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Effect of Independent Crank Cycling Training On Running Economy In Collegiate Distance Runners

Aaron W. Smith
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EFFECT OF INDEPENDENT CRANK CYCLING TRAINING ON RUNNING ECONOMY IN COLLEGIATE DISTANCE RUNNERS

by

Aaron W. Smith

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE in

Health and Human Movement

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UTAH STATE UNIVERSITY
Logan, Utah
2012
ABSTRACT

Effect of Independent Crank Cycling Training on Running Economy in Collegiate Distance Runners

by

Aaron W. Smith, Master of Science
Utah State University, 2012

Major Professor: Dr. Edward M. Heath
Department: Health, Physical Education and Recreation

The purpose of this study was to examine the changes in running economy of collegiate cross-country runners with 6 weeks of training on the PowerCrankSTM independent bicycle crank. Thirteen collegiate cross-country runners completed the study. Participants were asked to perform 6 weeks of training with either the PowerCrankSTM device or the standard cranks (control group). Participants trained 3 days per week with a 48-hour minimum rest time between training sessions. Pre- and post-running economy and VO₂ max test data were collected. Data were analyzed with SPSS version 19 using a paired-samples t test as well as an independent t test. The paired samples t-test results for the participants pre-training running economy in the PowerCrankSTM group were 2.98 ± 0.60 L/min to 3.08 ± 0.59 L/min post training; p = 0.057, t = -2.464. The control group for the PowerCrankSTM results were 2.68 ± 0.51 L/min pre-training, with post training results of 2.69 ± 0.57 L/min, p = 0.815, t = -0.245. Results for pre-training VO₂ max were 4.10 ± 0.72 L/min to 4.17 ± 0.75 L/min.
post training; $p = 0.230, t = -1.366$ with the PowerCranks™ group. The control group for VO$_2$ max results were $3.83 \pm 1.10$ L/min pre-training with post-training resulting as $3.92 \pm 1.09$ L/min, $p = .245, t = -1.287$. The results of the independent $t$ test also showed that there was no significant change in values for running economy ($t = -.112, p = .913$) or VO$_2$ max ($t = 1.569, p = .145$) when PowerCranks™ and control groups were compared. It was concluded that within the limitations of this study, experienced collegiate runners who performed 6 weeks of cross training with the PowerCranks™ independent cycle crank displayed no significant difference in running economy or VO$_2$ max results post training.

(62 pages)
PUBLIC ABSTRACT

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In the competitive sport world, the goal to become number one is what all athletes desire and train to obtain. Athletes and coaches are constantly looking for the new techniques to put their athlete atop of the podium. With that in mind, what is the new training technique that will accomplish that goal of success? Distance runners are always looking for the new training techniques that will accomplish that goal. Cross training, using one type of exercise to enhance another unrelated, is one way that athletes are constantly exploring to see if this can be successful.

Cycling is just one of those cross training techniques that needs to be explored more to see if desired results may be obtained. Along with that, by adding a new factor, independent crank cycle training may just be the one routine that may make an athlete more economical while he or she runs. Previous studies with independent cycle cranks have been performed to see the benefit of altering cycle training to see if greater results may be achieved. However, by adding this training technique to
distance runners, in comparison to standard cycle training, increased results may be achieved and discovered.

The purpose of this study was to investigate the effects of independent crank cycling training on collegiate distance runners and see if an increase of running economy may be achieved. By increasing a runner’s economy a runner may be able to increase his or her performance due to the decrease in energy that would be required come race time. Thirteen collegiate cross country distance runners participated in the study. Each participant was randomly selected to train in either the independent crank group or the standard crank control group. All 13 participants performed a standard VO₂ max test and running economy test to obtain a baseline for the study. Each participant then trained on either the independent or standard crank 3 times a week for 6 weeks. The participants were then retested post training to see if any change in economy resulted. The results showed no significant change post training or when compared to the standard crank group.
ACKNOWLEDGMENTS

I would like to thank those individuals who have been very helpful in the completion of this thesis and all of my academic goals. Deep-hearted thanks to Dr. Ed Heath for the time and patience he has put into helping me complete my thesis and throughout this master’s program. Thanks to Dr. Dale Wagner as well, for the guidance and direction he has given me throughout this process of degree obtainment. Special thanks to Brian Larsen, D.P.T., for his strong encouragement, friendship, and support while always reminding me that the end of this journey was near. Additional thanks to the faculty and staff of the HPER Department where friendships and valuable tutoring I received will never be forgotten.

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Aaron W. Smith
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CHAPTER I
INTRODUCTION

There is no question that training techniques for athletes are constantly evolving in the quest for improvement in the competitive sports world. Trainers and scientists need to be able to give recommendations to runners on the most effective means of improving running economy and enhancing an athlete’s maximal oxygen uptake (VO₂ max). Even though athletic performance is known to be highly related to genetics (Wolfarth, Bray, & Hagberg, 2005), continued research needs to be conducted in training-related factors to enhance training methods and athletic performance. Athletes and coaches are looking for “the edge,” the training technique that their competitor does not have or use, in order to push themselves, their team, or even their country onto the victory podium. To find a training method that gives an athlete the extra lift is becoming more and more important. Researchers and coaches are continually striving to find new ways to enhance methods to achieve an athlete’s desired performance. New cross training ideas and techniques should be explored and tested in order for individuals to obtain the advantage of their competitor.

Running performance, particularly in endurance events such as the marathon and cross country running, depends upon a number of factors. An individual’s performance depends on VO₂ max, the ability to sustain a high percentage of VO₂ max, and an individual’s running economy (Foster & Lucia, 2007). Of the training methods and other factors that involve improving an individual’s performance, running economy has been studied the least (Foster & Lucia, 2007). Running
economy is typically defined as the energy demand for a given velocity of submaximal running by measuring the steady state consumption of oxygen (VO₂) (Saunders, Pyne, Telford, & Hawley, 2004). To examine the importance of running economy, research needs to be completed to see if improving running economy increases performance in trained distance runners. And, if running economy improves, what methods were used for those runners to generate the greatest increase of economy while maximizing performance. Strategies for improving running economy remain to be developed, although it appears that high intensity exercise, plyometric training, high altitude exposure, and training in the heat have shown improvements in athletes' performance of running economy (Saunders et al., 2004). Even with these strategies that have shown improvement, new ideas and methods need to be tested.

It is believed that by altering the biomechanics of the technique of runners, performing alternate routines, and activating different muscle groups through alternative exercises, such as cycling, that both efficiency and economy could be improved through adaptations to the neuromuscular and cardiovascular systems (Luttrell & Potteiger, 2003). An effective use of force during movement to create power depends on not only the strength of the muscles involved but also on a series of coordinated neuromuscular patterns. A device that was designed for activation of poorly trained muscles, namely hip and knee flexors, is the independent cycling crank. This device is used to improve cycling economy. It produces an improved distribution of force throughout the entire 360° rotation of the pedal stroke, thereby activating less utilized muscles throughout the entire pedal stroke.
PowerCranks™ (PowerCranks™, CA, USA) uses a patented clutch design that produces simultaneous one-legged cycling to drive the bicycle. This creates a situation in which the individual must pull up with each leg on every pedal stroke and create a constant forward force applied to the pedals. In theory, PowerCranks™ encourage a smoother pedaling stroke by altering normal recruitment patterns, thereby stimulating the adaptive process in those muscles not commonly involved in the cycle stroke (Luttrell & Potteiger, 2003). Luttrell and Potteiger trained 12 cyclists with an independent cycling crank for 6 weeks to investigate whether improvements in VO\textsubscript{2} max, anaerobic threshold, and cycling efficiency occurred. Results of this study demonstrated that 6 weeks of training with the PowerCranks™ reduced heart rate from 157 ± 6 bpm to 141 ± 10 bpm, and increased cycling gross efficiency percentage from 21.5% ± 1.8% to 23.9% ± 1.4% during a 1-hour submaximal session. Furthermore, the results from this study show that short-term training with PowerCranks™ was more beneficial than training with normal cranks for reducing energy expenditure during exercise. It was determined that training with the independent crank induced physiological adaptations that resulted in biomechanical alterations created when using the PowerCranks™ device, thus leading to more muscle involvement throughout the pedal stroke. PowerCranks™ appeared to decrease energy expenditure at a given workload, which may enable athletes to increase speed more readily during competition and thereby improve performance (Luttrell & Potteiger, 2003). The study concluded by saying that it appears that 6 weeks of training with the PowerCranks™ induced adaptations that reduced the energy expenditure of cyclists. If this can reduce the energy expenditure of cyclists
and improve performance, why could it not do the same for runners’ economy of motion?

