater improvements in cycling specific activities: 30 s Wingate anaerobic test W_{max} and W_{ave}, and 15-min time-trial. Results suggested that HRCT may increase performance on bike related assessments when compared to RT.

Key words: high resistance cycling, leg press, Wingate anaerobic test, low cadence, time-trial, cycling

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A comparison of the effects of high-resistance cycle training and leg press on the Wingate anaerobic test, strength, and time-trial performance

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Abstract

The purpose of this study was to compare high-resistance cycle training (HRCT) with resistance training (RT), and their effects on Wingate anaerobic test watt max (W_{max}) and watt average (W_{ave}), strength (improvement in 1 repetition max [RM]), and time-trial performance. Twenty-five healthy college-age untrained male subjects were randomly assigned to the HRCT (n=10), RT (n=10), or control (n=5) group. All subjects completed pre and posttesting for the leg press (LP), 30 s Wingate anaerobic test, and 15-min time-trial. Subjects also completed familiarization tests prior to pretesting in the Wingate anaerobic test and 15-min time-trial. HRCT and RT subjects trained 2x/wk for 8 weeks with at least 48 hrs between training sessions. During each training session HRCT completed 4 x 30 sec efforts increasing resistance when >65 rotations per minute (rpm) could be maintained for the full training session. RT completed 3 x 10 repetitions of leg press with weight increasing 5 -10 lbs when all repetitions were completed during a training session.

ANOVA with Tukey post-hoc was used to determine if differences existed between the groups. Within group change was analyzed using paired T-test. Effect size was computed to determine meaningfulness of differences. HRCT and RT groups both showed statistical significance ($p < 0.05$) pre to posttesting in LP, Wingate anaerobic test W_{max} and W_{ave}, and 15-min time-trial. Control group also showed statistical significance ($p < 0.05$) pre to posttesting in LP and 15-min time-trial. Significant between group differences were noted between HRCT and control in Wingate anaerobic test W_{max} (p=0.03) and W_{ave} (p = 0.007) and 15-min time-trial (p = 0.003). There was a significant difference between RT and control on the 15-min time-trial ($p = 0.008$). When comparing HRCT and RT no statistical difference was seen in LP, Wingate anaerobic test W_{max} and W_{ave}, and 15-min time-trial. High-resistance cycle training and RT resulted in similar strength gains. However, HRCT showed greater improvements in cycling specific activities: 30 s Wingate anaerobic test W_{max} and W_{ave}, and 15-min time-trial. Results suggested that HRCT may increase performance on bike related assessments when compared to RT.

Key words: high resistance cycling, leg press, Wingate anaerobic test, low cadence, time-trial, cycling

Introduction

Competitive cycling, in most of its disciplines, requires high aerobic and anaerobic capacities (7, 8, 12). The ability to generate high power outputs repeatedly is required during racing mass starts, hill climbs, attacks, and sprints (3, 8, 12, 15, 16). The ability to increase anaerobic capacity and power output is an area of high interest among amateur/elite level competitive cyclists and coaches (2, 3). Competitive cyclists and coaches may engage in high-resistance cycle training (HRCT) and resistance training (RT) in a weight room to improve power output and anaerobic capacity (2, 3, 11).

Interval training for cyclists is generally done on the bicycle. Most cycling disciplines utilize various modes of interval training protocols. Based on specific needs and desired outcomes, duration (length of the interval), frequency (how many intervals per training session), intensity (% max heart rate [MHR], % peak watt output [W_{max}]) and mode (the type of interval: high and low cadence, standing and seated, level and climbing) will be modified per workout. Success in cycling events has been correlated with increased peak and average watt output (W_{max} and W_{ave}) and power to weight ratio (7, 12). Interval training protocols have resulted in improvements in some or all of these variables (1, 4, 10, 11, 20).

Macaluso et al. (13) suggested that after 8 weeks of high-resistance cycle training subjects' strength, power, and functional abilities improved significantly. Several studies have demonstrated that a resistance and or interval training program test increased W_{max} and W_{ave}, strength (improvement in 1 repetition max [RM]), power to weight ratio, time-trial performance, and time to fatigue (4, 10, 11, 13, 14, 17, 19, 20).

Other studies have considered the effects of RT on power output and strength. Resistance training has been shown to increase power output, strength, quadriceps cross sectional area, time to fatigue, fiber-type size and quantity (5, 6, 9, 14, 19, 21). Interval cycling training has resulted in an increase in pedal force (13), W_{max} and W_{ave} (4), anaerobic capacity, and 40-km bike time-trial, (4, 10, 13, 17, 22). With the results from previous studies it was hypothesized that HRCT would result in similar Wingate anaerobic watt max (W_{max}) and watt average (W_{ave}), strength, and performance gains as RT in a healthy untrained male college-aged population. The purpose of this study was to compare HRCT with RT, and their impact on Wingate anaerobic test W_{max} and W_{ave}, strength, and 15-min time-trial performance.

Methods

Subjects

Twenty-five (HRCT n=10, RT n=10, and control n=5) healthy untrained college-age males participated. Subjects were randomly assigned to each group. Subjects were asked to maintain their current activity level and not begin a training program while participating in this study. Subjects' health was assessed by a questionnaire and written informed consents were obtained. Subject's age, weight, and height were recorded before testing (Table 1). The Brigham Young University Institutional Review Board approved all experimental procedures. Identities of subjects were kept confidential.

