CHAPTER ONE:

INTRODUCTION

INTRODUCTION

In order for an athlete to become successful in their particular sport, proper training and hard work are two essential ingredients. There are many different philosophies regarding successful training. Some argue that a training style without any changes is adequate for an athlete to experience improvements in one's performances. Whereas, others feel that an overload training style is the only way a competitor will enhance their performance. Overload training is the process of stressing an individual to provide a stimulus for adaptation and supercompensation (Fry, R., Morton, A., Keast D., 1991, Budgett, R., 1990, VanBorselon F., Vos, N., Fry, A., Kreamer, W., 1992). Unfortunately, overload training for a continuous period of time results in performance decrements in the athlete. If performance decrements are prolonged, an overtraining response may be developing.

Fry A., Kreamer, W., Lynch, J., Triplett, N., Kozaris, L. (1994) and Kuipers, H., Keizer, H. (1988) hypothesize that overtraining syndrome involves either a short- term or a long- term imbalance between exercise and recovery, resulting in prolonged performance decrements. Other symptoms besides impaired physical performance can occur as a result from overtraining. Athletes commonly complain of fatigue at rest, a prolonged recovery rate following activity, inability to maintain the performance standards that they had already achieved, lack of energy, and loss of competitiveness (Stone, M., Keith, R., Kearney, J., Fleck, S., Wilson, G., Triplett, N. 1991, Callister R., Callister, R., Fleck, S., Dudley, G. 1990). These symptoms are commonly lumped together and often called 'staleness' in a sport (Budgett, 1990). Unfortunately, there are no reported physical signs that are consistent with the overtraining syndrome. Fry et al. (1991) and Budgett (1990) feel that an increased early morning heart rate, a slow return to normal pulse rate after exercise, increased oxygen consumption, and a decreased immunity are the common physical symptoms reported. Feelings of depression, decreased self- esteem, and anxiety are psychological symptoms that many sufferers experience (Budgett, 1990). Fry, A., Kreamer, W., Van Borselen F., Lynch, J., Marsit, J., Ro, E., Triplett, N., Knuttgen, H. (1994) hypothesize that there is a possibility that these symptoms may depend on the type of exercise: aerobic training or anaerobic training. In addition to the variability of symptoms in overtraining syndrome, the severity varies greatly among individuals.

Researchers feel that overtraining syndrome is hard to diagnose inspite of the performance decrements and the increased fatigue since many different symptoms vary among the individuals. An overtraining response can differ between individuals and can occur at a different time point in his/her training regimen. Thus, there is no 'gold standard' in diagnosing overtraining syndrome (Fry et al., 1991, Budgett, 1990, Kuipers et al., 1988). Kuipers et al. (1988) feel the best way to define overtraining is when performance deteriorates or failure to progress occurs in spite of training. The only apparent way to recover from overtraining is complete rest from that activity. Budgett (1990) suggests that each case should be looked at individually but rest for as long as three to five weeks is recommended. In order to prevent total detraining, if possible, the athlete should be active in a sport that is completely separate from their main sport.

However, they should stay away from competitions all together. Highly motivated athletes appear to be at the highest risk. Overtraining may actually prevent the athletes from becoming elite performers.

STATEMENT OF PROBLEM

Many researchers have conducted investigations directed at identifying what exactly triggers overtraining syndrome. Unfortunately, there isn't a standard diagnosis for overtraining syndrome. As stated earlier, overtraining may result from a sudden increase in training or inappropriate training neglecting recovery and supercompensation. Also, it appears that susceptibility in overtraining syndrome varies among the individuals. Recent studies suggest that the intensity of training seems to contribute more than the duration of training for inducing overtraining. (Kuipers et al., 1988)

A decline in maximal muscular force results in performance decrements in the individual. The force depression that results from the overtraining effect introduced a very important question. Is it a result of central or peripheral factors? For example, decreased output from the central nervous system (i.e. effort) could depress force. Also, changes within the muscle may impair performance. In this study, the two training protocols on different legs determined whether force declines are muscular (peripheral) or psychological (central). One leg will undergo an overtraining program, and the other leg a normal program. If both legs show decreased performance following training then the deficit is likely to be psychological. If the overtrained leg decreases and the trained leg increases in performance, the force decline is likely to be peripheral, that is within the muscle fiber itself.