It has been noted that running economy did improve in athletes with the addition of high intensity interval training added to their baseline mileage routine with no clear reason why this occurred (Conley, Krahenbuhl, & Burkett, 1981). Furthermore, it can be argued that the only way to improve the performance of elite runners is with the improvement of their running economy (Foster & Lucia, 2007). This is where the cross training factor comes into play. By investigating alternate methods of training for runners and adding the recruitment of those newly trained muscles, economy of motion and performance may be greater due to the decreased work load of the muscles of the lower limbs (Coyle, 1995). With this decrease of work on the large lower limb muscles, an increase of the economy of motion during running may be produced, and therefore, a greater performance in the selected task would be the result.

Muscular fatigue, defined as a reduction in the maximal strength generating capacity, has been found after long-duration exercise; including running, cycling, or cross country skiing (Forsberg, Tesch, & Karlsson, 1979). This may have an impact on one’s running economy. There have been no studies completed to compare the relative effectiveness of the different forms of training (France, Madsen, & Djurhuus, 1998). Utilizing additional training methods for distance runners, such as cycling, an improvement in running economy may become evident. Interval training of the supporting muscles of the lower limbs has shown an increase in economy and efficiency created by lowering the energy expenditure. Billat, Flechet, Petit, Muriaux,
and Koralsztein (1999) reported that there was 6.1-7.7% improvement of running economy secondary to adding interval training at 93-106% VO₂ max. However, the benefit seemed to be lost when this training was performed too often (Billat et al., 1999).

The addition of traditional strength training and plyometric training programs of distance runners has not been shown to enhance an athlete's VO₂ max, but a significant improvement in running economy has consistently been reported (Midgley, McNaughton, & Jones, 2007). In a study conducted by Turner, Owings, and Schwane (2003), 10 regular, not highly trained, runners displayed 2-3% improvement in running economy after plyometric training. Even though those results were small, those differences in economy can be important in competitive distance running. Midgley et al. also suggested that greater mechanical efficiency, resulting from increased muscle strength, improved motor unit recruitment patterns, and increased muscle stiffness were possible explanations for improved running economy. Typically, traditional strength training may lead to greater body and muscle mass, which may decrease performance (Turner et al., 2003). Croker (1995) recommended stretching to prevent injury and improve performance. However, additional studies have reported that flexibility was inversely related to running economy in trained distance runners (Williams & Cavanagh, 1987). The inclusion of additional training regimens that included high intensity interval training, resistance training, or high velocity training have shown to improve running economy. However, no studies have shown the relative efficacy of specific forms of training and intensities and their effect on the running economy of trained distance runners (Midgley et al., 2007).
With exercises that are commonly performed to improve the strength and conditioning of running, hip flexion has been one of the most ignored by athletes. (Deane, Chow, Tillman, & Fournier, 2005). A lack of hip flexion exercises that exist in conditioning practices may partly be due to difficulty in gaining access to equipment specifically designed to train hip flexor muscles (Deane et al., 2005). Although quadriceps, hamstrings, and calf muscles are mainly responsible for propelling the body forward during running exercise, hip flexor muscles may also contribute to these actions by assisting in bringing the free leg forward and upward during the recovery phase of running (Mero, Komi, & Gregor, 1992). Therefore, maximizing the strength of the hip flexor muscles is likely to be beneficial to athletes where running performance is an integral part of their sport (Deane et al., 2005).

Additional training methods and innovations have been developed in cycling to enforce muscle recruitment patterns and activate less utilized muscles in order to produce better exercise performance. This recruitment of new muscle fibers could in turn produce additional increases in running economy. With an increase of activation of smaller supporting muscle fibers a reduction of energy expenditure may be produced, lessening the oxygen demand of the active larger muscles of the leg. It has been suggested that cyclists were able to generate more pedaling force at a lower metabolic cost due to active recruitment and training of the hip flexor muscles when applying force throughout the entire bicycle pedal rotation (Coyle, Feltner, & Kautz, 1991). Those researchers also have suggested that any observed differences in the anaerobic threshold for running and cycling are the reflection of differences in the muscle recruitment during exercise (Coyle et al., 1988). Whether this was associated
with an increase of the muscle recruitment of hip flexors or quadriceps is not yet known. However, with the use of PowerCranks™ and the increased activation of the hip flexor muscles it would produce due to the distribution of force throughout the entire crank rotation, an increase of athletic performance may be produced (Luttrell & Potteiger, 2003).

As there have been no studies performed to examine the influence of training with an independent cycle crank device and its possible effect on an athlete’s running economy, further studies are required to examine the possible benefits of this training device and how it may successfully improve running economy.

**Significance of Study**

Because running is competitive in nature, researchers are continually striving to find new ways to enhance running performance. As stated before, there is little research on running economy related to performance. However, running economy is a major contributor in the result of an athlete’s performance. Physiologists have not determined exactly how to improve running economy and what training methods are needed to enhance that aspect. It is known that running economy seems to improve slightly with training, but the specific type of training that generates improvement remains a subject for discussion. Cross training has become a popular method for improving the performance and outcome of distance runners. By using training methods that focus on the hip flexors that assist in driving the free leg forward and upward during running an increase of economy of motion may be produced. The proposed study is intended to determine whether distance runners who perform cross
training with PowerCranks™ and focus on hip flexor training would improve their running economy. As stated before by Luttrell and Potteiger (2003), changing the athlete’s kinematics and offering new training routines (e.g., cycling) that activate different muscle groups might lead to a decrease of energy expenditure thereby improving running economy and performance.

**Purpose of Study**

The primary purpose of this study was to determine if 6 weeks of training, three times per week with the PowerCranks™ device would result in improvements in the running economy of collegiate distance runners, assessed by VO₂ at 8 and 9 mph.

**Research Questions**

1. Does 6 weeks of training with the PowerCranks™ independent crank arm system in distance runners enhance running economy?
2. Does 6 weeks of training with the PowerCranks™ independent crank arm system in distance runners affect their VO₂ max?

**Hypotheses**

1. Cross training with the PowerCranks™ independent bicycle crank system will improve an athlete’s running economy as compared to the control group.
2. With the use of PowerCranks™ an athlete’s ratings of perceived exertion (RPE) will decrease with no significant increase to their VO₂ max.
Limitations

1. Independent cycle crank training was not a typical training method that collegiate runners would typically be accustomed to this activity.