Pre and Posttesting

Anaerobic power measurements. Subjects completed a 30 s Wingate anaerobic test using a cycle ergometer (Monark ergomedic 894e, Sweden)(4). Subjects began with a

5-min warm-up cycling at 50 watts (W). For the 30 s Wingate anaerobic test peak power (W_{max}) and average power (W_{ave}) were recorded. During the test, subjects received verbal encouragement to perform the test at maximal effort.

Subjects completed a 15-min time-trial on the cycle ergometer (Exacalibur Lode, Netherlands) set in linear mode. In linear mode resistance increased in relation to cadence (4). The test began with a 10-min warm-up cycling at 50 W. Following the warm-up, subjects received verbal encouragement to pedal as quickly as possible. Kilojoules (kJ) and heart rate (HR) was recorded every 3 min during the time-trial.

One repetition maximum testing. Subjects warmed up for 5 min with 50 W of resistance on a stationary bicycle and then performed a 1 repetition maximum (RM) test on a seated leg press (LP) (Cybex 48601 seated leg press, Owatonna, MN) (13). 1 RM was calculated by the following method: each subject performed 5 reps at their body weight plus 20 - 50 lbs, 3 reps at an additional 10 - 20 lbs, and 1 rep at an additional 10 - 30 lbs. Each LP was performed with full extension, with 2-min rest between each set. Based on the subjects' perceived exertion following each 1 RM attempt, weight was increased 5 - 20 lbs, with 3-min recovery. 1 RM was reached when the subsequent attempt failed (18).

Testing time-line. Anaerobic power and 1 RM measurements were completed in one week with 48 h recovery before the first training bout. Subjects completed the 1 RM protocol with a 15-min recovery period before completing the 30 s Wingate anaerobic test protocol. Twenty-four hours later subjects completed the 15-min time-trial. Subjects completed a familiarization trial of the Wingate anaerobic test and 15-min time-trial testing protocol a minimum of 72 h before the actual test. The LP 1 RM protocol was completed on the same day as the Wingate anaerobic familiarization trial. This testing protocol occurred at pre and posttraining.

Training Protocol

Subjects were placed randomly in either the HRCT, RT or control group. The HRCT and RT groups trained 2 times per week with a minimum of 48 h between each session for 8 weeks.

Control group. Subjects assigned to the control group completed the familiarization, pre and posttraining tests. They were asked not to begin a new training program or change current level of activity for the duration of the study.

RT group. Training occurred in the Brigham Young University Human Performance lab 2 times per week. Each session began with a 5-min warm-up on a stationary bike at 50 W. Each subject completed 3 sets of 10 reps with the first training session beginning at 80% of their 1 RM. When subjects completed all the repetitions required in the training session the weight was increased by 5 - 10 lbs. There was a 90 s recovery between sets. Each subject performed 3 sets of 10 on LP (21).

HRCT group. Training occurred in the Brigham Young University Human Performance lab on a cycle ergometer 2 times per week. Each session began with a 5-min warm-up on a cycle ergometer at 50 W. Each subject completed 4 reps of 30 s efforts. During the first training session the resistance required to produce maximal pedaling of 50-65 rpm was calculated. Subjects began with the same resistance as used during their 30 s Wingate anaerobic test. Resistance was adjusted by 50 – 100 g of brake resistance based on pedaling cadence for the successive 3 reps until the proper resistance was determined. Average rpm for each bout was recorded. Workload was increased 50 – 100 g of brake resistance when the subjects could maintain 65+ rpm for all required reps. Between each set there was 2 min of active recovery spinning the cycle ergometer at 70-85 rpm with no resistance (4, 13).

Statistical Analysis

Between and within group differences for the three groups were calculated for leg press, 30 s Wingate anaerobic test W_{max} and W_{ave}, and 15-min time-trial using ANOVA with Tukey post-hoc analysis, and paired *t* test. Effect size was calculated to determine meaningfulness.

Results

1 Repetition Maximum

Within group statistical significance from pre to posttesting was found in the HCRT ($p < 0.001$), RT ($p < 0.001$), and control ($p = 0.04$) groups, with the mean increase being 25.2, 37.5, and 11 lbs, respectively (Table 2). There were no statistically significant differences between groups, however, the effect size was large between HRCT and control, and between RT and control. Effect size between HRCT and RT was moderate (Table 3).

30 s Wingate Anaerobic test – Peak Watt Power Output (W_{max})

The HRCT and RT groups increased significantly in W_{max} (Table 2). High-resistance cycle training demonstrated a significant (p=0.03) difference compared to the control group. There was no statistical difference between HRCT and RT, and RT and control. A moderate effect size was noted for HRCT and RT, and RT and control (Table 3).

30 s Wingate Anaerobic test – Average Watt Power Output (W_{ave})

High-resistance cycle training and RT increased significantly in average power output (Table 2). High-resistance cycle training and control were also significantly different (p = 0.007). The effect size for HRCT and RT, HRCT and control, and RT and control were all large.