Many of the studies have looked at aerobic training and the overtraining response, but only a few have addressed resistive training and the effects from overtraining. Fry et al. (1994) were the first and only to successfully develop a resistive training program that generated an overtraining response. The purpose of this study was to observe muscle strength performance decrements after overtraining one leg in comparison to properly training the other leg by knee extension exercises for two weeks in trained males between the age of 18- 35 years. Also, after overtraining the one leg for two weeks, the leg was placed on a reduced training program so that both legs are on the same low intensity training program for one week in order to look at the recovery of the overtrained leg.

SIGNIFICANCE OF STUDY

Overtraining can be very dangerous to an athlete. The athlete could suffer from depression, decreased performance, and an overall feeling of fatigue. Highly motivated athletes tend to be at the highest risk. This is also a source of controversy between coaches. Some feel the only way for an athlete to experience any improvements in performance is to overtrain the body. Others feel that the risks far outweighs the possible benefits. Being that there is no true standard way to diagnose overtraining syndrome, it is hard to detect and will probably be a controversial issue for several years to come. Fry et al. (1994) is the only study available that has been able to produce an overtraining response. The present study attempted to replicate the results of decreased performance after an overtraining period. Also, this study compared the effects of an overtraining protocol in one leg and a normal training protocol in the other leg, and also the recovery process of the overtrained leg.

RESEARCH HYPOTHESES

H_0: There are no differences in maximum voluntary force between contralateral legs subjected to an overtraining protocol and a normal training protocol.

H_0: There was be no difference in the muscle maximum strength in the overtrained leg after it has been on the low intensity training program(reduced training program) for one week in the apparently healthy trained males between the ages of 18- 35 years.

DELIMITATIONS

The following delimitations were acknowledged in the design of the study:
1) The subjects were apparently healthy weight trained (for at least six months) males between the ages of 18- 35 years.
2) Leg strength was measured isokinetically looking at peak torque and power using the Biodex.
3) Overtraining was determined if there was a performance decrement between the pre- and post-tests using the Biodex.

LIMITATIONS

The following limitations were applied to this investigation:
1) The limited number of subjects recruited due to the specific population of being apparently healthy weight trained (for at least six months) males between the ages of 18-35 years.
2) The subjects were recruited in a nonrandom fashion by signs posted at the Weight Club and Hokie Gym.
3) Despite that the subjects had been training for six months, the investigator had no control over previous leg workouts. (i.e.: intensity, duration, and frequency)

BASIC ASSUMPTIONS

The following basic assumptions were made by the investigator:
1) The individuals had been training for at least six months.
2) The individuals complied to all of the training sessions for both legs.
3) The Biodex and nautilus equipment were properly calibrated for each test and training session.
4) The subjects gave his maximum effort during the testing and training sessions.

DEFINITIONS AND SYMBOLS

1) overtraining (OT)- increase in volume and/or intensity training workouts resulting in a decreased performance specific to the training modality and prolonged fatigue.
The overtraining session's duration and intensity was 6 days per week at 100% repetition maximum based upon the pre-testing results.
2) standard training (TR)- based upon pre- testing results, training session duration and intensity: 2 days per week at 50% repetition maximum.
3) repetition maximum (RM)- the maximum load that a muscle group can lift over a given number of repetition(s) before fatiguing.
4) leg extension exercises- assuming a seated position on the machine, place ankles behind and in contact with roller pad with knee at 90% angle. With back flat against back pad, extend the leg(s) upward to create a full knee extension. Lower pad slowly and under control to beginning position. One needs to exhale through upward phase, and inhale during the downward movement.
5) pre- test- the first test before training on the Biodex.
6) post-test- the second test after two weeks of training on the Biodex.
7) final test- the third test after the reduced training week on the Biodex.