2. The time frame of training with PowerCranks™ is short.

Delimitations

1. The subjects only trained with the PowerCranks™ for a period of 6 weeks and were not exposed to the training stimulus for a prolonged duration.

2. Subjects were not required to have an extensive knowledge of cycling training and therefore the subjects’ learning curve might affect their training results.

3. Subjects were not required, but were requested, to add the additional cross training method of an independent crank system to their normal full training schedule.

Assumptions

Six weeks of cross training with the PowerCranks™ independent bicycle crank would initially show a small decrease of an athlete’s running economy due to the activation of less utilized muscles. However, with a longer duration of training and an increase of an athlete’s anaerobic threshold, successful increases in running economy would be justified.
**Definitions**

1. Running Economy: Measure of how efficiently a person uses oxygen while running at a given pace. Expressed as the rate of oxygen consumption (ml/kg/min), running economy is the energy required to run sub-maximally at a given velocity.

2. VO₂ max: The maximum capacity of an individual's body to transport and use oxygen during exercise. The name is derived from V - volume, per time, O₂ -oxygen, max - maximum. VO₂ max is expressed either as an absolute rate in liters of oxygen per minute (L/min) or as a relative rate in milliliters of oxygen per kilogram of bodyweight per minute (ml/kg/min).

3. Metabolic Measurement Cart: Expired gas analysis system used for cardiopulmonary stress testing, measuring indirect caloric usage, and O₂ consumption.

4. Anaerobic Threshold: The point during increasing intensity of exercise where there is a change in respiratory parameters that perhaps coincide with the lactate threshold.
CHAPTER II
REVIEW OF LITERATURE

VO₂ max, lactate threshold, and running economy have been regarded as the most important determinants of a runner’s performance, and therefore, effective training techniques should be focused on their enhancement (Berg, 2003). It has been unclear which training methods are the most effective to enhance running economy (Midgley, McNaughton, & Wilkinson, 2006), and the development of new ideas and strategies is needed. Routine training techniques are typically used to enhance the normal sports mechanics, but new cross training techniques need to be developed for activation of dormant muscle fibers which, in theory, would increase running economy.

It has been stated that VO₂ max, when measured properly, may be the best index of cardiovascular fitness for a healthy person (Åstrand & Rodhal, 1977). Running performance, on the other hand, particularly in endurance events such as marathons and triathlons, depends on a complex interplay of factors (Foster & Lucia, 2007). Along with good genetics and proper training techniques, new methods need to be examined to ensure that all muscles may be activated to decrease the physical demand of the athlete. Past training techniques have been repeated with much success. However, it is believed that by introducing new cross training techniques and activating less utilized muscles, an athlete can enhance running economy and performance. Conventional training techniques in demanding sports, when repeated, may produce chronic adaptation. But those training intensities need to be sufficient to
produce the adaptive response. Running is one of the most demanding sports (Dowzer, Reilly, Cable, & Nevill, 1999). This is due to the activation of the large muscle groups as well as the impact force that the skeletal system experiences during running (Gross & Napoli, 1993). But by introducing new training techniques, athletes will activate less utilized muscle fibers, decrease the demand of the large muscle groups, provide an increase of multiple muscle activity, and in theory, increase their running economy.

The purpose of this chapter is to provide a review of the literature and the research basis for the study. The importance of cross training techniques and how they may or may not affect an athlete's economy of motion and VO$_2$ max will be highlighted. The organization for this review is (a) running economy, (b) the relationship between VO$_2$ max and running economy, (c) the PowerCranks™ versus the standard bicycle crank, and (d) methods of running and cycling training.

**Running Economy**

Even though it has been known since the 1970s that running economy is an important factor in an athlete's performance, this factor has been relatively ignored in the scientific literature. Due to a lack of research, knowledge of running economy is less when compared to our understanding of other elements of running performance. For this reason, additional research is needed to better understand running economy and the process needed for improvement of an athlete's performance.

Measurement of running economy has typically been determined in the laboratory setting with standard traditional methods. These past methods involved an
athlete running at progressively increasing speeds for 4-10 min until a physiological steady state was achieved (Foster & Lucia, 2007). Running economy is deemed as the energy required for running sub-maximally at a given velocity. It is calculated by measuring oxygen consumption at a steady state within one’s aerobic range, while taking body mass into consideration. It is expressed as the rate of oxygen consumed (ml/kg/min), or at the rate of oxygen consumption per distance covered (ml/kg/km). In short, those who are able to consume less oxygen while running at a given velocity are said to have a better running economy. Even though running on a motorized treadmill is not the same as over-ground running, it gives a good indication of how economical a runner is and how running economy changes during the exercise (Foster & Lucia, 2007).

It appears that a number of biomechanical and physiological factors may influence running economy in highly-trained and elite runners (Conley & Krahenbuhl, 1980). Athletic performance is known to be related to genetics and training factors (Wolfarth et al., 2005). With genetics being a fixed factor, training related components depend on an athlete’s ability to learn and apply new routines and methods to excel at the prescribed regimen. Athlete’s physical training may provide profound effects on physiological adaptation and athletic performance (Hoffman, 1999). Trained distance runners will often seek the most effective training techniques and methods to enhance and improve performance (Midgley et al., 2006). This is probably most evident where elite distance runners have reached a plateau in performance with traditional techniques (Londeree, 1997). Current training and performance enhancement methods are mostly developed from a “trial-and-error”
approach for runners and their coaches, with contributions coming from scientists (Hawley, Myburgh, & Noakes, 1997). Coaches and runners may be reluctant to acknowledge and employ these new scientific methods without certainty of proven increases of performance in the past (Midgley et al., 2007). For this purpose, new training methods to improve economy must be continuously researched and tested to assure that those coaches and athletes have the best knowledge available for achieving the greatest performance in competition.

With the importance of running economy to running performance, there have been surprisingly few studies completed to examine specific methods that will improve running economy. As stated before, in a study by Saunders et al. (2004) certain interventions were reviewed, such as plyometric training, altitude training, and training in the heat, which may improve an athlete’s running economy (Saunders et al., 2004). Even with these training procedures showing promise for running economy enhancement, no solid mechanical link is yet evident (Foster & Lucia, 2007). It was shown that during a certain case study, running economy improved with the addition of high-intensity interval training added to baseline running (Conley et al., 1981) even though there was no clear reason why such training caused the improvement. In a recent study, the addition of traditional strength training and plyometric training for distance runners did not enhance their VO2 max, but increases in running economy had been reported (Midgley et al., 2007). The authors suggested that this increase was due to the greater muscle strength, improved muscle recruitment patterns, and the increase of tendon stiffness. That is why additional training regimens need to be explored and tested for additional options of training for runners. No alternative
training studies have been conducted to investigate the improvement of economy of motion of an athlete with new alternative forms of training techniques (Midgely et al., 2007).

As stated before, running economy has been regarded as one of the most important factors of long-distance running performance and new and effective training techniques should be explored to focus on its enhancement (Pate & Branch, 1992). If efficiency can be learned, the question arises as to whether an individual’s running economy can be increased through the activation of small, less utilized muscles in the large muscle groups of the legs. Granted, with increased activation of less utilized muscles, initially, running economy may worsen due to the additional need of oxygen for those less active muscles now stimulated. However, through repetitive training resulting in an increase of an athlete’s anaerobic threshold, the workload of the athlete may be lessened and performance may improve due to chronic adaptation. Through high levels of training and ideal genetic factors, elite athletes have relatively high values for their $\text{VO}_2\text{max}$ and running economy. Nevertheless, to sustain those high values, athletes will need to engage in additional cross training techniques to increase their economy of motion and performance.