15-min Time-trial

All three groups had within group pre to posttesting statistical significance (Table 2). Both the HRCT and the RT groups had considerably larger improvements than the control group, while demonstrating no significant difference between the groups (Table 3). The effect size for HRCT and RT, HRCT and control, and RT and control was moderate, large, and large, respectively.

Discussion

The primary finding of this study was that HRCT and RT both improved significantly ($p < 0.05$) in Wingate anaerobic test W_{max} and W_{ave}, 1 RM, and 15-min time-trial performance after 8 weeks of training and were not statistically different from each other. Effect size was also calculated to determine meaningfulness of between group differences.

High-resistance cycle training had a greater improvement than RT in the 30 s Wingate anaerobic test W_{max} and W_{ave} (p<0.05) and the 15-min time-trial. Resistance training had the greater improvement in the 1 RM test, suggesting that specificity played a role in training.

The purpose of this study was to see if using a HRCT protocol would produce similar strength gains and improve on the bike performance when compared with a traditional LP training program. To our knowledge this may be the first study that used a cycle ergometer bike with incremental increase in resistance while maintaining 55-65 rpm. The Monark ergomedic 894 e allowed for instant desired resistance due to the dropping mechanism of the weight basket. This was important to allow consistent resistance through the 30 s effort. The other potentially unique effect of this training protocol was that subjects continued to spin during the recovery period, possibly resulting in a beneficial effect on the aerobic energy system more so than the leg press group.

While both groups showed significant improvement from pre to posttesting ($p<0.05$), there were trends and moderate to large effect sizes noted for differences between the groups. It was anticipated that RT would have a greater improvement in the 1 RM, however, it was only a moderated effect size. A similar moderate effect size also is seen with the improvements in the HRCT group in the 30 s Wingate anaerobic test W_{max} and the 15-min time-trial. Only the 30 s Wingate anaerobic test W_{ave} had a large effect size. This was most likely due to specificity of training and the cycle-trained subjects' increased familiarity with the 30 s efforts over 8 weeks. One interesting note was that while there was no difference statistically and only a moderate effect size for the 15-min time-trial there was an average 5.9 kJ greater improvement for HRCT than the RT group. High-resistance cycle training improved 12 kJ while RT improved 6.1 kJ, equaling about a 45+ s and 22+ s improvement in a 15-min time-trial performance, respectively. Most cyclists would welcome an additional 22+ s improvement in time-trial performance.

Conclusion

In conclusion HRCT produced similar strength gains in LP as RT but showed more favorable changes in cycling specific activities, including 30 s Wingate anaerobic test W_{max} and W_{ave} and 15-min time-trial. These findings supported the findings of Macaluso et al. (13) who found that after 8 weeks of HRCT subjects increased in force, power, and functional abilities (maximal treadmill walking speed, box stepping, and vertical jumping). We suggest that HRCT may be a viable way to increase performance on the bike even when compared to a LP training program.

Implications and Recommendations for Future Research

From amateur to professional cyclists the search for increased power and performance is a topic of continued research. High-resistance cycle training is possibly an additional tool that will significantly increase strength, power – both peak and average, and a 15-min time-trial performance. This knowledge combined with similar gains in strength to a traditional LP training program may help cyclists with limited training time to be more efficient. Rather than spending time in a gym working on LP, it is possible that by performing a HRCT protocol the cyclist will not only increase in strength but will increase on the bike performance.

The findings of this study suggest the need for further research using HRCT. This study should be repeated with trained subjects to investigate whether the results would be similar. There is also a need to look at the physiological parameters, such as VO_2, blood lactate, muscle fiber size and type changes, and other variables such as cross-sectional area of target muscles. Additional area of research would be comparing a different mode of resistance training such as squat versus leg press. Another consideration would be to use HRCT as an alternative form of resistance training for populations that may not have access or ability to use traditional resistance training equipment such as a LP machine.

Limitations

Before data collection began a power analysis was conducted which indicated a group size of 10 resulted in a power of > 0.99 with statistical significance set at 0.05. However, with a larger group size, statistical significance in more comparisons would have been likely. When testing small numbers of human subjects, motivation and health of an individual may have had a larger impact on results. Most of the subjects were students in a health/fitness class and were required to exercise for a grade. Several subjects in all three groups participated in extramural team sports while training for this study. This may have had an effect on testing, particularly in the control group. While they were instructed not to begin any training program, they may or may not have increased their activity level once the semester began. In addition, the results of this study can only be directly applied to healthy untrained college-age males.

