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Comparison Between Hear Rate Based Training, Perceived Effort, and Power Based Training in Competitive Elite Cyclists

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by

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DECLARATION OF ORIGINALITY

I do hereby declare and attest to the fact that this is an original study based solely upon my own scholarly work here at Lindenwood University and that I have not submitted it for any other college or university course or degree here or elsewhere.

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This thesis has been approved as partial fulfillment of the requirement for the degree of Master of Science in Human Performance at Lindenwood University by School of Sport, Recreation, & Exercise Sciences.

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Abstract

There are many different philosophies on how cyclist should train and about the different training modes available to them. It is important to know how to use these different modes of training to maximize the efforts. Training with power, heart rate, and perceived effort all have several advantages and disadvantages. The purpose of this study was to compare these different modes of training over an 8 week period to see if there is a difference between them. The participants were tested before and after the training period to show if there was any significant differences between them.

The study consisted of 22 total participants. These participants were broken into 3 groups: power, heart rate, and perceived effort. 1 participant failed to complete the training protocols. Each group had 7 subjects (5 males and 2 females). Each group performed a roughly 20min threshold test and up to 30sec maximum power tests 3 total times before and after an 8 week training period. Averages were taken for the 3 maximum power sprints as well as finish maximum heart rate and finish times for data comparisons. Sports Emotional Reaction Profiles were made at both pre and post training period to determine if there was a specific physiological profile for each type of training mode.

A significant difference ($p = .038$) was found in the heart rate group for an increase in maximum power. This group also saw a positive difference ($p = .052$) for an increase in finish time. An increase was seen in the power group for average maximum power. No other significant or positive results were seen within the study. There was no difference in the physiological profiles from the SERP questionnaire of the athletes in any of the groups.

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Chapter One

Introduction

Overview

Training methods in elite cyclists are in an evolutionary stage at this time in history. Since the breakthrough inventions of the heart rate monitor and power meter, there is not only an incredibly vast collection of data, but also ideas on how to best use these newer means of conducting and monitoring training.

Each method of conducting training in elite cyclists has its positives and negatives. Cardiac drift is a major limitation of heart rate based training (Jeukendrup, 1998). Bike position has an impact on both heart rate and power based training (Jeukendrup, 1998). The raw data drawn from power-based training alone is incapable of measuring whole-body stress which can both help and hinder the understanding of the outputs of elite cyclists (Jeukendrup, 1998). An increase or decrease in strength largely affects power-based training but has only a nominal impact on heart rate based training (Jeukendrup, 1998). Power-based training can measure instantaneous changes in a rider's work output, and there is not the same lag-time issue that is evidenced in heart-rate based training (Robinson, 2011).

It has been established that, in recreational cyclists, power-based and heart rate based interval training is equally effective (Robinson, 2011). While this is true for recreational cyclists where large gains can be made quickly using interval training, there are very few or even no studies on the effectiveness of these two popular training methods on elite cyclists. Once certain gains have been made from interval training, improvements are made more slowly through strength and conditioning training by more highly training athletes. Elite cyclists rarely see gains at the same increments as recreational cyclists.

Because of the lack of research on elite cyclists, studies are needed to measure the small gains made in highly trained cyclists. Some elite coaches and athletes believe that the tried and true methods of heart-rate based training remain the safest to use because there is an extra decade worth of research in its support. Others feel that power-based training is far superior because of the immediateness of the shifts in data based on raw output (Robinson, 2011).

Statement of the Problem

The aim of this study is to determine if there is a superior method of training for elite cyclists when comparing protocols using power meters, heart rate monitors and rate of perceived effort.

Hypotheses

The following research hypotheses were articulated for this study:

1. There will be no difference in performance outcome variables of heart rate, maximal power output, and total finish time for elite cyclists using power meters as their primary training protocol.
2. There will be no difference in performance outcome variables of heart rate, maximal power output, and total finish time for elite cyclists using heart rate monitors as their primary training protocol.
3. There will be no difference in performance outcome variables of heart rate, maximal power output, and total finish time for elite cyclists using perceived effort as their primary training protocol.

4. Choice of training mode for elite-level cyclists differ based upon individual psychological profile.

Significance of Study

Thousands of coaches in the world are looking for the best methods to train their elite cyclists. With the inadequate amount of research performed to date, it would be difficult to either validate or discredit the newer method of power-based training. Knowing how to properly use power-based training may revolutionize the ways in which elite cyclists are trained. Perhaps these two methods of training could best be used together. If coaches had a proper knowledge of the effects of power-based training on elite cyclists, then the use of power and heart rate could be used in coordination to maximize the performance gains out of their athletes. At this time, there is insufficient research to support this new medium of power-based training and its effect on elite cyclists. With the technological advances that allow the measure of heart rate and wattage, it is important to have studies like this to better understand the effects on athletic performance.

Assumptions

1. We assume that the accuracy of the power meters and other equipment used in the study will be accurate within normal parameters set by the manufacturer.
2. We assume that all athletes will perform the activities to the best of their ability.
3. We assume that all athletes will adhere to the prescribed training protocols and understand the importance of accurate data collection.

Limitations

1. The amount of rest the athletes will have before testing will not be consistent or controlled.
2. Adherence to the specific training programs will be up to each individual.

3. Misrepresentation of training information.
4. Weather, if training is performed outside.

Delimitations

1. Testing will only be performed on elite level cyclists.
2. Only two types of power meter devices will be used.

Definitions

All groups will consist of 8 athletes. All athletes will be under the same testing conditions as each other each time they do the performance evaluations. Each group of athletes will train under their respective conditions for their training assignments of power, heart rate, and perceived exertion. Below is a detailed definition of each group. During the physiological testing, all groups will not be using their respective training methods and will all perform the same evaluation.

Group 1: Control Group

This group is designed to give a base line of information from the physiological testing performed. They will not have any extrinsic measuring devices such as heart rate monitors and power meters during training. They will train by perceived effort. Perceived effort is where training efforts are done by how the body feels during the workouts. Perceived effort will be assessed by a ranking system referred to as a Borg scale. A score of 1-20 will be applied to each effort with 1 being equal to sleeping and 20 being equal to the hardest thing the athlete has ever experienced. This group will perform all of the same type of training as the other groups which will be determined for the time of year that the research is being gathered (Borg, 1992).

Group 2: Power Meter Training Group

This group will have all of the same training components in their workout as every other group. The only difference is that this group will have a power meter on board their bike to collect data. The power meters will be used to dictate how intense the training efforts will be. As in other groups, the type of training will be the same. The athletes will be required to maintain specific "power" levels (watts) during different intensity levels of effort. A threshold power value will be assigned to the individual athlete to determine the percentage of maximum effort. All efforts will be done at a varying percentage of this functional threshold power value depending on the type of workout being performed. While some of these devices record heart rate, this data will not dictate the intensity of the training performed by the athlete (Coggan, 2010).

Group 3: Heart Rate Training Group

The heart rate training group will require the use of a heart rate monitor. The athlete will use their maximum heart rate value to determine workout zones. The zones consist of a percentage of maximum heart rate. These zones will then be used to dictate and format the athletes' training program. Maximum heart rate will be determined by the actual maximum heart rate of the athlete that has been tested. All of the athletes that will participate in the study will have had physiological testing done in the last 6 months that will have determined a maximum heart rate. In cases that the athlete does not have a known maximum heart rate, then a 220 – age = heart rate equation will be used. All participants will be required train within 75-95% of heart rate maximum. All efforts will be done based on these zones of max heart rate (Jeukendrup, 1998).

Wattage- The measurement of power.

Power Meter- Device that measures power in wattage that is attached to a bicycle (Coggan, 2010).

Heart Rate Monitor- A device that measures the given heart rate of a person and can be worn on the person during exercise (Bell, 2013).

Elite Cyclist- Category Pro 1-2 or 3 Road cyclists as defined by USA Cycling. This system states that any cyclist is considered elite who has earned a category of 3 or better on the USACycling ranking system. USACycling's ranking system is described as; a beginner rider is considered a category 5 racer. To upgrade to a category 4 racer, an athlete has to compete in 10 mass start races. To upgrade from a 4 to a 3, an athlete must win 20 points based on placing in finishes with 1st place being worth 5 points, 2nd – 3 points, 3rd – 2 points, and 4th – 1 point. To upgrade to a category 2 an athlete must earn 25 points using the same scale and for a category 1 upgrade the athlete needs 30 points. A category 1 is the highest rank and is considered to be a semi- professional racer. The jump to professional is done by the team license that the athlete rides for. All "professional" riders must be category 1 before they can be picked up by a professional team. Years racing will not be an excluding factor for this study, but it is assumed that it takes at least 2-3 years to complete the upgrade ranking system to be considered elite level cyclist. These are riders that have earned enough points through top placings in elite professional races (USA Cycling, 2016).

Cardiac Drift- Increase in heart rate over a period of time without an increase in workload or output (Bell, 2013).