**The Relationship Between $\text{VO}_2\text{max}$ & Running Economy**

In the past, there were few studies that have been conducted that involve trained distance runners, their training regimens, and the comparison of their $\text{VO}_2\text{max}$ with running economy results (Midgley et al., 2007). Within those past studies that have been conducted, many were shown to have mitigating factors that made
their results difficult to interpret regarding the effect of their training on maximum oxygen uptake and running economy. This is why additional research is needed to examine the effects of crosstraining techniques and the relationship between VO\textsubscript{2} max and running economy results. It is also required to determine if an athlete’s VO\textsubscript{2} max has a direct relationship to his/her running economy result and the training he/she endures in order to improve both. This section will explore the effects of past training to increase one’s running economy and the result of post training VO\textsubscript{2} max.

With the improvement of running economy, an athlete’s VO\textsubscript{2} max may or may not be affected. Past studies have shown equivocal results in the relationship between improving a runner’s economy of motion and their VO\textsubscript{2} max result. Some studies have reported that interval training at 93-106% of VO\textsubscript{2} max resulted in an improvement of an athlete’s running economy (Billat et al., 1999). However, other studies using similar training intensities for runners have reported no significant improvement (Smith, Coombes, & Geraghty, 2003). It was also shown that those runners that trained at 132% VO\textsubscript{2} max demonstrated significant improvement of their VO\textsubscript{2} max; however, it was not effective in improving running economy due to a possible loss of running form at high velocities (Midgley et al., 2007). Through this high intensity regimen of interval training, continuous running/training at 132% of VO\textsubscript{2} max, and resistance training of distance runners an improvement in running economy was not achieved. However, there has been limited research to show the relative efficacy of the different forms of training (France et al., 1998) and the conclusion of each specific regimen in regards to its results. Researchers also have suggested that hill running may be an effective form of training to produce an
improvement of an athlete’s running economy (Lydiard, 1979). However, since there have been no training studies to investigate this claim (Lydiard, 1979), it is necessary to investigate other training methods and regimens to examine the impact of how improving one's running economy would affect VO2 max results.

Previous studies have suggested that resistance training and high-intensity running may be effective training methods. Unfortunately, the research that has been completed is much too limited to formulate any level of strong confidence in such activity to improve an athlete’s VO2 max or running economy. However, by using previous research, scientists may direct coaches and athletes in worthwhile training programs that will enhance the desired levels of running economy and VO2 max; thereby, achieving the desired performance in competition.

**PowerCranks™ versus Standard Bicycle Crank**

Recent developments in bicycle crank designs have attempted to introduce muscle recruitment patterns to encourage the application of force throughout the entire 360° rotation of the pedal crank. In cycling training, as well as other repetitive motion training, it has been concluded that neurological and muscular adaptations will increase and reduction of the overall demand of those recruited muscles will be the result (Coyle, Coggan, Hopper, & Walters, 1988). Therefore, muscle recruitment is needed to increase the number of muscles activated or used during activity to possibly help reduce muscle fatigue and increase performance. This adoption of recruitment patterns may enable an increase of muscle activity with a stimulation of those less utilized muscle fibers to improve performance.
A single pedal revolution can be broken down into three phases: (a) the power/downstroke phase, (b) recovery/upstroke phase, and (c) the pushing phase, in which the foot is pushed forward at the top dead center (So, Ng, & Ng, 2005). These phases are typical although some modifications may exist during the pedaling of a cycle depending upon the individual. During the phases of the standard stroke, muscles of the leg become less active during the recovery phase. This tends to give the cyclist a sense of rest/recovery and preparation after they pass the power/downstroke phase. As shown in Figure 1, it is important to recognize activity when each of the muscles of the legs is being used for power generation or recovery. If a method can be implemented to force/ensure continuous muscle activity during the
entire pedal stroke, greater muscle generation and continuous activity may be created. Muscle recruitment is necessary to promote a possible increase in performance and reduction of fatigue. It has been reported that fatigue and perceived exertion might be reduced by activation of two joint muscles during the phases of movement (Prilutsky & Gregor, 2000). Studies would need to investigate the recruitment of additional muscles during exercise; a greater performance may be achieved with less fatigue. To apply this technique of recruitment, the cycling training device PowerCranks™ was developed (see Figure 2). This device works an independent crank cycle motion by integrating a one-way clutch design in each crank arm. Each leg drives the bicycle crank without having the other leg assist in motion. This is a substantial variation from the traditional bicycle cranks system where both pedals work in conjunction. This patented design claims to eliminate problems of inefficient cycling by eliminating the resistive forces produced during the recovery portion of the normal pedal stroke. When the individual does not pull up while using the PowerCranks™, the crank arm will drop back down to bottom dead center; as seen in Figure 2. A usage of the possible limitation with the use of a modified crank system is with the increased additional muscles, an initial increase in the demand of oxygen of those muscles will be produced. An increase of fatigue in the additional muscle groups may become counterproductive. This limitation may be corrected over time because it has been noted that when muscles become better trained the overall body demand for oxygen would decrease, hence an increase of efficiency would be produced (Luttrell & Potteiger, 2003).
One possible difference in performance among cyclists is the adaptations within skeletal muscle groups that do not necessarily involve an increased oxygen extraction (Coyle et al., 1988). Coyle et al. also suggested that elite cyclists tend to pull up during the pedal stroke more than novice cyclists. This enables the knee extensor muscles of the opposite leg to perform less work. They also suggested that it is possible to dramatically reduce muscular stress by being better able to distribute the muscular work of the lower legs (Coyle et al., 1988). This distribution of muscle activity may be measured with the help of surface electromyography. Electromyography is a technique for evaluating and recording the electrical activity produced by skeletal muscles (Kamen, 2004). Surface electromyography (EMG) allows the measurement of the total electrical activity of a muscle (Duc, Betűk, &
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As a result of continued training, the muscle activation parameters are changed via central neural structures in response to the novel movements (Mileva & Turner, 2003). Through this process, the nervous system is more readily able to adapt to these new mechanical actions very quickly (Dietz, 1997). As more powerful and coordinated muscle movements produce better athletic performance, it is important to consider how these recruited muscle patterns adapt to cycling, running, or other physical sports. It is also important to know how these new training devices may aid in increasing adaptations and results.

In past studies, the motor recruitment patterns of leg muscles have been studied during cycling using EMG. For example, Ryan and Gregor (1992) assessed the activation patterns of eight lower leg muscles at different phases of the crank cycle. The authors concluded that muscles crossing two joints (e.g., rectus femoris and gastrocnemius) were associated more highly with power distribution. This allowed the power generated to be spread across all the joints of the lower limb, resulting in a greater ability to propel the bicycle forward. In comparison, those muscles that only crossed one joint (e.g., vastus lateralis), were more highly associated with power generation (Ryan & Gregor, 1992). A study conducted by Nuckles, Bills, Wagner, and Bressel (2007) took the opportunity to examine the effects of PowerCranks™ training over a six week period with the knee and hip flexors on eight subjects. This study consisted of five minute exercise bouts using the PowerCranks™ and normal bicycle cranks. The authors found that the iliosopas and rectus femorus muscles displayed more activity, 31% and 35%, respectively, during the use of the PowerCranks™. However there was no difference displayed in the
biceps femoris and gastrocnemius during activity of the PowerCranks™.