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Table 1. Anthropometric Measurements

Group	Age	Weight	Height
HRCT	21 ± 4	76.3 ± 20 kg	179.2 ± 9 cm
RT	20 ± 4	77 ± 18 kg	172.2 ± 11 cm
Control	22 ± 2	75.9 ± 17 kg	173.9 ± 8 cm

Notes:
HRCT - High-resistance Cycle Training
RT - Resistance Training

Table 2. Within group difference pre to posttesting for LP, Wingate anaerobic test, and 15-min time-trial

Leg Press (lbs)

Group	Pre Mean	Post Mean	Change	T	P
HRCT	318.00	343.20	25.20	4.99	<0.01†
RT	329.50	367.00	37.50	5.51	<0.01†
Control	280.00	291.00	11.00	2.99	0.04†

30 s Wingate anaerobic test - peak power/body mass (W/kg)

Group	Pre Mean	Post Mean	Change	T	P
HRCT	8.7	10.4	1.7	5.08	<0.01†
RT	8.4	9.9	1.4	11.87	<0.01†
Control	7.4	8.5	1.1	1.79	0.15

30 s Wingate anaerobic test - average power/body mass (W/kg)

Group	Pre Mean	Post Mean	Change	T	P
HRCT	7.33	8.71	1.38	12.74	<0.01†
RT	6.94	7.90	0.96	3.97	<0.01†
Control	5.92	6.81	0.89	2.45	0.07

15-min time-trial (kJ)

Group	Pre Mean	Post Mean	Change	T	P
HRCT	199.96	211.00	12.00	2.87	<0.01†
RT	191.56	197.57	6.10	1.98	<0.01†
Control	154.12	156.44	2.32	0.86	<0.01†

Notes:
HRCT - High-resistance Cycle Training
RT - Resistance training
†Sig. = $p < 0.05$

Table 3. Between group difference and effect size pre to posttesting

Leg Press (lbs)

1	2	mean Difference (1 - 2)	P	ES*
HRCT	RT	-12.30	0.70	0.43
HRCT	Control	14.20	0.33	0.73
RT	Control	26.50	0.11	1.09

30 s Wingate anaerobic test - peak power/body mass (W/kg)

1	2	mean Difference (1 - 2)	P	ES*
HRCT	RT	0.40	0.74	0.66
HRCT	Control	1.60	0.03†	1.3
RT	Control	1.21	0.16	1.1

30 s Wingate anaerobic test - average power/body mass (W/kg)

1	2	mean Difference (1 - 2)	P	ES*
HRCT	RT	0.60	0.36	1.20
HRCT	Control	1.66	<0.01†	1.97
RT	Control	1.06	0.12	0.94

15-min time-trial (kJ)

1	2	mean Difference (1 - 2)	P	ES*
HRCT	RT	5.90	0.33	0.51
HRCT	Control	9.68	<0.01†	1.97
RT	Control	3.78	<0.01†	1.67

Notes:
HRCT – High-resistance Cycle Training
RT – Resistance Training
ES. 0.2 = small differences
ES. 0.5 = moderate differences
ES. 0.8+ = large differences
†Sig. = $p < 0.05$

Appendix A

Prospectus

Chapter1

Introduction

Competitive cycling, in most of its disciplines, requires high aerobic and anaerobic capacities (15, 17, 23). The ability to generate high power outputs repeatedly is required during racing mass starts, hill climbs, attacks, and sprints (5, 17, 23, 31, 33). The ability to increase anaerobic capacity and power output is an area of high interest among amateur/elite level competitive cyclists and coaches (4, 5). Competitive cyclists and coaches may engage in high-resistance cycle training (HRCT) and resistance training (RT) in a weight room to improve power output and anaerobic capacity (4, 5, 22).

Interval training for cyclists is generally done on the bicycle. Most cycling disciplines utilize various modes of interval training protocols. Based on specific needs and desired outcomes duration (length of the interval), frequency (how many intervals per training session), intensity (% max heart rate (MHR), % peak power output (W_{max})) and mode (the type of interval: high/low cadence, standing/seated, level/climbing) will be modified per workout. Success in cycling events has been correlated with increased peak/average power output (W_{max}/W_{ave}) and power to weight ratio (15, 23). Interval training protocols have demonstrated the ability to increase these parameters (3, 8, 21, 22, 39).

It has been suggested by Macaluso et al. that after 8 weeks of high-resistance cycle training subject’s strength, power, and functional abilities improved significantly (25). Several studies have demonstrated that by implementing a resistance and/or interval training program test subjects were able to increase W_{max}/W_{ave}, strength (improvement in

1 repetition max (RM), power to weight ratio, time-trial performance, and time to fatigue (8, 21, 22, 25, 27, 34, 38, 39).

Several studies have researched the effects of RT on power output and strength. RT has demonstrated an increase in power output, strength, quadriceps cross sectional area, time to fatigue, fiber type size and quantity (12, 13, 19, 27, 38, 40). Interval cycling training has demonstrated an increase in force (25), W_{max}/W_{ave} (8), average for 4-km, anaerobic capacity, 40-km time-trial, (8, 21, 25, 34, 41) . With the results from previous studies it is hypothesized that HRCT will result in a similar W_{max}/W_{ave}, strength, and performance gains as RT in a healthy untrained male college aged population. The purpose of this study is to compare HRCT with RT, and their impact on W_{max}/W_{ave}, strength, and performance.

Statement of Purpose

The purpose of this study is to compare HRCT with RT, and their effects on Wingate (W_{max}/W_{ave}), strength (improvement in 1 repetition max (rm), time-trial performance, and body composition.

Hypothesis

It is hypothesized that based on the law of specificity HRCT will result in similar or greater W_{max}/W_{ave}, strength, and time-trial performance improvements as RT in a healthy untrained male college aged population.

Null Hypothesis

There will be no or less improvements on W_{max}/W_{ave}, strength, time-trial performance, and body composition following HRCT when compared to RT.