VO2 max- The maximum rate of oxygen consumption as measured during incremental exercise, most typically on a motorized treadmill (Kravitz, 2005).

Maximum Power Testing- This uses a specific devices to determine the maximum power an athlete can attain at different time increments (Coggan, 2010).

Threshold power Testing- This is a specific test done at either 20min or 1 hour time increments to determine the lactic threshold and highest sustained average power of an athlete (Kravits, 2005).

Sport Emotional Reaction Profile - Tutko & Tosi (1976) developed a psychometric tool to measure athletes sport-specific emotional reactions in the areas of desire, assertiveness, sensitivity, tension control, confidence, personal accountability and self-discipline. The end result of taking the SERP (Sport Emotional Reaction Profile) is an iceberg profile that help measure personality strengths and weaknesses.

Chapter Two

Literature Review

Introduction

The sport of cycling has been around for over one hundred years. Competitive cyclists have been trying to maximize their abilities for at least that long. Throughout the last forty years, athletes have had the ability to use technology with their training. These new ways to track training and monitor efforts have evolved and revolutionized the sport of cycling. With the advent of heart rate monitors and power meters, the ability to dial training in to the finest little detail has proven to have great performance affects (Sparks, Dove, Bridge, Midgley, and Mcnaughton, 2015). There are several different mentalities among coaches about how best to use these different tools in training. The additions of onboard power meters have offered an extra capability to athletes that provide detailed, real time training data. This is still a relatively new way of training, and it is constantly growing as technology continues to improve data collection tools for athletes during workouts.

Polar developed the first training based, EKG heart rate monitor in 1977 (Bell, 2013). This first heart rate monitor was developed for the Finnish Cross Country Ski Team as a training tool. It was used by holding a fingertip against the screen until a reading appeared (Bell, 2013). Ever since then, heart rate monitors have exploded with technology in terms of size and capability.

In the mid 1980s and the early 1990s, SRM (Schoberer Rad Messtechnik) developed the first onboard power meters for bicycles (Coggan, 2010). This brand of power meter is now one of the leading and most reliable units on the market today. Power training had started a few years earlier, but the machines were stationary. These could only be used in lab settings. This new development by SRM was groundbreaking. This would prove to be an important factor for the future of testing and training in the sport of cycling. In the short time that power meters have been in existence, they have become a mainstay in the cycling peloton. Over half of any given group of cyclists have a power meter, and more than half a dozen companies are manufacturing them (Coggan, 2010). This is an observation that can be made on any given Saturday morning group road ride.

With the relatively recent inventions and improvements of these mechanisms, this is a fairly new area in sport to study. There is very little data on the differences between training with heart rate values versus training with power-based data. There are some who are die hard, heart rate based coaches and athletes. There are also those in the "power meter only" crowd that believe they have found the next big advantage. A few "old-school" coaches and athletes believe that neither is necessary for training and that perceived effort is all that is needed. Is there really a difference in performance of cyclists who use their power numbers to train versus those who use heart rate data or perceived effort to train?

Cyclists who elect to train with heart rate must overcome the drawbacks of the phenomenon called cardiac drift. This is where the heart rate will increase over a sustained increment of time without an increase in workload (Jeukendrup, 1998). This increases the rate of perceived effort even though the actual effort is not increasing. This, among other things, can cause a mental block that is sometimes hard to overcome. Another key factor that affects heart rate in cyclists, according to one study, is bike position (Jeukendrup, 1998). If a person is sitting to up right then this could affect venous return rates causing a change in heart rate. On the other end of the bike fit scenario is if someone is bent over too much while riding than this could put pressure on large veins and arteries in the hip, also affecting heart rate.

One large downfall to power based training is that the data alone is incapable of measuring whole body stress (Jeukendrup, 1998). This is a major negative when it comes to an elite athlete training to be in the best condition possible. This study will examine the different aspects of these two types of training, along with training with perceived effort alone and determine which is most effective. Maybe the answer is that combining heart rate and power-based training together with perceived effort is the most efficient way to train.

Training with Perceived effort

For hundreds of years, people have worked as hard as their body and mind would allow. There are countless examples of both athletes and workers who push themselves to the brink of exhaustion. This ability to push the body and mind to its limits, or stay within those limits, is a notion of perceived effort. Perceived effort is the best way to determine physical strain on the body (Borg, 1982). In the 1980s, the Borg scale was created as a way to determine the physical exertion level during exercise. This scale is unique in that it takes into account the fitness of the athlete by associating a number during intensity with how hard the exertion feels, such as fairly light and moderate. Using this rate of perceived effort, an athlete can determine how hard they are training against their lactic threshold (Borg, 1982). In cycling, there are a large number of people who still only train this way. It is common for professional riders to do away with the power meters and heart rate monitors because they get tired of comparing numbers and will train by perceived effort for the remainder of the season. This is a debatable way for an athlete to train. If they are having any kind of mental or physical strains, then the rate of perceived effort will be influenced.

This method, when used in a training setting, can be effective but can also be easily affected by mood, weather, and other extrinsic factors (Balague, 2015). Feelings of heaviness and strain during training are an indicator of perceived effort that has an effect on rates of perceived exhaustion (Balague, 2015). This could end a workout or a physiological test earlier than expected, which could affect the results and, therefore, necessitate a change in training plans. This is a good tool for a coach to have because the athlete can report how they are feeling during or after training sessions. A coach can possibly help determine if the athlete is having troubles with parts of the training program or other factors in life such as mental health. Some coaches still use perceived effort during the really hard portions of interval training. This allows the athlete to push as hard as they possibly can both mentally and physically during the intense portion of their interval workouts. The effort is not capped on the top end, but the effort is also not a disappointment when the athlete fails to meet a certain heart rate or power reading. This could prove to be a positive method of training that goes hand in hand with heart rate and power based training. Perceived effort is a great tool to incorporate into a training program. It allows an athlete a little freedom to push themselves without the strains of meeting certain expectations. It can also teach the athlete how hard they really can push themselves.

Heart Rate Based Training

Heart rate based training has been used for a long time. It is the foundation of interval training. The concept of increasing heart rate over specific periods of time has been understood to be the most effective way to train for specific events. In cycling, a good coach can use the information gathered from various heart rate values to determine overtraining, illness, and even stress levels. The major problem with heart rate training is the phenomenon of cardiac drift (Jeukendrup, 1998). This is where the heart rate will jump to a specific level during exercise, and, if the intensity is maintained, the heart rate will "drift" higher without an increase in workload (Jeukendrup, 1998).

Heart rate based training consists of using known heart rate variables such as an athlete's maximum heart rate capability and the heart rate associated with the rider's lactate threshold. A coach would use these variables to build a training program with predetermined heart rate zones. Each zone would be based off of the maximum heart rate of the athlete. Specific intervals would be developed using lactate threshold as well. The use of these intervals and zones would determine the types of efforts the athlete would be performing during training. The basic concepts of these zones were broken into three groups: aerobic, fat burning, and anaerobic. For elite athletes, this can be divided into further groups to include lactate threshold training and certain recovery training days. Day to day micro-cycles would determine rest and hard training days. This would correlate with macro-cycles that would include a recovery block.

The concept of maximum heart rate is interesting. According to the American College of Sports Medicine, the general formula to find one's maximum heart rate is 220 minus your age (Melone, 2012). This is a good formula for the general public to use to get started with an exercise program. Each individual is different, so this method cannot be completely accurate. For any athlete, it is best to be tested to determine a true maximum heart rate. The best "test" for this is simply recording the maximum heart rate during race efforts or simulated race training when both maximal sustained efforts and maximal sprint efforts are included in the workout program. This can also be verified by maximum Vo2 testing in a laboratory setting.

In general, anaerobic threshold is the point that the body can sustain a submaximal effort for an extended amount of time (Nimmerichter, Easton, Bachl, and Williams, 2015). This is a debated topic among researchers as to what really constitutes anaerobic threshold. The term anaerobic is when the body does work without free oxygen in the system. The debate is formed around this idea. There is not enough definitive research to suggest when the body switches from aerobic systems to anaerobic systems (Kravitz, 2005). Some researchers believe that anaerobic threshold happens due to maximum oxygen uptake, causing the "burn." Others believe that anaerobic threshold is the point that the body is filtering lactic acid at the same rate as oxygen consumption (Kravitz, 2005). This theory is built upon the foundation of the idea of homeostasis at an anaerobic effort, and this effort can be maintained for a short, extended period of time.

Heart rate zones can vary between athletes. A person's heart rate can be broken down into several different zones. Any given coach can have their opinion of how effectively this can be done. In general, most coaches use either a three zone or a five zone workout model (Knechtle, 2004). There are at least three ways to create the zones. The first is to use Vo2 max and lactic threshold values from metabolic testing to create the zones based on these values. The second is to use true maximum heart rate from metabolic testing. In the sport of cycling, many coaches also use the actual maximum heart rate from field data rather than from testing. Either way, the zones will be very similar to each group. The zones will usually be based on a specific percentage of the given heart rate values. A basic example of this would be: Zone one- up to 55%, Zone two- 55-65%, Zone three- 65-75%, Zone four- 75-90%, and Zone five-90-100%. This type of setup allows for different intervals to be used in each zone, maximizing the athlete's full range of ability (Knechtle, 2004).