Nevertheless, it is safe to assume that the use of PowerCranks™ may induce additional and positive muscle activity that may lead to greater cycling performance. While the study by Luttrell and Potteiger (2003) provides evidence to suggest gross efficiency may increase when training with the PowerCranks™, the sample size that they used was small and with limited number of physiological measurements.

**Cycling and Running Training**

Running and cycling are performed with muscle contraction of the lower limbs. The main muscle groups that are primarily involved in cycling and running activities are the quadriceps and plantar flexors, respectively (Bijker, De Groot, & Hollander, 2002). It has been suggested by researchers that any observed differences in the anaerobic threshold for cycling and running are a reflection of the differences in muscle recruitment during exercise and between exercise modes (Coyle, 1995). Coyle et al. (1988) had shown that both the lactate threshold and the performance level in cycling would be influenced by the differences in force application to the bicycle crank system. However, it has been suggested that better cyclists were able to produce more pedaling force with less energy expended, due to the recruitment of the hip flexor muscles (Coyle et al., 1988). Therefore, with this added involvement and in collaboration with the new adaptations introduced through specific training of cycling and running programs, anaerobic threshold and running economy may be influential in tri-athletes and single sport athletes. In a study by Marcinik et al. (1991) it was found that a short term strength training program results with an improvement in
lactate threshold in cycling regardless of any cycling training. They concluded that strength training resulted in an improvement in muscle recruitment patterns during exercise. Therefore, with the results of Marcinik et al. together with the conclusions of Nuckles et al. (2007) and Coyle, there seems to be an indication that running economy may be influenced by the muscle recruitment and increase of activity of the less utilized muscles of the lower limbs. This, however, would need to be tested with longitudinal studies involving different cycling and running training interventions.

It has been reported that the physiological variables in running and cycling may be due to the perceptions of greater difficulty in cycling than running (Hassman, 1990). The greater perception of effort observed may be in part due to the less utilized muscles and lower leg muscular strength now being used during cycling, as compared to running. But by activating these untrained muscle groups, leg muscle activity during running can be influenced by cycling training (Millet, Vleck, & Bentley, 2009). However, the amount of time given to a training session for chronic adaptation is crucial for enhanced functional capacity. Typically, the number of training sessions that an elite or sub-elite runner performs is 10-14 sessions per week (Billat, Demarle, Paiva, & Koralsztein, 2002). This in turn would produce a chronic adaptation. Chronic adaptation will occur only if the adaptive response is achieved through sufficient training intensities (Casaburi, Storer, Sullivan, & Wasserman, 1995). An adaption threshold is achieved when an athlete’s intensity and duration no longer surpasses his previous routine. This threshold will be achieved if no other factors become involved. Therefore, distance runners should seek optimal training intensities and methods, rather than time duration, to increase the likelihood of achieving...
chronic adaptation for long lasting results. The optimization of training methods may also reduce the need of continuous increases of training volumes in athletes, which has been implicated in a premature stagnation of performance (Smirnov, 1998). Cycling training, regardless of the mechanisms involved, has been determined to lead to continued neurological and/or muscular adaptations that will reduce the overall demands of those recruited muscles (Coyle et al., 1988). Through additional muscle conditioning improvements and an increase of motor patterns, efficiency and economy of motion may be increased.

Summary

The purpose of this chapter was to provide a review of the literature and a research basis for the study of the importance of investigating cross training techniques or devices and how it may or may not affect an athlete’s performance with regard to economy of motion and VO₂ max. This literature review was organized to examine (a) running economy, (b) the relationship between VO₂ max & running economy, (c) PowerCranks™ versus the standard bicycle crank, and (d) cycling and running training.

Research that has been conducted in the past involving PowerCranks™ mainly studied the effect it may have on cyclists for the purpose of generating greater cycling performance. It is now evident, from the research gathered, that by altering athletes’ routines, activating different muscle groups, and investigating new biomechanical techniques of training exercises for athletes, an additional cross-training method using PowerCranks™ may be plausible for the increase of an
athlete’s economy of motion. This literature review provided an additional reason for runners to add new cross-training techniques to their training methods for the purpose of increased muscle activation and improving running economy.
CHAPTER III

METHODS

This chapter will describe the methods that were employed to address the purpose of this study. The purpose of this study was to determine if 6 weeks of training, three times per week, with PowerCranks™ would result in improvements in the running economy, assessed by VO\textsubscript{2} at 8 and 9 mph, and VO\textsubscript{2} max of collegiate distance runners. This chapter will discuss the participants, instrumentation, general procedures, data analyses, and statistical treatment of data.

Participants

Eighteen participants, 9 male and 9 female, of the Utah State University cross-country team consented to participate in a study designed to investigate the 6-week training effects of PowerCranks™ on VO\textsubscript{2} max and running economy. This study was previously approved by a human subjects committee and the data were previously collected. All participants read and signed an informed consent document approved by the Utah State University Institutional Review Board that included the purpose, methods, and risks of the study. The volunteers were instructed during the informed consent process that half of the consented individuals would be randomly assigned to participate in the experimental group, and the other half would be part of the control group. In addition to the informed consent document, all participants were informed of their right to terminate their involvement in the study at any time.
Instrumentation

The independent bicycle crank used for the training was the PowerCranks™ independent training system (PowerCranks™, USA). An image of the training mechanism was shown previously in the literature review (see Figure 2). Cycling shoes with locking foot clips were not used during the training. Toe stirrups were used so the participant did not have to use different and unaccustomed footwear during their training. For the independent crank testing group, a Monark ErgoMedic 824E cycle ergometer (Monark ErgoMedic, Vansbro, Sweden) was used with the PowerCranks™ device installed using the manufacturer’s guidelines. A duplicate Monark ErgoMedic 824E with a standard cycle crank was used for the control group. To promote a uniform standard of training for all of the participants involved, a metronome was used to measure and control the subject’s cadence during the exercise procedure. A cadence of 60 rpm was used for the duration of the training.

Maximal oxygen consumption measurements were taken by the researcher for each subject in the study. These measurements were taken at the Utah State University Exercise Physiology Lab. Expired air was measured using a ParvoMedics TrueMax 2400 Metabolic Measurement Cart (ParvoMedics, Sandy, UT) during the exercise protocol. The pneumotach was calibrated with a known volume of air using a 3-L syringe, and the gas analyzers were calibrated with a known concentration of O2 (16%) and CO2 (4%) prior to each testing session. A NordicTrack 600 (ICON Health & Fitness, Logan, UT) adjustable treadmill was used for both VO2 max and running economy testing in the study. A Polar T31 (Polar Electro, Lake Success, NY) heart
rate monitor was worn by each of the participants to monitor heart rate (HR). Ratings of perceived exertion (RPE) were also monitored using Borg’s 15-point scale (Borg, 1982).

**General Procedures**

Participants reported to the Exercise Physiology Lab at Utah State University for an initial pre-test session that included gathering the participant demographics of sex, age, weight, and height. Descriptive statistics for study participants are given in Table 1 in the results section. Participants were randomly assigned to either the experimental group or control group with gender being the only sorted factor for equal distribution. Participants were then asked to perform an initial VO\textsubscript{2} max test to obtain baseline results. Procedures included fitting the proper size head gear with the athlete and making sure the nose clip was in place for proper testing results. The VO\textsubscript{2} max protocol was individualized for each runner. After 2 min of resting data were collected, each participant began at a pace that was equal to his or her 5 km pace. Each stage was 2 min, with the speed increasing by 1 mph for the first three stages. The first three stages (6 min) were at 0% grade. After that, the speed remained constant and the workload was increased by increasing the grade 2% each stage until exhaustion. RPE was recorded at the completion of each 2 min interval. Participants performed a walking recovery phase of 3 min at the completion of their VO\textsubscript{2} max.