Operational Definitions

Peak power output (W_{max}) – maximal power output during a 30 s Wingate anaerobic test.

Average power output (W_{ave}) – average power output during a 30 s Wingate anaerobic test and 15 min time-trial.

Resistance training – Leg press (LP; Cybex 48601 seated leg press, Owatonna, MN) protocol working at 80% of a one repetition max.

Interval training – riding a bike at a given intensity for a set duration with a set recovery time between repetitions.

Power starts – Begin from a stop on flat or a slight decline in a high (hard) gear 53 x 12, accelerate as quick as possible to 80+ rotations per minute (rpm)

Low cadence drills – in a gear that requires you to spin at 50-65 rpm perform repeated 15 sec to 5 min efforts; as intensity increases decrease time of effort.

Jumps – spinning between 15 and 20 miles per hour (mph) shift to a high gear and sprint until 95–110 rpm is reached.

Hill climbs – on an incline repeated 5-10 min efforts at 60 rpm.

Assumptions

Subjects will not have engaged in a regular (structured, consistent weekly) training program for the last 6 months, are healthy college age males, and will comply with the training protocol of this study.

Delimitations

This study applies to untrained healthy college age males.

Limitations

Limitations of this study could be that subjects are unable to complete or comply with the training protocol. Subjects may engage in heavy exercise outside of the required training protocol.

Significance

Interval and resistance training have increased W_{max}/W_{ave} and performance in cycling events. HRCT on a bike has demonstrated an increase in muscle strength in older women (25). A review of literature revealed that there hasn't been a study comparing the difference between a HRCT and RT protocols. If gains are similar or better utilizing a HRCT, individuals may be able to increase W_{max}/W_{ave} effectively utilizing an on-the-bike HRCT protocol. This may indicate that cyclists can spend more time on their bikes and less time in a gym and receive similar strength and power gains. This study may also produce the need for further research into cycling as an alternative form of resistance training, which could lead to alternative methods of strength training in populations who may not have access, ability, or desire to perform traditional weight room resistance exercises.

Chapter 2

Review of Literature

Introduction

Cycling is a sport with several different disciplines: road, mountain biking, cyclocross, and track racing to name a few. Though different in duration, terrain, and equipment used, the goal is the same, be the first across the finish line. Cyclists, regardless of the discipline they are training and competing in all try to increase power output, resulting in an increased power-to-weight ratio. Cycling events require high aerobic and anaerobic capacities (1, 15, 16, 23, 32, 33). Mass starts in racing, attacking, sprinting, climbing and passing slower riders often requires high anaerobic power output capacity (1, 15, 17, 23, 31, 33). Cyclists and coaches therefore utilize several training methods to increase power output.

Cycling disciplines require high amounts of force, strength, work, and ultimately power. Cycling requires dynamic force and strength creating tension in muscle groups to push and pull the crank, pull on the handlebars and propel the bike forward. Muscle strength is capped by the maximal ability to generate tension. If muscles have the appropriate resistance training overload, several adaptations take place that will increase the ability to generate tension and increase strength and power. Some adaptations are increased motor unit recruitment, fiber size and type, and workload at which onset of blood lactate accumulation (OBLA) occurs (8, 14, 20, 38).

Work is defined as the product of force x distance. Increasing the amount of work that can be accomplished is a result of increasing the amount of force or strength a given muscle group can produce. Power can be described as work/time, or force x distance/time. Increasing power output is often the most important component of training and is an indication of functional strength gains (4, 10, 15).

The bases of this study are the findings by Macaluso et al. In their study they trained 31 older women for 16 weeks using a mechanically brake cycle ergometer as the mode of resistance training. They measured force, power, and functional abilities (maximal treadmill walking speed, box stepping, and vertical jumping). They had 3 groups; 8 sets of 16 revolutions at 40% 2 revolution maximum (2RM), 8 sets of 8 revolutions and 80% 2RM, and a combo group 4 sets of 16 revolutions at 40% 2RM and 4 sets of 8 revolutions and 80% 2RM (25). All groups had 2 min recovery interval between sets. They demonstrated significant increase from 0-8 weeks in all three groups in force, power, and functional abilities. There was no further significant increase from 8-16 weeks (25). The goal of this study is to in a healthy college-age male population compare HRCT with RT in a, and their effects on Wingate (W_{max}/W_{ave}), strength (improvement in 1 rm), time-trial performance, and body composition.

Cycling Characteristics

Elite cyclists competing in road and mountain biking events have demonstrated similar W_{max}/W_{ave} both in laboratory and field tests, which suggests cyclists in most disciplines benefit from training that increases W_{max}/W_{ave} and consequently power to weight ratio (7, 15, 23).

By increasing power output, onset of blood lactate accumulation (OBLA) occurs at a higher absolute workload. The increase in power output capacity allows for cyclists to work at a higher % MHR and to maintain high power outputs for longer durations of time, before OBLA occurs, improving their ability to perform. Padilla and associates determined % MHR for 18 professional cyclists during several different time-trials: prologue (<10 km, PTT), short (<40 km, STT), long (>40 km, LTT), uphill (UTT), and team time-trial (TTT) (32). They found the following %MHR: 89%, 85%, 80%, 78%, and 82% for PTT, STT, LTT, UTT, and TTT respectively (32). What these findings seem to indicate is that the elite cyclist can maintain an intensity level of 80% MHR for distance of 40+ km, which is only a 9% decrease from the PTT (89%) (32).