Power Based Training

The concept of power based training is relatively new. It was developed in the early 1980's and, over the past 15 years, has become a mainstay in competitive cycling. New technology is coming out to make any bike and trainer capable of producing power profiles. This type of training is becoming very popular, but a lot of people misunderstand how to really use it to its full potential. A large flaw in this type of training right now is that the accuracy of the measurements taken is fairly low when comparing with other devices of different manufacturers. With heart rate, any monitor will pick up one heartbeat. Because this is the case, when you get a new heart rate monitor, any future heart rate monitor – regardless of brand – will work with almost identical accuracy. The accuracy between devices is consistent. Power meters, on the other hand, have many different ways to collect data. There are power meters that use the chain as a predictor; others use crank arms, pedals, and wheels. All these equipment options are accurate in their respective ways but none with respect to each other. This makes it hard to quantify the data in a meaningful, analytical way. It takes away any generalizations that can be made to training because there are different types of power meters. If someone were to break their power meter and purchase a new one, there would be inconsistency even when purchasing the same brand and model as the replaced power meter. Each power meter is build to give data within a given spec range. This variance would make going from one power meter to another of the exact same brand be slightly different, thus giving an inconsistency between power meters.

A large predictor of ability in certain types of cycling, mainly time trialing, is functional threshold power. There are a lot of factors that make up functional threshold power, but it is basically the maximum amount of power that an athlete can sustain for an hour-long effort without fatigue. This is very similar to lactate threshold heart rate, only using a power number to signify when the athlete is at threshold (Coggan, 2008). Functional threshold power is believed to be a strong predictor in ability for events as short as three kilometers to as long as a three-week stage race. As mentioned above, there are a lot of different factors that can have an impact on the athlete's ability such as maximal oxygen consumption as well as anaerobic and aerobic energy systems. Every athlete is different in the way their body uses and produces energy, thus making the capabilities of functional threshold power between individuals unique to the athlete. When using power, weight of the athlete becomes an important factor as well. It is important to maintain a proper power to weight ratio for good performance. A low weight with high power is optimal.

There are several ways to determine functional threshold power. It can be tested in a laboratory setting with actual blood lactate values during specific timed performance testing (Coggan, 2008). An easier way, and more popular due to the ability to reproduce the test by athletes at home, is to simply collect training and race data in a tracking software program. These programs can chart the power data and create power profiles for the athlete. Functional threshold power can easily be seen in the power profile as a sharp increase in power at a given time, usually of about ten to fifteen watts.

Several different software programs are available to an athlete and are highly recommended to use when training with power. These power profiles are generated by the software program based on the data that is uploaded from specific training rides and races. At first, an estimated functional threshold power number is used. Then, after about two weeks of use, the program will have enough data to calculate an actual functional threshold power number. Based on this number, different power zones are created for the athlete to use during training. These power zones are called power profiles and are similar to those of heart rate training zones. A coach then uses this power profile of the athlete to form specific training workouts for the athlete to perform. The use of this method allows very specific training to occur. This type of training is very similar to that of weightlifting in a gym. In the gym, an athlete knows what their three to five repetition maximum is and can do specific lifts, thus increasing this value. Using the power profile, a coach knows exactly what the athlete can do for any given time interval. This allows for the athlete to push a very specific wattage to train an increase in the power profile as they get stronger.

The power zones that make up the power profile are extremely important in this type of training. Similarly to training with heart rate, these power zones are created based on percentages. Remember that the heart rate zones were created based on percentage of maximum heart rate or threshold. The power zones are created based on percentages of functional threshold power. This is an area of controversy regarding this type of training because functional threshold power is based on a lactate threshold theory, not a maximum effort. There are some coaches and athletes that believe that the zone values are too low and, therefore, do not maximize the efforts performed (Popowych, 2014). According to Coggan, other factors – such as training stress scores – which assign the workout with a number that indicates the level of difficulty of the workout – have been implemented to make training with power more accurate than training with heart rate (Coggan, 2008). The concept of power zones is very similar to that of heart rate zones and is considered the most accurate way to train by some people, but there is little research to verify the accuracy of this mindset. It is true, because of the cardiac drift phenomena, that an athlete has the ability to train at a more precise level with power. However, because of fatigue, sometimes an athlete is unable to train within certain power profiles.

Another important aspect to this power profile for a specific type of rider is a maximum wattage output. In the cycling world, a sprinter is the type of rider that is most likely to be interested in maximum power numbers. These are the guys that race on the velodrome or a shorter style of road racing called criteriums. Maximum power is most equal to the one repetition max. It is exactly as it sounds, the maximum power that an athlete produces at any given time usually up to five seconds. One minute and other specified lengths of timed maximum power numbers are also important to other types of riders (Power, 2013). Most athletes can get consumed with maximum power numbers. While these are important aspects of training with power, it is not the main component. The most important aspect is working in the proper zone for which you are trying to build at that moment in training.

Benefits to training with power, heart rate and perceived effort together

Each of these types of training methods is very good in its own right. Each has very specific attributes that make them unique and successful. Heart rate training has been around since the seventies. It is an accurate way to monitor intrinsic activity of the body. The heart rate zones associated with this type of training are designed to push an athlete to their full potential. The biggest downfall to this type of training is cardiac drift. Because of this phenomenon, it does not allow heart rate training to be good for pacing (Shultz, 2014). Keeping a steady pace is almost impossible due to heart rate fluctuations (Shultz, 2014).

When training with power, it is easier to maintain this steady pace effort and is more accurate when it comes to specific efforts. Power is a mechanical measure that can be very exact. This allows steady state pacing to be precise and easy to control. Training with power has allowed coaches more access to information that allows them to compare with other athletes. It has also provided another way to view performance of the athlete in and out of competition. The invention of training with power has brought out the weakness of accuracy in heart rate based training (Shultz, 2014). This weakness is due to the body's ability to maintain a steady state effort from cardiac drift. Using a power meter allows the athlete to control the effort in a more specific way. Each power meter provides a large amount of very specific data that can easily be analyzed in a number of different software packages. This allows tailored training for each athlete.

Training with all three types of methods would seem to be the most efficient way to train. There are ways to use heart rate training, power based training, and perceived effort as a whole that seem to use the best of all three methods while eliminating the weaknesses of each (Shultz, 2014). If an athlete trained most of the off-season with a focus on heart rate while watching power, then this would allow for the athlete to really focus on base and aerobic type training. As the season progresses and the focus changes to increasing anaerobic fitness, as well as maintaining or building aerobic fitness, it would be important to focus more on power while using the heart rate to make adjustments in the efforts in aerobic zones. During peak performance season, it would be appropriate to focus on power for the interval type efforts with a swing in focus to heart rate on rest specific days to ensure proper recovery of the entire body. Training with power is also a proven method of training that can be very specific in detail and, when coupled with heart rate training, can have amazing results (Shultz, 2014). Incorporating perceived effort as a means to determine overall body feeling on the day of training or competition is a good way to communicate the athlete's mindset. The coach can then make adjustments to training as needed to help the athlete overcome the stresses they have and provide a positive atmosphere while promoting positive results. As mentioned above, the ability to create a training plan based on the mechanical abilities that power provides allows coaches and athletes to control the workouts in a finely tuned way. The only real drawback is the ability to do maximum efforts without having to change the power variable. These kinds of efforts with power would require constant changing of power values and could even change based on how the athlete feels on a given day. This is a disadvantage that is eliminated with perceived effort intervals.

Cost of Equipment

As far as costs go for each mode of training, perceived effort requires no additional equipment at all; therefore, it is the cheapest of the three methods. One big advantage that training with a heart rate monitor has over power is in the price of the equipment. An athlete can purchase a heart rate monitor for less than one hundred dollars from any sporting goods store. Training with heart rate is proven to be effective and can produce an elite level athlete, therefore, for a recreational cyclist with a limited amount of money, this is a very good way to gain fitness with little financial investment (Robinson, 2011). A power meter, on the other hand, could cost up to three thousand dollars and can only be purchased through specific retailers. This makes power meters the most expensive option. For most of the recreational population it is hard to justify the cost of a power meter. This is also a major barrier of entrance for those wishing to begin a power-based training program. As technology progresses, there will be no doubt that the cost of this equipment will decline.