Second, a running economy test was performed on each subject prior to the training period. Participants were given a minimum 48-hr rest between their running economy test and their VO\textsubscript{2} max test. Athletes were tested with the same metabolic
cart used previously. The same head gear, heart rate monitor, and nose clip were used as before. Again, calibration of the metabolic cart was performed prior to testing. The athletes were asked to run, 8 mph for females and 9 mph for males, on a treadmill at 0% grade. The metabolic cart was set up to average data every 20 s. Data were collected and recorded throughout the exercise protocol. The test lasted 6 min with the average of the last 2 min used to determine running economy. Running economy was calculated using results expressed in terms of the rate of oxygen consumed (L/min).

Upon completion of the pre-training VO₂ max and pre-training running economy tests, each participant was randomly assigned to perform either the training with the PowerCranks™ device or standard bicycle crank system. Training sessions, in the PowerCranks™ and Standard crank groups, included exercise time of 30 min at a cadence of 60 rpm with their respective bicycle crank system. The weight resistance was set identical for both groups training bikes at 3 kg. Both groups were instructed to come 3 days a week and perform 30 min of exercise training. The first exercise session included a 10-15 min practice with the equipment for the athletes to become familiar with the crank system they were assigned. When the athletes completed their familiarization period, each participant exercised for 30 min for 3 days a week at a cadence 60 rpm. A rest time of 48 hr was given between each training session. After the first three sessions of training, each participant’s time of exercise was increased to 40 min and weight resistance was increased to 3.5 kg. After the first six training sessions were completed, training time was increased to 50 min with no additional increase in weight resistance for the duration of their study visits. (Due to the duration
of the exercise, if requested the participants were given rest periods during their exercise sessions not to exceed 3 min. The time of their exercise was not a continuous exercise time, only a time of exercise duration.)

At the conclusion of the 6-weeks, 13 of the initial 18 participants were able to complete a post-training VO\textsubscript{2} max test and a running economy test to determine if any change from their pre-training results occurred. All post-training treadmill testing procedures were performed the same as before.

**Statistical Analyses**

Descriptive data including means and standard deviations of age, height, weight, VO\textsubscript{2} max, and running economy were each reported. Descriptive statistics along with results of the pre-and post-training tests were recorded and calculated using a paired-samples \textit{t} test with the Statistical Package for Social Sciences (SPSS, version 19). To determine the statistical significance the alpha level was set at .05. A calculation in the change of scores (pre and post data) was also completed along with an independent \textit{t} test to compare the PowerCrankSTM group to the control group.
CHAPTER IV

RESULTS

The primary purpose of this study was to determine if 6 weeks of training, three times per week with the PowerCranks™ device would result in improvements in the running economy of collegiate distance runners, assessed by VO\textsubscript{2} at 8 and 9 mph. Eighteen runners (9 males and 9 females) were asked to perform the additional training for the study in addition to their normal training regimen to determine if running economy increased. Half of the total participants (9) were randomly selected to perform the training regimen with the PowerCranks device, with the remaining nine to perform the training with a standard bicycle crank. Additionally, pre-training and post-training VO\textsubscript{2} max data were collected. A paired t test was performed to determine if there was a significant difference in running economy and VO\textsubscript{2} max after the 6 weeks of training with the PowerCranks™ device. Only 13 runners, from the initial 18, were able to complete the study due to collegiate competition and personal scheduling conflicts. Demographic data, for the 13 participants who completed the study including age, height, weight, and BMI, is listed in Table 1. All of the males and only one of the female runners who trained with the PowerCranks™ device completed the program as indicated in Table 2. In the control group, all of the female and only half of the male runners completed the study. Completion of the study was labeled as an athlete completing all 6 weeks of requested training within their assigned group and post training VO\textsubscript{2} max and running economy test within the requested timeline. As a result, there was a 72.2% completion rate for the study.
Table 3 display results of the paired *t* tests for running economy and VO$_2$ max, respectively.

The paired samples *t* test for running economy (Table 3) in the PowerCranks™ group showed that 6 weeks of training with the investigational device displayed no significant difference ($p = .057$). The paired samples *t* test for running economy in the standard crank control group also displayed no significant difference ($p = .815$) post training. The paired samples *t* test for VO$_2$ max in the PowerCranks™ and standard crank groups also displayed no significant difference ($p = .230$, $p = .245$) as reported, respectively.

Additional analyses were also run to calculate the change in VO$_2$ max and running economy scores (pre-post) and complete an independent *t* test to compare the PowerCranks™ group to the standard crank control group. As reported in Table 4, there was no significant change in values for running economy ($t = -.112$, $p = .913$) or VO$_2$ max ($t = 1.569$, $p = .145$) when PowerCranks™ and control groups were compared.
Table 1

Participant Demographic Data

<table>
<thead>
<tr>
<th>Volume (N = 13)</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>20.4</td>
<td>170.9</td>
<td>61.5</td>
<td>20.7</td>
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<tr>
<td>Minimum</td>
<td>18.0</td>
<td>62.0</td>
<td>50.9</td>
<td>18.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>24.0</td>
<td>73.8</td>
<td>74.4</td>
<td>23.0</td>
</tr>
<tr>
<td>SD</td>
<td>1.6</td>
<td>9.9</td>
<td>8.2</td>
<td>1.3</td>
</tr>
</tbody>
</table>

*Note. SD = Standard Deviation, Age = years, Height = cm, Weight = kg, BMI = Body Mass Index*

Table 2

Study Participation and Randomization

<table>
<thead>
<tr>
<th>Initial</th>
<th>Final</th>
<th>Final %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>ConMale</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>PCMale</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>ConFemale</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>PCFemale</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>13</td>
</tr>
</tbody>
</table>

*Note. Con = Control (Standard Crank), PC = PowerCrankSTM*
### Table 3

**Paired Samples t Test for PowerCranks™ and Standard Crank for Running Economy and VO₂ max**

<table>
<thead>
<tr>
<th></th>
<th>Con/Pre/Max</th>
<th>Mean</th>
<th>n</th>
<th>SD</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>Con/Post/Max</td>
<td>3.92</td>
<td>7</td>
<td>1.09</td>
<td>-1.287</td>
<td>.245</td>
</tr>
<tr>
<td></td>
<td>PC/Pre/Max</td>
<td>4.10</td>
<td>6</td>
<td>0.72</td>
<td>-1.366</td>
<td>.230</td>
</tr>
<tr>
<td></td>
<td>PC/Post/Max</td>
<td>4.18</td>
<td>6</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 3</td>
<td>Con/Pre/Econ</td>
<td>2.68</td>
<td>7</td>
<td>0.51</td>
<td>-0.245</td>
<td>.815</td>
</tr>
<tr>
<td></td>
<td>Con/Post/Econ</td>
<td>2.69</td>
<td>7</td>
<td>0.57</td>
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<td></td>
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<td></td>
<td>PC/Pre/Econ</td>
<td>2.98</td>
<td>6</td>
<td>0.60</td>
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<td>.057</td>
</tr>
<tr>
<td></td>
<td>PC/Post/Econ</td>
<td>3.08</td>
<td>6</td>
<td>0.59</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Con = Control (Standard Crank), PC = PowerCranks™, Pre = Pre training, Post = Post training, Max = VO₂ max, Econ = Economy, Units = L/min