Cyclists racing time-trials, hill climbs, and mountain bike cross country races ride at similar intensities which are close to lactate threshold (LT, approximately 370 to 390 W) with shorter efforts reaching near and sometimes surpassing OBLA (approximately 400 to 420 W), even during relatively flat stages cyclists spend an average 30 to 100 min at, and above LT, with 5 to 20 min at or above OBLA (23, 30, 32, 33). Davison et al. suggest the ratio of power output to body weight is a significant indicator of performance in uphill racing (10).

Cyclists and coaches therefore spend a significant amount of time, energy, and expense attempting to increase the power-to-weight ratio. While a great deal of time and money are spent making bikes lighter and equipment more aerodynamic, most of the time is spent pursuing adaptations to the physical body. Several modes of overloading the body’s systems are used. Time is spent riding at sub-maximal levels to build the aerobic base and increase the ability to generate power at sub-maximal levels. High resistance training is implemented to increase the muscle group’s power output capacity. HRCT and RT are two modes that are used in a regular training program to increase power output.

Resistance Training: Protocols and Adaptations

RT programs manipulate four factors: intensity (weight), duration (sets/reps), mode (type of lift), and recovery when setting up a program. Many studies investigating strength and power gains and the physiological adaptations that occur will take a percent of 1RM to find the target weight. Many initially use 40%-85% of 1RM, with a majority using 80% of 1RM as the resistance weight (2, 12, 14, 18, 24, 36, 40). Likewise most protocols will include 3 sets of 8-12 reps with 1.5-3 min recovery time between sets.

RT with an appropriate overload stimulus produces many physiological adaptations, which increase strength and power. Several studies have reported significant increases in neural recruitment, structural protein content, changes in fiber type and size, muscular strength, and power output after 8 weeks of RT (14, 19, 29, 38, 40). RT overload stimulus increases type IIa fibers size and quantity (26, 40), which may contribute to increased muscular force production capacity, increasing W_{max}/W_{ave} and 1 RM. Fitts and Widrick suggested that following training type I fibers may increase in contractile speed translating to improved force generation speed, which during an endurance event at an absolute sub maximal workload may delay the recruitment of less effective type II fibers (11) improving time to exhaustion.

In untrained subjects the strength increases from RT, not only produced increased power output but also improved laboratory short time-trial performances and time to exhaustion (6, 18, 27). Hickson et al. reported RT to have increased leg strength by 30%, short-term cycling endurance (4-8 min) by 13%, and time to exhaustion increased from 71 to 85 min ($P < 0.05$)(12). Many studies suggest that the improved time-trial performances are a result of increased power output, which improves the economy of untrained subjects (24, 28, 37).

Cycling Interval Training: Protocols and Adaptations

HRCT utilizes on the bike training sessions, often in the mode of interval training. Coaches and exercise physiologists recommend several different modes of interval training to increase power output (4, 5). Power starts, low cadence drills, jumps, and hill climbs are modes used to increase power output (4, 5, 9). These types of interval sessions are high intensity, high resistance bouts that overload the muscle groups promoting strength gains and increased power output on the bike. These intense bouts of exercise are often followed by 48 hours of recovery, similar to the recommended recovery time for RT (4, 5, 8).

Interval sessions can range from 30 s to 10 min depending on the desired adaptations. Most intervals focusing on increasing power output are shorter in duration, ranging 15 s to 30 s. After 4 weeks of 30 sec maximal interval training Creer et al. reported a 6% increase in W_{max}/W_{ave} and total work completed (8). Laursen et al. reported in two different studies that following 4 weeks of interval training the subjects demonstrated significant improvement in W_{max}, VO_2 peak, and time to complete a 40 km time-trial (21, 22). Taylor-Manson found similar results with trained cyclists utilizing low (40-80 rpm) cadence interval sessions; 6.4% ± 7.7% improvement in 40-km time-trial and 6.1% ± 3.3% improvement in W_{max} (39). Burgomaster et al. reported that after only 2 weeks using a 3 days a week and 4 – 7 repetition of 30 s out interval training the endurance capacity of recreationally active males was doubled (3).

There are several studies that demonstrate that cycling interval training increases W_{max}/W_{ave}, leg strength, time-trial performances, and time to exhaustion (3, 8, 21, 22, 25, 34, 39, 41). Some studies using a high intensity cycling interval training have suggested the increased W_{max}/W_{ave}, leg strength, time-trial performances, and time to exhaustion have been due to several adaptations that occur as a result of the training. These included increased muscle oxidative potential (3), possible increase in VO_{2peak} (21, 22), neural activation (25), increased plasma lactate levels (8), while two studies showed no increase in thigh circumferences.