Aerobic Threshold and Affects on Other Sports

Aerobic threshold is an important factor in many kinds of sports. It is a measure of when an athlete goes beyond the point when free oxygen is available (Nimmerichter et al, 2015). The point at which an athlete goes anaerobic is a critical time and tool in training of an athlete for many types of events. For cycling, training above aerobic threshold is imperative in being able to handle the many jumps and accelerations that happen within a race. Finding an athlete's aerobic threshold is important in setting up a proper training program. This point in an athlete's ability to maintain a constant effort can be manipulated with proper training. The goal is to increase the amount of power and time produced at threshold. Theoretically, it is the best thing for an athlete's performance if the athlete's aerobic threshold is as close as possible to their maximum heart rate. This would mean that you can push harder for a longer amount of time, effectively increasing the amount of power generated. This is also very handy in other sports such as soccer, running, and swimming.

In the sport of soccer, training at or above aerobic threshold can help a player reach deeper into their reserves in the latter stages of a game. The ability to maintain a high level of energy near the end of a game could have positive results. It is noted that 90% of a player's energy used in one soccer game comes from the aerobic metabolism process (Sliwowski, 2013). When an athlete trains above this threshold, it increases the fatigue process of the athlete. This allows them to maintain a higher level of speed and energy during the game (Sliwowski, 2013).

Training aerobic threshold is an important part of the sport of running. Runners, as well as many athletes from other sports, will use aerobic threshold as a marker for interval training. Training above aerobic threshold will increase recovery. Using specific intervals with time mediated rest between each will increase the body's ability to recover (Tocco, Sanna, Mulliri, Magnani, Todde, et al, 2015). The idea is to be able to recover as fast as possible. This will contribute to an increase in an athlete's ability to maintain a higher effort when passing a competitor during a running event.

Swimmers have a common placed practice among the elite athletes to use low volume-high intensity training to supplement workouts. This concept is widely popular and is growing among master's age swimmers as well (Pugliese, 2015). Any given event in swimming is no longer than 8 minutes. This classifies almost all swimming events in competition as an intense work load. Swimmers will use aerobic threshold to determine high intensity workouts that can easily be modified to accommodate these intense workout sessions. This low volume- high intensity training can be a great way for athletes to maximize their time in the pool without spending many hours per day training.

Periodization of Cycling

All athletes have to have periodization built into their training programs. This is due to off-season, pre-season, and in-season timing within a given year. These are generally the three periods during the year for elite cyclist. Each of these can be broken down into other sub categories. The off-season can consist of general preparation. Most elite level cyclist have an off- season to rest and re-coup from the previous year's training and racing. This time of year is spent either doing other sports for fun or catching up with family and friends. Some elite cyclist's will spend time working on parts of their training that were overlooked during the season such as core strengthening and base mile phases. These two phases of the off- season are critical in implementing corrective movement strategies and building endurance on the bike to have a solid foundation of training for the forthcoming season (AceFitness, 2010).

The second period is pre- season which can be broken down into three different phases to work within. The first phase of pre- season is the endurance load specific preparation phase (AceFitness, 2010). This is where the foundation base mileage built in phase two of period one is expounded and higher intensity endurance is added to the training program. This phase acts as the corner stone of the year in competition, as the ability to perform efforts here will make it easier to perfect those efforts later in the season.

The second phase of the pre- season is the strength load specific preparation phase. This is when weightlifting becomes most important (AceFitness, 2010). Repetitions are increased as well as weight and speed. The strength phase is added on top of the endurance work already being done, forcing the body of the athlete to adapt to new workloads. These adaptations will provide another layer of groundwork for efforts in the future.

The last phase of the pre- season is the pre-competition phase. This phase is all about performance power. In this phase, the athlete will fine tune and make final adjustments to very specific intervals within their respective workouts (AceFitness, 2010). The idea of this phase is to be ready for competition. The amount of high-intensity workouts increase and endurance/base miles will begin to be phased out.

The final period of the year for the athlete is the competition phase. In this period, the athlete will do maintenance intervals to be ready for competition. The workload of the athlete will be drastically decreased so they can be fully recovered for each event. Things that become very important during this time are nutrition and hydration. It is very easy for an athlete to be racing so much that they are not getting enough energy. This time period is just about maintaining and fine tuning all of the gains that the athlete made during the off and pre-seasons.

Building of training programs for elite cyclists

Block periodized training is an important part of an elite training program. It is noted that endurance athletes need to have a mixture of low intensity training as well as high intensity training built into their respective training programs (Ronnestad, 2012). Training periods of one to four or five weeks is a common practice among cyclists. Knowing how to build this type of training program is imperative to the success of a training program. Usually it begins with the athlete's main race goals for the upcoming season. Once these goals have been determined and mapped, the coach will then back up every four or five weeks, depending upon the training level of the athlete, all the way to the current date on the calendar. At every 4^{th} or 5^{th} week, there will be a full week of active rest and recovery for the athlete to have to get ready for the next round of training. This rest week is fundamentally important and is a main area that most athletes will overlook. Training too hard during this time could affect how hard the athlete can push in the coming weeks of training.

Once the coach has effectively laid out the timeline for the training blocks, he or she can start to build specific daily workouts. The time of year is very important to note while building this workout as off season training will be slightly different from in-season training. After these considerations are made, a building approach should be made during each week of the cycle. This phase of building the program could start out with a mix of more low- intensity training with a small amount of high- intensity for the first week. The following weeks will progressively build into less low- intensity and more high- intensity as each week comes. The final week would in theory be the hardest week of the block with the least amount of low-intensity work and the most amounts of high intensity intervals. It is important to note that the rest weeks will line up with the athlete's main target races for the year to where they fall at two weeks before the target event for proper tapering.

Generally speaking an athlete should be broken down by the end of the training cycle and would feel the need for the rest week. The first week back to intense training, the athlete should feel really heavy, and it should be difficult to perform the intervals. By the second week of the training cycle, the athlete should feel adapted to the efforts and be able to push through the intensities.

Psychology of Elite Training

It is interesting to consider the mindset of an elite athlete. Most successful elite athletes are very self-motivated and driven to train and compete. Developing a sport emotional reaction profile for these athletes can help determine athletic performance. A description of the SERP questionnaire is as follows:

The Sports Emotional Reaction Profile contains 42 statements, and measures the following seven traits: desire; assertiveness; sensitivity; tension control; confidence; personal accountability; and self-discipline. Each trait is scored ranging from 5 to 30. The statements are answered in the following format 'almost always,' 'sometimes,' 'seldom,' 'never.'

A. Desire: To strive for the outcome in realistic goals. A low score in desire is representative that the individual is disinterested in the outcome. A score that is too high is an indication of being overly outcome goal oriented.

B. Assertiveness: The level of self-determination an athlete has to succeed. A low assertiveness score likely indicates the athlete is intimidated by other players, and high levels in assertiveness translate into aggression in competition.

C. Sensitivity: The interpretational emotion of success and unsuccessful performances. A low sensitivity score is representative of resiliency, and a high score is characterized by outside emotional influence which could have a negative effect on athletic performances.

D. Tension Control: The ability to handle stressful situations. A low tension control score is relatable to lowered performance, while high tension control is an asset to performances.

E. Confidence: The athlete's belief in their ability. A low confidence score is indicative of low self-esteem and lack of ability. A score too high is associated with insecurities and affects performance by the athlete feeling the need to prove their worth.

F. Personal Accountability: To have humility during unsuccessful moments. Low accountability is generally associated with blaming others. Those with high personal accountability blame themselves for their lack of success.

G. Self-Discipline: The ability to endure hardships and commit to a goal. A low self-discipline score is often associated with indecisiveness, while high self-discipline athletes are very persistent (Tutko & Tosi, 1976).

With this questionnaire, a coach or sport psychologist could determine the performance ability potential of an athlete. This tool could also play a role in determining leadership and other roles within a team. Knowing how a person thinks about given situations during training and competition can have an impact on success within their given sport.

Using the SERP to determine an athlete's mindset during different training modes is important for the success of the training program. All athletes handle training in different ways. If there is an athlete that does not respond well to the mode of training that uses power, then a coach might want to use heart rate or perceived effort. Knowing that an athlete has a specific psychological profile will determine how best to train them and utilize them in their respective sport (Tutko & Tosi, 1976).

Talent identification

In addition to using the Sports Emotional Reaction Profile, there are many tools available to coaches when it comes to finding talent for their sports. Performance evaluations such as Vo2 max and threshold power testing are just a couple that are used for the sport of cycling. In professional football, the National Football League uses the 40yard dash, bench press, vertical jump, broad jump, 3 cone drill and shuttle run for their scouting of athletes in the NFL Combine (nfl.com, 2015). In the sport of cycling, it is a common thought that, if a coach were to take an NFL linebacker and do maximum power testing and Vo2 testing, it could grow the Olympic sprint team on the track. The reason for the thought is that the NFL linebacker has the same body type as an Olympic track sprinter: big and powerful. This mindset in itself is a talent identification tool. If an athlete shows a particular build of body without training for a specific sport, then there is a strong possibility that they could be good in a sport that uses that build. In Korea, anthropometric measures of height, weight, chest circumference, leg and arm circumference as well as strength measurements were taken in high school students to determine athletic ability (Ko, 2014). This was the foundation of what is known today in Korea as the KISS foundation. (Korean Institute of Sport Science)

Coaches, physical education teachers, and sport scientists can all play an important role in talent identification (Buekers, 2013). Physical education teachers are usually one of the first to interact with young students as well as coaches in little league play. Talent identification in this group is classified into two areas: intrinsic and extrinsic (Buekers, 2013). Intrinsic factors in this model include; physical techniques, technical ability, and psychological aspects (Buekers, 2013). Whereas extrinsic factors would include; training level and genetic disposition from parents (Buekers, 2013).