### Table 4

**Independent t Test Comparing Change Difference of pre and post-testing scores for Standard Crank versus PowerCranks™ group for Running Economy and VO₂ max**

<table>
<thead>
<tr>
<th>VO₂ max</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>SEM</th>
<th>MD</th>
<th>SED</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>7</td>
<td>-.089</td>
<td>.182</td>
<td>.069</td>
<td>-.010</td>
<td>.092</td>
<td>-.112</td>
<td>.913</td>
</tr>
<tr>
<td>PowerCranks™</td>
<td>6</td>
<td>-.078</td>
<td>.140</td>
<td>.057</td>
<td>-.092</td>
<td>.058</td>
<td>1.569</td>
<td>.145</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Running Economy</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>SEM</th>
<th>MD</th>
<th>SED</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>7</td>
<td>-.010</td>
<td>.108</td>
<td>.041</td>
<td>.092</td>
<td>.058</td>
<td>1.569</td>
<td>.145</td>
</tr>
<tr>
<td>PowerCranks™</td>
<td>6</td>
<td>-.102</td>
<td>.101</td>
<td>.041</td>
<td>.058</td>
<td>.058</td>
<td>1.569</td>
<td>.145</td>
</tr>
</tbody>
</table>

*Note.* Units = L/min, SD = Standard Deviation, SEM = Standard Error Mean, MD = Mean Difference, SED = Standard Error Difference
The purpose of this study was to determine that if collegiate distance runners completed 6 weeks of training, three times per week, with an independent cycling crank device (PowerCranks™), increases to their running economy would result with observation of any change in their VO₂ max post training. This was done to answer the question that if experienced runners used an independent bicycle crank, improvements to their running economy would result from this crosstraining method. A standard bicycle crank control group was also used to compare the differences of both cross training methods to see if a significant difference was produced by either group at the $p \leq .05$ level. Eighteen experienced runners from the Utah State University Cross Country running team were recruited for this study. The hypothesis of this study was that cross training with the PowerCranks™ independent bicycle crank would increase an athlete’s running economy and VO₂ max as compared to training with a standard crank.

As noted in the results section, five participants were unable to complete the running economy and VO₂ max post testing due to scheduling and competition conflicts. As a result, their measurements were not included in the discussion and only 13 participant’s data were included in the study. An independent samples $t$ test was used to identify whether there was a significant difference in running economy and VO₂ max when the independent cycle crank was used compared to the standard crank. This chapter is designed to address the results of the study and discuss their
importance. It is organized according to the following headings: VO₂ max and running economy results, limitations, implications, future research, and conclusions.

**VO₂ max and Running Economy Results**

As displayed in Table 3, VO₂ max results of the PowerCranks™ groups showed no changes from pre- and post-data collection (4.10 ± 0.72 to 4.18 ± 0.75 L/min). This does support the hypothesis that even with the use of PowerCranks™ by experienced runners, no significant increases to their VO₂ max resulted. There was a slight increase to the control group means of VO₂ max (3.83 ± 1.10 to 3.92 ± 1.10 L/min); however, no significance difference was reported, as shown in Table 3. As stated before by Foster and Lucia (2007), an individual’s performance depends on their VO₂ max and the ability to sustain a high percentage of their VO₂ max for an extended period of time.

No significant differences were found in running economy and VO₂ max of data collected pre- and post-training of all participants using a paired samples t test. As shown in Table 3, the pre-training means of running economy in the PowerCranks™ group were 2.98 ± 0.60 L/min and post-training means were 3.08 ± 0.59 L/min. The PowerCranks™ group actually decreased their economy of motion 0.10 ± 0.006 L/min when post-training data were collected. The hypothesis was rejected that experienced runners who performed 6 weeks of cross training with an independent cycle crank would increase their running economy. With the application of force throughout the entire 360° rotation of the pedal crank and the muscle recruitment pattern change in legs with PowerCranks™ (Coyle et al., 1988), the
overall oxygen demand for those newly recruited muscles may have increased; which may account for the no significant change in running economy results. With only having the 6 weeks of training with PowerCranks™ and not creating a chronic muscle adaptation, this may also be an explanation for no significant change in running economy results. Even though there was an increase in gross efficiency of cyclists of 2.4 ± .4% in the study by Luttrell and Potteiger (2003), the PowerCranks™ device was not used as a cross-training method. Their study was designed to investigate the possible increases of efficiency and reduction in HR of cyclists during a 1 hr submaximal session after training for 6 weeks with an independent crank system and not to see possible benefits of cross training with an independent cycle crank. The control group means of running economy results, shown in Table 3, had no significant change from 6 weeks cross training on a standard crank (2.68 ± 0.51 to 2.69 ± .57 L/min) pre-and post-training data collection. As stated before, in a past study by Billat et al. (1999) running economy did improve when interval training was performed at 93-106% of VO₂ max. However, that study was not designed to measure results of running economy due to crosstraining with an independent cycle crank. Although the results of our study show that there was no significant difference in running economy or VO₂ max results after 6 weeks training with the PowerCranks independent crank system, the values can still be useful. As stated in past studies, there are few studies conducted that involved trained distance runners, the methods they use, and a comparison of their VO₂ max and running economy results (Midgley et al., 2007). The results of this study displayed that there again
seems to be no direct relationship with VO₂ max and running economy results when an independent cycling crank is used for cross training.

**Limitations**

The PowerCranks™ independent cycle crank is not a typically used training mechanism for athletes. This device is not used by most athletes due to cost and the availability. Therefore, continued training on an independent bicycle crank is not a routinely used method. Participants involved in this study were not familiar with this device initially and knowledge of the device’s mechanics and instruction of use was needed. Once they understood how the device worked they were able to train muscles typically not used in their training regimen. This can be viewed as a limitation as well as a delimitation of the study. To further explain, the participant’s unfamiliarity with the device created some uneasiness, and fear of possible injury was expressed by some of the athletes. Participants did learn how to use the device, but the effectiveness was lessened due to the new nature and short duration of the training. All of the individuals did express knowledge and past usage of a standard bicycle crank; however, the independent cycle crank did provide new challenges in learning the most effective means for routine practice. All participants expressed that chronic adaptation and familiarity did occur with the device at the end of the study.

The length of the study (6 weeks) also presented a limitation for the athletes. Due to the competition schedule of the runners, additional training that would also be added by their coaches for competitions, adding an additional scheduled training 3 days a week, presented a difficulty for most runners to complete all the study visits.
Travel schedule for competitions presented challenges for the participants to complete all 18 training visits during the 6 weeks of the study timeline as well. In order to complete all scheduled trainings, the 48-hr rest time period between visits, was not always completed. As stated before, chronic adaptation and familiarity was expressed by all participants at the conclusion of the study, however, the participants also suggested that a longer duration would be beneficial for training purposes. At the conclusion of the 6 week study and with the familiarity of the device that was now obtained, some participants stated that they “could push themselves more, now that they know how to use it.” They expressed they could train much better with the device and receive a “better workout” than with the use of a standard bicycle crank during training regimens. They also stated that during competitions, leg strength was increased and experienced less fatigue than before. These statements from the participants support, although not prove, the hypothesis that an athletes’ RPE would decrease from training with PowerCranks™. Further research would need to be completed before solid conclusions could be made.