Summary

From beginners to elite cyclists the goal is often the same, improve performance. While there are several ways to improve performance the one that seems to have the greatest impacted on race outcome and individual performance is the ratio of weight to power output ratio(7, 15, 23). Most cyclists have limited training time to fit into their schedule, so training as cycling specific as possible is critical. RT has demonstrated it's effectiveness at increasing power output, but takes time from cycling. HRCT is a cycling specific training that will hopefully produce similar power gains. HRCT demonstrated in elderly women a significant increase in power output after 8 weeks of training(25). Several on the bike interval training studies also produced significant power gains in 8 weeks (8, 21, 22). Based on the law of specificity the power gains attained from bike specific HRCT may have a more significant effect on cycling performance than that of

RT. If gains are similar or better utilizing a HRCT cyclists may be able to train more effectively with less time off the bike. This study may also produce the need for further research into cycling as an alternative form of resistance training, which could lead to alternative methods of strength training in populations who may not have access, ability, or desire to perform traditional weight room resistance exercises.

Chapter 3

Methods

Subjects

Thirty (ten subjects per group: HRCT, RT, and control) healthy (free of disease and a BMI between 18.5 and 24.9) untrained (not engaged in a regular training program for the past 6 months) college-age (between ages of 18-30) males will be recruited to participate. Subjects will be randomly assigned a group. Subjects will be asked to maintain their current activity level and not begin a training program while participating in this study. Subjects' health will be assessed by a questionnaire and written informed consent will be obtained. The Brigham Young University Institutional Review Board will approve all experimental procedures. Identities of subjects will be kept confidential.

Pre and Posttesting

Anaerobic power measurements. Subjects will complete a 30 s Wingate anaerobic test using a cycle ergometer (Monark ergomedic 894e, Sweden)(8). The test will consist of one 30 s Wingate anaerobic test. Subjects will begin with a 5-min warm-up cycling at 50 W. For the 30 s Wingate anaerobic test work and W_{max}/W_{ave} will be recorded. During the test, subjects will receive verbal encouragement to perform the test at maximal effort.

Subjects will complete a 15 min time-trial on the cycle ergometer (exacalibur Lode, Netherlands) set in linear mode. In linear mode resistance increases in relation to cadence (8). The test will begin with a 10 min warm-up cycling at 50 W. Following the warm-up, subjects will receive verbal encouragement to complete pedal as quickly as possible. W_{max}/W_{ave} and kJ will be recorded. HR will be recorded at the end of every minute during the warm-up and time-trial.

Anthropometric measurements. Each subject's height, weight, age, and body composition will be recorded prior to pre and post training testing. Body composition will be determined by bodpod (Life Measurements Inc., Concord, CA) to record any changes.

One repetition maximum testing. Subjects will warm-up for 5 min with 50 W of resistance on a stationary bicycle. They then will perform 1 RM test on a seated leg press (LP) (Cybex 48601 seated leg press, Owatonna, MN) (25). 1 RM will calculated by the following method: each subject will perform 5 reps at their body weight plus 50 lbs, 3 reps at an additional 20 lbs, and 1 rep at an additional 30 lbs with full extension, with 2 min rest between each set. Based on the subjects' perceived exertion following each 1 RM attempt, weight will be increased 10 - 50 lbs, with 3 min recovery. 1 RM will be reached when the subsequent attempt is failed (35).

Testing time-line. Anaerobic power and 1 RM measurements will be complete in one week with 48 h recovery before the first training bout. Subjects will complete the 30 s Wingate anaerobic test protocol. After completion of the Wingate subjects will have a 30 min recovery before completion of the 15 min time-trial. During the recovery period subjects will be allowed to drink, stretch, and use the restroom. Subjects will complete a familiarization trial of the Wingate anaerobic tests and time-trial testing protocol a minimum of 72 h before the actual test. The LP 1 RM protocol will be completed on the same day as the familiarization trial. This testing protocol will occur at pre and posttraining. Anthropometric measurements will be taken before pre and posttesting.

Training Protocol

Subjects will be placed randomly in either the HRCT, RT or control group. The HRCT and RT groups will train 2 times per week with a minimum of 48 h between each session for 8 weeks.

Control group. Subjects assigned to the control group will complete the familiarization, pre and posttraining tests. They will be asked not to begin a new training program or change current level of activity for the duration of the study.

RT group. Training will occur in the Brigham Young University human performance lab 2 times per week. Each session will begin with a 5 min warm up on a stationary bike at 50 W. Each subject will complete 3 sets of 10 at 80% of their 1 RM. Every 2 weeks 1 RM will be retested before training following the previously outlined protocol and weight adjustments will be made. If subjects complete all the repetitions required in the training session then weight will be increased by 10 lbs. There will be 90 sec recovery between sets. Each subject will perform 3 sets of 10 of LP (40).

HRCT group. Training will occur in the Brigham Young University human performance lab on a cycle ergometer 2 times per week. Each session will begin with a 5 min warm up on a cycle ergometer at 50 W. Each subject will complete 4 reps of 30 s efforts working at a percentage of their W_{max} calculated from the 30 s Wingate anaerobic test. During the first training session the resistance required to produce maximal pedaling of 50-65 rpm will be calculated. Subjects will begin with a resistance set at 100% of their W_{ave} calculated from the 30 s Wingate anaerobic test. Resistance will be adjusted by 100g of brake resistance based on their pedaling cadence for the following 3 reps until the proper resistance is set. Average rpm for each bout will be recorded. Workload will be increased 100g of brake resistance when the subjects can maintain 65+ rpm for all required reps. Between each set there will be 2 min of active recovery spinning the cycle ergometer at 70-85 rpm with no resistance (8, 25).