More talent identification in the United States and the world could be advantageous to the future of sport programs across the globe. In programs in the United States that are currently considered weak right now, such as the men's track cycling program, there could be a significant benefit to holding talent identification camps and testing protocols. This is something that could be researched more thoroughly and potentially proven to have great benefits to different programs across the United States.

Chapter Three

Methods and Procedures

Introduction

The purpose of this study is to compare results from heart rate based training, power based training, and perceived effort training in elite level cyclists. The idea was to see if there was a significant difference between the methods of training and find out if any were more superior to the others for training purposes.

Sample Population

The athletes that were used for this study were comprised of professional and category 1, 2, and 3 level cyclists from the Lindenwood University Cycling Team and surrounding area professional and elite amateur teams. The Lindenwood University Cycling Head Coach agreed to allow her category A riders to participate in the study and all athletes agreed to participate.

Exclusions

The exclusion criteria for this study included those with high risk of cardiac, pulmonary, and musculoskeletal problems. All athletes not considered at an elite level of cycling determined by the category system in place for USACycling. Time on any cycling team was not an excluding factor. In addition: A personal information sheet and Medical history inventory was given to all potential participants to screen for any medical conditions. Any athlete who reported being treated or previously diagnosed with asthma, sickle cell, anemia, pulmonary, cardiac or uncontrolled metabolic and orthopedic problems was also excluded.

Instruments

The instruments used for the testing procedures were the Computrainer Systems computer simulators. Pedal Hard Training facility provided the Computrainer equipment used for this study. These devices allow the rider to use their own bicycles in the trainer and shows real time power, speed, heart rate, and course information. These were used to maintain the training procedures for the power based training group. Polar heart rate monitors that display basic heart rate information were used for the heart rate based training group.

Methods

The riders underwent a rigorous 8 week training program. There were 3 groups of 7 riders each. One group for power only data, one group for heart rate only data, and one group with perceived effort that used of no monitors. Each group was given specific training intervals that pushed them in their respective based training procedures. There was maximum power testing and roughly 20 minute power threshold testing. The power testing required the participant to exert a maximum effort that lasted about 30 second each. They did this power test 3 times. They were asked to pedal as hard and as fast as they could for the duration of the test. Maximum power was graphed out and determined during this test. The 20 minute power threshold test required each participant to start at a base line power point that was approx 40-60% of max heart rate. Every 3 minute the effort of the rider was increased by 50 watts for the first increase and 25 watts for each increase after that. The actual time of the test was determined by the strength and fitness of the participant. The estimate of 20 minute was very close; some went a little longer, while others went a little shorter. Each interval was monitored to ensure proper duration and efforts were performed. Each training session was one to two hours in length and accommodated proper rest, build procedures. Each pre- and post-test was performed exactly the same with 3 days active rest just before the test to ensure the athlete was able to excel to the best of their ability. No exclusions were made for nutrition, so the participant was free to drink and eat as they felt necessary for the duration of the training and testing. SERP questionnaires were issued before each testing session. The exact testing protocols that were used and sent to Pedal Hard Training Facility were as follows:

Protocol for Threshold and Maximum Power testing in Lindenwood Elite Cyclist Study

Threshold Test

- Each rider after calibration will have a 10 min warm up period.
- The workload will be at approximately 150 watts on the Computrainer for the first 3 min of the test.
- The workload will increase to 200 watts after the first 3 minutes and will continue for the next 3 min.
- The workload will increase 25 watts every 3 minutes after until maximum exertion is reached by the participant.
- Proper cool down will then be performed before the next bout of tests.

Maximum Power Test

- After proper cool down and recovery (Approx 10-15 min) The participant will perform a series of maximum sprint efforts. This test will be on a 3 mile course starting with a -4% downhill for .4 mile. The course will then increase to a +3% grade uphill for .1 mile. The power effort will be performed on the .1 +3% grade uphill in the form of a maximum sprint. At the .5 mile mark the course will repeat to a -4% grade downhill until the .9 mile mark, then the +3% grade will repeat for the second sprint. This repeats for 3 miles with 6 total sprints. The first 3 sprints are used only as practice for the participant to get used to the feel of the trainer and transition. These first 3 sprints are not maximum effort and are used only as practice. The last 3 sprints are used as the measure points. The highest power of the three sprints is taken for data collection.

The training plans for each group that were sent to each participant in their respective group of the study were as follows:

Heart Rate Training Group

This group will be doing training based on Heart Rate to the best of their ability. No power or perceived effort data will be collected and all efforts should be done by heart rate monitor only if possible. All intervals or training percentages are to be done at the percentage of Maximum Heart Rate (MHR). Training will be done AT LEAST 5 days per week with one hour per day MINIMUM. Below is a basic guideline to follow. This can be altered to fit work/school schedules as well.

Monday- Rest day easy spin 45min to 1hour approx, 60-70% of MHR

Tuesday- Warm up well, interval tree of 3,2,1,2,3 with 2min between each effort. Each interval is to be done at 90-100% of MHR. Cool down well for at least 1 hr total on the bike.

Wednesday- 1 hour minimum ride at 70-75% of MHR (near Tempo pace)

Thursday- Warm up well, do 2 – 5min intervals at 85% MHR with 10min recovery between each. Cool down well for at least 1 hour total on the bike.

Friday- Rest day easy spin 45min to 1 hour approx, 60-70% of MHR.

Saturday- 1+ hours 70-85% of MHR. Mix it up. Do a group ride or just ride with a mix of pace for at least 1 hour, can be more, or Race.

Sunday- 1+ hours 70-85% of MHR. Mix it up. Do a group ride or just ride with a mix of pace for at least 1 hour, can be more, or Race.

Power Training Group

This group will be doing training based on power to the best of their ability. No heart rate monitor or perceived effort data will be collected and all efforts should be done by power only if possible. All intervals or training percentages are to be done at the percentage of Functional Threshold Power (FTP). Training will be done AT LEAST 5 days per week with one hour per day MINIMUM. Below is a basic guideline to follow. This can be altered to fit work/school schedules as well.

Monday- Rest day easy spin 45min to 1hour approx, 60-70% of FTP

Tuesday- Warm up well, interval tree of 3,2,1,2,3 with 2min between each effort. Each interval is to be done at 110-115% of FTP. Cool down well for at least 1 hr total on the bike.

Wednesday- 1 hour minimum ride at 70-75% of FTP (near Tempo pace)

Thursday- Warm up well, do 2 – 5min intervals at FTP effort with 10min recovery between each. Cool down well for at least 1 hour total on the bike.

Friday- Rest day easy spin 45min to 1 hour approx, 60-70% of FTP

Saturday- 1+ hours 70-85% of FTP. Mix it up. Do a group ride or just ride with a mix of pace for at least 1 hour, can be more, or Race.

Sunday- 1+ hours 70-85% of FTP. Mix it up. Do a group ride or just ride with a mix of pace for at least 1 hour, can be more, or Race.

Perceived Effort Training Group

This group will be doing training based on perceived effort to the best of their ability. No heart rate monitor or power data will be collected and all efforts should be done by effort only if possible. Training will be done AT LEAST 5 days per week with one hour per day MINIMUM. Below is a basic guideline to follow. This can be altered to fit work/school schedules as well.

Monday- Rest day easy spin 45min to 1hour approx, 60-70% effort

Tuesday- Warm up well, interval tree of 3,2,1,2,3 with 2min between each effort. Each interval is to be done at maximum effort. Cool down well for at least 1 hr total on the bike.

Wednesday- 1 hour minimum ride at 75% (Tempo) pace.

Thursday- Warm up well, do 2 – 5min intervals at 85% effort with 10min recovery between each. Cool down well for at least 1 hour total on the bike.

Friday- Rest day easy spin 45min to 1 hour approx, 60-70% effort.

Saturday- 1+ hours 70-85% effort. Mix it up. Do a group ride or just ride with a mix of pace for at least 1 hour, can be more, or Race.

Sunday- 1+ hours 70-85% effort. Mix it up. Do a group ride or just ride with a mix of pace for at least 1 hour, can be more, or Race.