**Implications**

Due to the limited research with independent cycle cranks, trained distance runners typically do not use those devices as a normal training regimen to increase performance. Also, with the short time (6 weeks) of crosstraining with the PowerCranks™ device, the participant’s adaptation of muscle use and familiarity with the device may have only been achieved at the end of the study. With the results of running economy decreasing with those participants training with the
PowerCranks™ device, it can be implied that the use of oxygen would increase due to the activation of less utilized muscles. However, through longer training periods, the chronic adaptation of the newly trained muscles and the initial increase use of oxygen would decrease due to the lessened work load of the larger muscles of the lower limbs. The distribution of work of the lower limbs would also increase and an increase of running economy of the runner would possibly appear. It also can be implied that due to the higher results of VO2 max of the trained collegiate runners when compared to the typical individual, there was no significant change in regards to the participants' VO2 max when their training period had ended.

The participants in the PowerCranks™ group did express that they felt a decrease in their RPE when post training test results were completed during their VO2 max test. Because the RPE of the participants was not fully recorded or analyzed, no definite conclusions could be made regarding this information. However, with this information, it may be implied that adding an additional cross training regimen to the athletes' exercise program may improve the athletes' conditioning. However, there was only a slight decrease in RPE of the standard crank control group when the testing was completed. The decrease in the PowerCranks™ groups RPE mean proposed the implications of greater training and a more difficult task regimen was experienced when compared to the control group. With the greater training experienced by the participants, this would possibly result in less fatigue experienced by the participant during VO2 max testing.
Future Research

This study had a short duration of training with no chronic muscle adaptation with independent cycle cranks. Further research is needed to examine the long term benefits of training with the device. As trained collegiate distance runners were used for this study, it would be needed to examine the benefits and possible increase of running economy of runners not highly trained for competition. It would also be important to examine the results of a longer training duration and if that chronic adaptation and training would produce an increase of running economy when the independent cycle crank was used as a crosstraining method. An increase of the number of participants would also be beneficial to account for an increase in percentage of complete participation of the study.

Examining the muscle activity, with electromyography, would also be beneficial to determine which muscles of the lower leg are activated, or produce greater activation, with the use of the independent cycle crank. A closer look at which muscles are newly activated and more utilized would also support the conclusions that lesser workload would be created.

Conclusions

This study has shown that collegiate distance runners who completed 6 weeks of training with the PowerCranks™ independent cycle crank device produced no significant changes in running economy or VO₂ max when compared to a control group using the standard crank cycle. The participants VO₂ max testing showed no
significant change from pre- to post-testing within each of the groups. There was also no significant change in results from pre- and post-testing of each of the groups with running economy. There was a slight decrease in running economy results for the PowerCranks™ group, although not significant. This can be implied, that the independent cycle crank possibly trained less utilized muscles, which would produce a greater need for oxygen in those muscles. Thus, a lesser economy of motion would be the result. Further research is needed to examine the influence of training with an independent cycle crank over a longer duration to see if an improvement in running economy would be produced.
REFERENCES


APPENDICES
Effect of Powercrank Training on Running Economy and Muscle Activity Level

Introduction/Purpose Professors Eadric Bressel and Dale Wagner in the Department of Health, Physical Education, and Recreation at Utah State University are conducting a research study to find out more about how stationary bicycling with and without powercranks influences running performance. Powercranks are identical to traditional bicycle cranks yet move independent of each other and thus impose a different training stimulus. You have been asked to take part because you are between the age of 18 and 30 years and are on the USU track and field team. There will be approximately 30 participants asked to participate in this research.

Procedures If you agree to be in this research study, the following will happen to you. You will complete two days of pre-tests lasting approximately 40 minutes each day. After pre-testing you will undergo a 6 week training program that requires you to ride a stationary bicycle ergometer three days per week for 30 minutes at a moderate intensity. After 6 weeks of training, you will complete two days of post-tests that will be identical to the pre-tests. One test performed during the pre and post test will be a graded maximal exercise test on a treadmill to determine cardiovascular fitness level (i.e., VO2max test). A second pre and post test will include a sub-maximal run on a treadmill to assess running economy. The running economy test will be performed at 2 and 4 weeks post training to monitor any early changes in economy that may have taken place. Pre and post-tests will require you to breath through a two-way valve mouth piece so that oxygen consumption can be computed. Additionally, the muscle activity of select lower leg muscles will be monitored during the running economy tests using electrodes attached to the skin.

New Findings During the course of this research study, you will be informed of any significant new findings (either good or bad), such as changes in the risks or benefits resulting from participation in the research, or new alternatives to participation that might cause you to change your mind about continuing in the study. If new information is obtained that is relevant or useful to you, or if the procedures and/or methods change at any time throughout this study, your consent to continue participating in this study will be obtained again.
INFORMED CONSENT
Effect of Powercrank Training on Running Economy and Muscle Activity Level

Risks Participation in this research study may involve some temporary fatigue and exhaustion. However, the fatigue and exhaustion that you may experience will not be greater than what you experience during typical training. It should be noted that as with any study there may be some unforeseen risks that could occur that are not described above.

Benefits There may or may not be any direct benefit to you from these procedures. You will be provided information on your cardiovascular fitness and will be given the opportunity to train using a different modality that may improve fitness. Additionally, the investigators may learn more about how stationary bicycling influences cardiovascular fitness in well trained athletes.

Voluntary nature of participation and right to withdraw without consequence Participation in research is entirely voluntary. You may refuse to participate or withdraw at any time without consequence or loss of benefits.

Confidentiality Research records will be kept confidential, consistent with federal and state regulations. Only the investigator will have access to the data which will be kept in a locked file cabinet in a locked room. Personal, identifiable information will be kept just long enough to analyze the data. As soon as the data is analyzed identifiable information will be destroyed.

Care if Harmed In the event you sustain injury from your participation in this research project, Utah State University can reimburse you for emergency and temporary medical treatment not otherwise covered by your own insurance. If you believe that you have sustained an injury as a result of your participation in this research project, please contact the Vice President or Research Office at (435) 797-1180.

IRB Approval Statement The IRB (Institutional Review Board for the protection of human participants at USU) has reviewed and approved this research study. If you have any questions or concerns about your rights, you may contact the IRB at (435) 797-1821

Copy of consent You have been given two copies of this Informed Consent. Please sign both copies and retain one copy for your files.
INFORMED CONSENT
Effect of Powercrank Training on Running Economy and Muscle Activity Level

Investigator Statement “I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered.”

Explanation & Offer to

Answer Questions
If you have other questions or research-related problems, you may reach Professor Eadric Bressel at 797-7216 or Professor Dale Wagner at 797-8257.

Signature of PI

Signature of Co-PI

Signature of PI
Eadric Bressel
Principal Investigator
797-7216

Signature of co-PI
Dale Wagner
Co-investigator
797-8257

Signature of Participant By signing below, I agree to participate.

Participant’s signature Date

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Date Created: 10/5/06
PowerCranks Study Data Collection Form

# ___________________________
Name: ______________________

Treatment Group: ______________________

Age: _______ Class: _______ Years on team: _______

Baseline

Height: ______ inches Weight: ______ kg BMI: ______
VO2 max: _________ ml/kg/min _________ ml/min
RPE: _______
Economy VO2: _________ ml/kg/min _________ ml/min

Mid-Study Economy (if applicable)

Height: ______ inches Weight: ______ kg BMI: ______
Economy VO2: _________ ml/kg/min _________ ml/min
RPE: _______

Post-test

Height: ______ inches Weight: ______ kg BMI: ______
VO2 max: _________ ml/kg/min _________ ml/min
RPE: _______
Economy VO2: _________ ml/kg/min _________ ml/min

Comments:
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