Statistical Analysis

A power analysis was conducted with help from the Brigham Young University statistical department for group size. With group size set at 10 the power is > 0.99 with statistical significance set at 0.05. Results for the three groups will be compared using a MANOA and post hoc analysis, comparing changes within and between groups for pre and posttraining. After completing the statistical analysis findings will be reported from which conclusions and recommendations will be drawn.

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Appendix A-1

Consent form

CONSENT FOR PARTICIPATION IN A RESEARCH PROJECT

Brigham Young University
Department of Physical Education
Human Performance Laboratory

Invitation to Participate and Description of Project

Title of Project: A Comparison of the effects of high-resistance cycle training and leg press on the Wingate anaerobic test, strength, time-trial performance, and body mass

Principle Investigator: Aaron W. Stites and Ron Hager Ph.D.

Introduction
You are being selected because you are a healthy (free of disease and a BMI between 18.5 and 24.9) untrained (not engaged in a regular training program for the past 6 months) college age (between ages of 18-30) male.
This research is being conducted by Aaron W. Stites and Dr. Ron Hager at Brigham Young University to compare the effects of high-resistance cycle training and leg press on Wingate anaerobic test, strength, time-trial performance, and body mass.

DESCRIPTION OF PROCEDURES

<u>Overview of Study</u>

You will be asked to complete a familiarization trial and pre/posttraining tests. These include completing a 30 second cycling maximal effort test, a 1 repetition max on the leg press, 15 minute cycling time-trial, and a Bodpod body composition assessment. You will be randomly assigned into one of three groups: control, leg press, or high-resistance cycle training. If assigned to the leg press or cycle training groups you will be training twice per week for 8 weeks with each session lasting from 10-14 minutes. Training and testing will occur in 121 RB. You will be asked to maintain their current activity level and not begin a training program while participating in this study. You will fill out a health risk questionnaire and a research subject consent form. Your identities will be kept confidential.

RISKS AND INCONVENIENCES

Risks and inconveniences associated with intense exercise include possible fatigue, weakness, dizziness, and/or disorientation, muscular tiredness and muscle soreness on the following day. The stationary bike intense exercise or the leg press exercise performed test and training will both be stressful but, generally, are easily tolerated by people and not dangerous for healthy individuals. We will monitor heart rate during the familiarization trial and pre/posttrainning tests. The likelihood of heart problems in a healthy population during maximal exercise testing is 1/100,000 (American College of

Sports Medicine Guidelines for Exercise Testing). In the event of an emergency 911 will be contacted from a phone located within the laboratory.

BENEFITS

Benefits include possible strength gains and a decrease in body fat. Results for this study may provide increased understanding on methods of resistance training and associated improvements.

COMPENSATION

All subjects will be compensated $13 for their participation in the study.

CONFIDENTIALITY

All information provided will remain confidential and will only be reported as group data. Each subject will be listed as “subject #.” All data, including questionnaires, test results will be locked in an office and only those conducting training/testing will have access to the information. Following the completion of the study all subject’s information will be destroyed.

IN CASE OF INJURY

If you are injured as a direct result of your participation in this research study, the medical staff at the local hospital will provide immediate emergency care; short-term hospitalization and/or short-term outpatient care to you. However, you or your insurance carrier will be billed for the cost of this treatment.

Additionally, you should know that there are no plans to compensate you for physical or mental disability, lost wages or any other losses or damages occurring over the long term or if an injury becomes apparent after your participation in the study has ended. However, by agreeing to participate in this research study, you are not waiving or giving up any legal rights to seek compensation. If you believe that you have been injured, please contact Aaron Stites at 422-5548, awstites@hotmail.com, or Dr. Ron Hager at 422-1183, hager@byu.edu immediately.

VOLUNTARY PARTICIPATION

You are free to decide whether to participate and to withdraw from the study at any time. If you decide not to participate or if you withdraw, this will not adversely affect any future interactions with the Department of Exercise Sciences or Brigham Young University.

QUESTIONS

In developing this consent form it was necessary to use of a number of technical terms. Before you sign this form, please feel free to ask about any words or conditions of the study that may be unclear to you. Consider this consent form carefully for as long as you feel is necessary before making a decision regarding your participation in the study.

Questions about the Research
If you have questions about this study please contact Aaron Stites at 422-5548, awstites@hotmail.com, or Dr. Ron Hager at 422-1183, hager@byu.edu.

Questions about your Rights as Research Participants
If you have any questions you do not feel comfortable asking the reseache4r, you may contact Christopher Dromey, PhD, IRB Chair, (801) 422-6461, 133 TLRB, christopher_dromey@byu.edu.

Authorization
I have read this form and decided that __________________________________ will
(name of subject)
participate in the project described above. Its general purposes, the particulars of involvement and possible hazards and inconveniences have been explained to my satisfaction. My signature also indicates that I have received a copy of this consent form.

Signature:__________________________________

Date:______________________________________