Statistical Analysis

SPSS 23.0 (Statistical Package for the Social Sciences) was used to analyze the data that was collected. All data was collected and stored in an EXCEL format and then imported into SPSS for analysis. Frequency analysis was used for the purpose of data cleaning. Only one set of pre-test data (participant in power-only group) completed the pre-testing but failed to complete posttest. This individual's data was excluded from the study. After data cleaning, the participants were dummy-coded into comparison groups. Each group was analyzed using a paired samples t-test to assess whether there were significant changes from pre-test to post test. The level of significance for the study was set at $p< .05$. Simple correlational analysis was also used to assess the congruence and consistency of pre-test versus post test data for each of the three experimental groups. After conducting the analysis we used EXCEL to graphically show the relationship between dependent and independent variables for each participant in each group (see Chart 1, 2, and 3).

Conclusion

Technology has allowed some amazing advancements in the way an athlete can train. In cycling alone, the ability to have a device that can measure an athlete's power output per individual leg is remarkable. The ease of access due to the technological advancements makes either one, or all three of these training methods great. An athlete has the means to track this data with relatively low weight gain in components to a bicycle. Most onboard computer systems are smaller than the average smart phone and are easily connected to home computers. This makes data transfer very easy. There are now wireless systems that the athlete can use that do not require any manual hookups. These advancements, as well as the way these types of data can be collected, make it easier than ever for coaches to train elite athletes.

The debate over which method of training is best will continue, but there will be a shift that will prove more and more that all three methods, used in conjunction with one another, are the best overall for training. Heat rate based training will undoubtedly never overcome the Cardiac Drift phenomenon. While it is a great way to track whole body issues, especially intrinsic such as sickness and fatigue, it is weak in its ability to train specific things like steady state pacing. Power based training is ideal for specific workouts. When an athlete wants to dial in an area of their performance, a power meter has that ability. It offers a chance to perfect an athlete's ability with fine detail. The weakness of a power meter's ability to read what is happening inside the body will be extremely hard to overcome alone. This is why the use of heart rate, perceived effort, and power is the most beneficial way for an athlete to train.

Chapter Four

Results

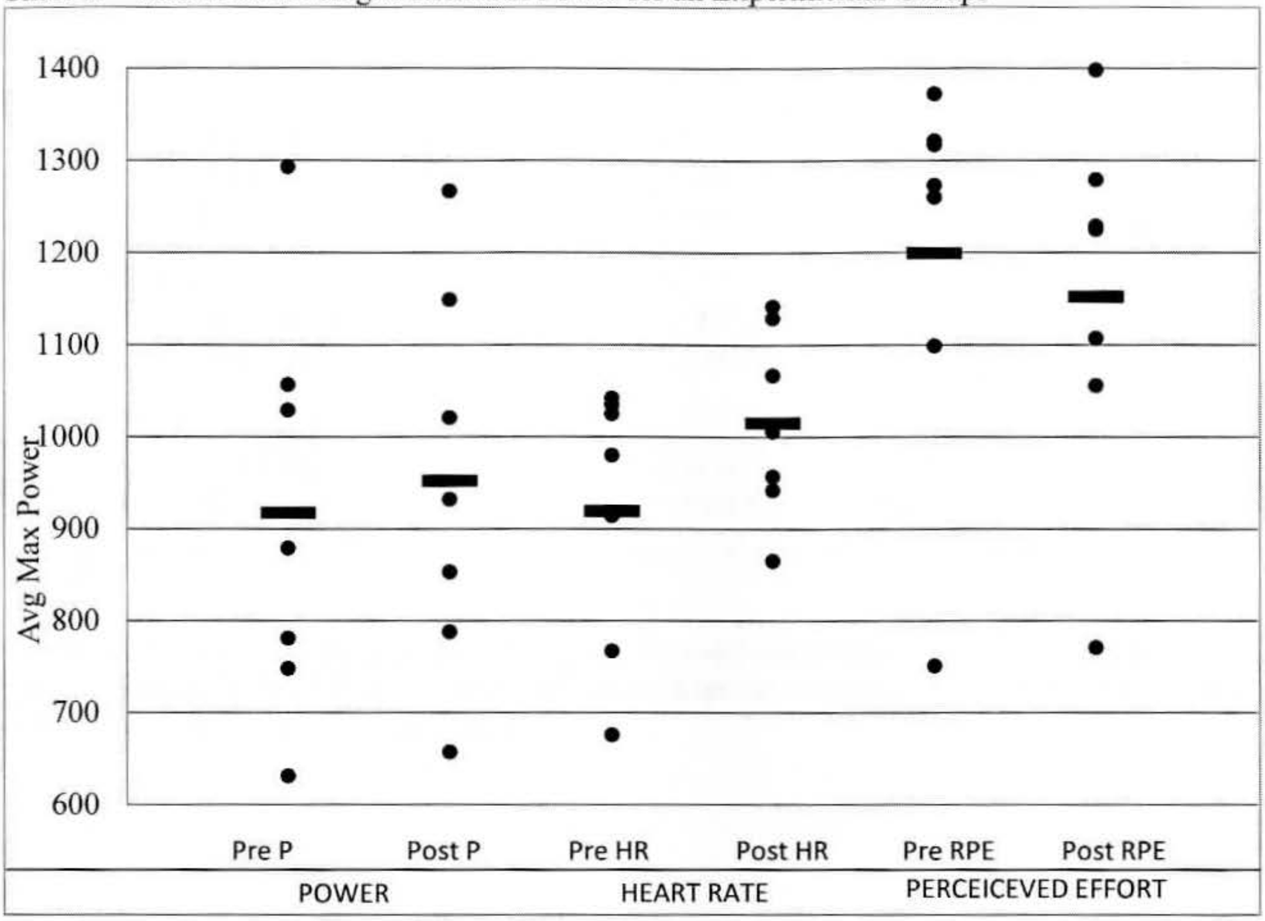
Table1: Paired Sample T-Test Results for Power Testing for all Experimental Groups

Variable	N	Mean	Std. Dev.
Power Only Group			
Pre-Test	7	919.48	226.37
Post Test	7	952.81	210.92
Heart-Rate Only Group			
Pre-Test	7	919.81	144.76
Post Test	7	1015.71	102.56*
RPE Only Group			
Pre-Test	7	1199.57	215.44
Post Test	7	1152.24	201.62

*p< .05

The only group that showed a statistically significant jump from pre-test to post test on the maximum power test was the heart rate group ($\underline{t} = -2.643$, $\underline{df} = 6$, $\underline{p} = .038$). The power only group did experience a positive increase of 33 watts from pre-test to post test ($\underline{t} = -1.761$, $\underline{df} = 6$, $\underline{p} = .129$). However, the RPE group experienced a decrease of an average of 47 watts.

Chart 1: Individual Average Maximum Power for all Experimental Groups



The average maximum power for all 3 groups illustrates the positive movement in both the heart rate group and the power group. There is a significant positive gain in the heart rate group that was discussed in table 1.1 ($\underline{t} = -2.643$, $\underline{df} = 6$, $\underline{p} = .038$). This also shows the positive movement in the power group though it is not statistically significant. The power only group did experience a positive increase of 33 watts from pre-test to post test ($\underline{t} = -1.761$, $\underline{df} = 6$, $\underline{p} = .129$). However, the RPE group experienced a decrease of an average of 47 watts.

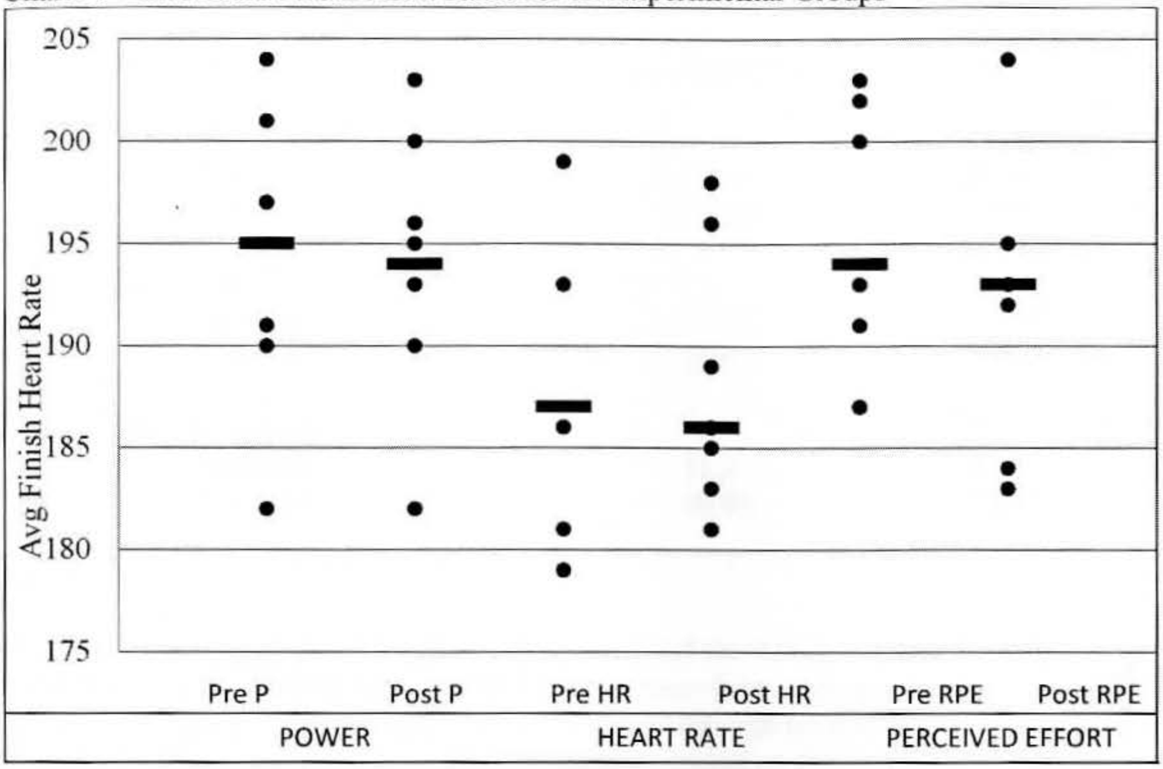
Table 2: Paired Sample T-Test Results for Finish Heart Rates for all Experimental Groups

Variable	N	Mean	Std. Dev.
Power Only Group			
Pre-Test	7	194.57	7.46
Post Test	7	194.14	6.87
Heart-Rate Only Group			
Pre-Test	7	187.14	6.86
Post Test	7	186.42	8.14
RPE Only Group			
Pre-Test	7	194.71	6.89
Post Test	7	193.57	8.42

*$p < .05$

Slight decreases are shown in all groups, though no statistically significant differences are proven. Essentially, the finishing heart rate across all groups were the same from pre-test to post-test regardless of training protocol used.

Chart 2: Individual Finish Heart Rates for all Experimental Groups



There is no significant difference in the finish heart rates within any of the subject groups. All groups experienced a less than 1.5bpm decrease which is statistically insignificant.

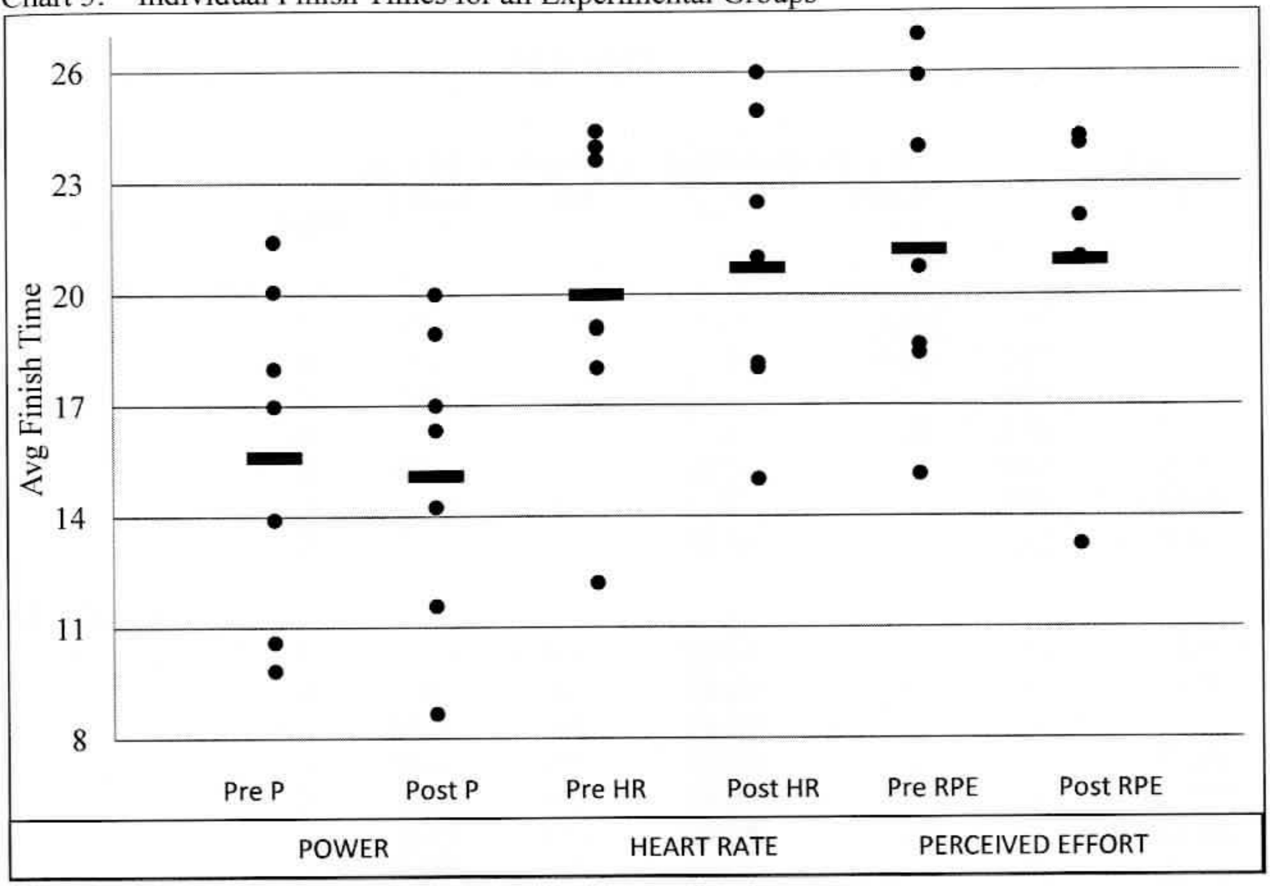
Table 3: Paired Sample T-Test Results for Finish Times for all Experimental Groups

Variable	N	Mean (min)	Std. Dev.
Power Only Group			
Pre-Test	7	15.61	4.60
Post Test	7	15.09	4.09
Heart-Rate Only Group			
Pre-Test	7	19.98	4.35*
Post Test	7	20.69	3.93
RPE Only Group			
Pre-Test	7	21.21	4.41
Post Test	7	20.91	3.69

*p< .05

Both the Power group (t = .893, df = 6, p = .406). and the RPE group (t = .216, df = 6, p = .836). show a decrease in finish time. The Heart Rate group shows a longer finish time comparing pre-test with the post test (t = -.644, df = 6, p = .543). Although none of the three protocols showed a statistically significant difference from pre-test to posttest on finish time, the heart rate group did increase their finish time by almost one minute. This might show a potential effect of training with a heart rate monitor.

Chart 3: Individual Finish Times for all Experimental Groups



As illustrated in both table 3 and chart 3, there was little difference in the pre-test and post test scores for finish time.

Table 4: Raw Participant Data for Experimental Groups Based on Training Protocol

		PRE TEST			POST TEST		
Variable	Subject	Avg Max Power	Avg Max HR	Avg Finish Time	Avg Max Power	Avg Max HR	Avg Finish Time
Power Only Group							
	1	1293	197	20:05	1267	196	20:01
	2	781	201	16:59	853	200	16:20
	3	748	191	13:55	788	195	14:15
	4	631	197	9:50	658	193	11:35
	5	879	204	18:00	933	203	17:00
	6	1046	190	21:25	1149	190	18:57
	7	1057	182	10:36	1022	182	8:40
Heart Rate Group							
	1	1035	186	23:38	1129	189	18:08
	2	676	181	18:00	865	181	18:00
	3	980	186	24:00	942	186	26:00
	4	914	186	12:12	957	183	15:00
	5	767	199	19:07	1006	198	21:00
	6	1025	179	24:25	1142	185	24:58
	7	1042	193	19:04	1067	196	22:30
RPE Group							
	1	1273	187	18:39	1398	193	21:00
	2	1372	187	20:45	1229	183	21:00
	3	1321	191	24:04	1279	184	22:06
	4	752	200	15:08	771	192	13:14
	5	1261	203	27:00	1225	195	24:03
	6	1317	202	25:54	1056	204	21:00
	7	1100	193	18:25	1107	204	24:15

Table 4 shows raw individual average data for each group broken down into pre and post test as well as Power, Heart Rate, and Finish Times.

Table 5: Paired Sample T-Test for Sports Emotional Reaction Profile for all Groups

Variable	N	Mean (min)	Std. Dev.
Power Only Group			
Pre-Test	7	122.42	8.70
Post Test	7	121.96	7.73
Heart-Rate Only Group			
Pre-Test	5	125.60	5.13
Post Test	5	125.80	8.58
RPE Only Group			
Pre-Test	7	127.43	4.79
Post Test	7	126.57	5.00

*p< .05

The average scores for each participant on the Sports Emotional Reaction Profile suggest that athletes are emotionally stable within the contexts of their athletic discipline. This is not too surprising based upon the fact that participants self-selecting themselves to the study were all elite USA Cycling Category 1 or 2 competitors. Based upon the paired sample t-tests, none of the three groups showed a statistically significant difference on SERP score from pre-test to post test (Power Group -- $t = .231$, $df = 6$, $p = .825$; Heart Rate Group -- $t = -.064$, $df = 4$, $p = .952$; RPE Group -- $t = .427$, $df = 6$, $p = .684$). An ANOVA analysis was also run for change score between the three groups. The non-significant ANOVA did not warrant any post hoc analysis ($F = .043$, $df = 18$, $p = .958$).

Summary

Following the analyses, there were found to be few statistically significant findings for the different groups (Power, Heart Rate, and RPE). A significant difference was found in the Heart Rate group with an increase in maximum power. There was a close, significant difference for the Heart Rate group for finish time. The Power group showed an increase for maximum power and it is speculated that with a larger sample size that we would see a significant difference in this area. The SERP questionnaire did not show any significant difference within the athletes and their chosen method of training. Chapter Five will further investigate the results of the analyses and discuss the rationales. The chapter will also discuss the purpose of this study on finding the benefits of the different training modes on performance in elite cyclists and propose future implications of these findings.

Chapter Five

Discussion

This study looked at the effects of a short (8-week) training program consisting of three different training modes. The study had 22 total participants (with 1 athlete failing to complete the study) and was broken into three groups, of seven, with three different training specific modes of exercise. These groups were Power, Heart Rate, and Perceived Effort. The athletes were recruited from the Lindenwood University Cycling Team and from the Greater St. Louis cycling community. Athletes were tested pre and post training at Pedal Hard Training facility located inside the Big Shark Bicycle Company bike shop. This chapter will discuss the significant findings and will interpret the results found within the study. The study's limitations will be presented again as well as suggestions for future research and associated practical implications.

Results and Rationales

The following research null hypotheses were tested within this study:

1. There will be no difference in performance outcome variables of heart rate, maximal power output, and total finish time for elite cyclists using power meters as their primary training protocol.

2. There will be no difference in performance outcome variables of heart rate, maximal power output, and total finish time for elite cyclists using heart rate monitors as their primary training protocol.

3. There will be no difference in performance outcome variables of heart rate, maximal power output, and total finish time for elite cyclists using perceived effort as their primary training protocol.

In addition, the following research hypothesis was tested within this study:

Choice of training mode for elite-level cyclists differ based upon individual psychological profile.

In order to test these hypotheses, the athletes were tested before training began and then again after an eight-week program. The testing protocol was exactly the same for each athlete for both pre and post testing. An approximate 20minute threshold testing was performed and then each athlete did three maximum power tests after a 15minute recovery period. After the eight-week training program a significant difference of $p=.038$ was found for the Heart Rate group with an overall average increase of 96 watts in maximum power. There was also a positive difference in overall finish time of approximately 45seconds in the Heart Rate group. The perceived effort group saw an overall average decrease in every test category. This could be due to the short duration of the study protocol. It is proposed that a significant result for the Power group would be seen if the study populations were larger. It is interesting that a significant result was found within the Heart Rate group within such a short study time frame. Normally 8 weeks is not long enough to see this kind of result when working with elite athletes. The increase seen in the finish time of this group also shows that there is something happening that is having a positive effect with the athletes in this group based upon the training protocols. The Power group also shows the same trend lines, but the sample size is too small to make the same strength in the results. The improvements in these two groups (Power and Heart Rate) show that over a short time frame, they may have a greater impact on training performance than

Perceived Effort. The results of the Sports Emotional Reaction Profile did not show any differences between the groups nor the choice of training modes.

Limitations of the Study

There were several limitations to this study. There was no way to know for sure that each participant was doing the training program set up for each group. There were measures in place to help control concordance with their assigned protocol, but each athlete was on their own to do the training. The testing protocols were the same for each athlete, each time they were tested. However, the equipment used made it difficult for the athletes to maintain the specified wattages during the test. The athletes were required to maintain a given wattage for every level of the test, progressively increasing at specified intervals. It was very easy for an athlete to not do the required power output and thus affect the length of their test. There were also problems with the heart rate function of the Computrainer system. Several athletes that were tested in the first round of the study only had manual heart rates taken every 3 min. The computer did not read or save the data needed to have every 1 min of data. Most of the second round was fine and the problems were fixed.

Scheduling was also a limitation to the study. Athletes were given only approximately 3 days notification prior to the first round of testing due to scheduling conflicts at Pedal Hard Training Facility. The second round of testing did not have this problem as schedules were in place many weeks in advance. Another significant limitation to the study was the amount of participation to the study. Due to the time of the year, (off season) most of the eligible athletes were not able to participate in the study. One person could not complete the study due to not following the training protocol at all during the study. Overall, it was difficult to control certain aspects of the participants' programs and lifestyles to add strength to the results.

Recommendations and Implications of the Future

Training in the world of cycling has changed a lot in the last twenty years. Heart rate monitors have come a long way since they were first implemented commercially in the early 1980's (Bell, 2013). Power meters started out as big clunky machines that an athlete had to go to a lab to use. Now they are small, lightweight devices found on numerous bikes in the pelotons of today. The way coaches use these devices, along with perceived effort, differ between personal coaching preferences. The new way of thinking about training is fostered by the ability to collect and analyze data on a single ride basis. New power meters and heart rate monitors allow this to happen. The ability to be very specific with training intensity with the use of power is very positive. However, the use of heart rate is the ability to measure the adaptation of the body to the type of training. The ability to push 400 watts for some simply cannot be done by others. The ability to hold 180bpm can be done by most people, thus allowing the body to respond to different types of training. The use of all of the methods within this study together is most important for proper training at an elite level. One not only needs to be strong enough to hold 400 watts for a given effort, but also needs to have knowledge of how their body is responding to the workload with heart rate. Perceived effort is also good to have a complete knowledge of during racing and group rides to know when the athlete is within or past their limits.

While the data from a power meter is definitely useful, and it is possible that with a larger sample population there could be more significant gains from a power-based training mode than was shown with the smaller sample size of this study, it certainly appears that power-based training is a less effective training mode than heart rate based or perceived effort training. Trainers, coaches, and athletes wishing to increase maximal power outputs can use the data in this study to prescribe more heart-rate based training and less perceived effort and power based efforts.

When constructing a training plan for an elite cyclist who wishes to increase maximum power and lower heart rate at a given, sustained power output, it would be best to avoid perceived effort training altogether. This training mode actually appears to decrease an elite cyclist's ability to maintain a high wattage for both short and extended periods of time.

Based on this data, it would be recommended that a power meter be used as a tool primarily to measure progress rather than to increase fitness, much like VO2 or Wingate testing is used more as a gauge than as a training mode. Wingate and VO2 tests are both useful data collection tools, but these tests are not used as a means to an end in daily training programs for elite cyclists. This arena of testing may be where power meters fit in the picture. Just as athletes do not undergo VO2 testing several days each week to increase their VO2 output, performing at specified wattages several days each week is not the best formula for an increase in power output. Even with the cardiac drift factor, heart rate is still the best tool for this. When armed with this information, athletes can feel more confident in applying their financial investment into less equipment and more into the hiring of a reputable trainer or coach.

It could be worthwhile to explore combining heart rate based training and power based training into a single training regimen. With the significant findings in the heart rate group and promising results in the power group, it is plausible that the optimal training program for an elite cyclist has both heart rate and power based training modes included within the same regimen. This study is the first of hopefully many studies. Future studies that would benefit the cycling community would include using the original three groups, plus a fourth and fifth control group:

one that combines heart rate and power modes into a single regimen and another that combines all three methods into a single regimen.

Other changes that could be made would be to have another study that would allow periodization to be analyzed that would consists of a complete year-long study of athletes in the same periods of training at the same time of the year. This would allow each training mode to be analyzed in each training cycle.

Although this research project did not reveal a large number of significant findings, it provided a preliminary exploratory study complementing existing research on this topic. Additionally, athletes might not follow the experimental protocols closely during this 8-week study. This study looked at the differences between three modes of training over a short period of time. The industry is full of new expensive devices that make it easy to collect data. The implications of this type of study could dictate the need for amateur athletes to spend the money to purchase these devices unnecessarily. Training hard versus training smart is where a study like this can be effective. This study showed that in an 8-week time frame, that heart rate training had a greater effect on the athlete's ability to make gains in performance over training with power and perceived effort. There is a need for more studies of this kind to help coaches and athletes be informed about proper use of the different training modes available.

Conclusion

In conclusion, this study provides a valuable look into the comparisons of different training modes with the sport of cycling. There are studies that show why each mode of training is beneficial, but there are not many studies that compare directly the different modes themselves. This study did not show many statistical significant differences in the results. The few significant differences that were present show that there is possibly a benefit, at least in the short term, to heart rate training over the other modes it was tested against. Power also shows promise in this regard, too, as more research is needed. For many reasons listed within this study, this type of research is important for the maximization of an athlete's individual training program. The ability for elite athletes to reach higher potentials and also for general amateur athletes to be able to make informed decisions is important.

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