SUMMARY

Overtraining is an imbalance between exercise and recovery. Unfortunately, the mechanisms causing overtraining are not known. Fry et al. (1994) claim that overtraining can result from an increase in training volume or intensity, leading to decreased performance. The symptoms, susceptibility, and severity varies among the individual. For the above mentioned reason, researchers have an overall belief that there is no "gold standard" in order to diagnose overtraining syndrome. Some symptoms include leg fatigue, depression, inability to maintain current performance, and an overall fatigue. Highly motivated athletes seem to be at the highest risk. Some researchers feel that overtraining is more dependent upon the intensity than the frequency of training. Many studies have looked at the effects of overtraining in aerobic conditioning, but few have looked the effects of overtraining in anaerobic conditioning. This investigation compared the effects of muscle strength performance in the quadricep after two weeks of overtraining one leg and regularly training the other leg. This study also sought to determine if overtraining results from peripheral or central factors. Finally, this study evaluated the possible benefits for the subject during a reduced training period after overtraining.

CHAPTER TWO:

REVIEW OF LITERATURE

INTRODUCTION

Overtraining syndrome can be very dangerous for highly motivated individuals. Some researchers feel that it can possibly prevent some "accomplished" athletes from becoming "elite" athletes. The overtraining syndrome is also known as 'staleness' or 'burn out'. Overtraining syndrome refers to the final stage in a proposed continuum of increasingly severe, chronic fatigue states that may develop (Callister et al., 1990). Performance is often compromised when suffering from overtraining. Some physical signs besides performance decrements are overall feeling of fatigue, loss of body weight and body fat, increased heart rate at rest and during submaximal exercise, changes in resting blood pressure, increased risk of illness and injury, and chronic muscle soreness (Callister et al., 1990). Overtraining appears to vary in each individual. The symptoms associated with overtraining also seem to be different in aerobic versus anaerobic sports. There is currently no "gold standard" available to identify symptoms of overtraining.

Many studies have been conducted examining the effects of overtraining and aerobic conditioning. However, few studies are available examining anaerobic conditioning, resistance training, and overtraining. In fact, the report of Fry et al. (1994) is the only investigation which actually reaches a definitive state of overtraining after a high intensity resistance training program. This literature review will look at various studies that investigate neuromuscular adaptations to exercise and fatigue, overtraining syndrome, high-intensity resistance training programs, the possibility of developing overtraining, and recovery after overtraining while on a reduced training program.

NEUROMUSCULAR AND MUSCULAR ADAPTATIONS

Is it possible to obtain increases in strength without a muscular adaptation but actually an neuromuscular adaptation from the nervous system? Yes, Enoka (1994) states that one common approach in examining the neuromuscular mechanisms behind training-induced increases in strength is compare the time course of changes in EMG, a measure of neuromuscular activation level, and muscle size. Many studies show a disproportionately larger increase in the maximal EMG than the increase in muscle size. The maximal EMG begins to show an increase before the muscle shows an increase in cross sectional area. Increases in strength the first six weeks generally are neural adaptations. Whereas, increases in strength after the first six weeks of training are generally muscular adaptations. Imagined contractions, coordination, coactivation, cross education, bilateral deficit, reflex potentiation, synchronization are seven different neural adaptations that play an important role in the beginning part of training (Enoka, 1988). These different neural adaptations are quite common especially in novice athletes. Also, adaptations tend to occur throughout the whole nervous system. It is very difficult to determine what types of neural adaptation are occurring during the strength gains. Sale (1986) also believes that rapid strength gained initially after the first training session results from a neural not muscular adaptation. These neural adaptations cause rapid activation of the muscles more quickly and improve coordination of the voluntary contraction.

In support in Enoka's beliefs, Staron et al. (1994) recite that there are two major factors that contribute to strength gains: neural adaptation and hypertrophy. Muscular adaptations play an important role in strength gains during training. This increase in muscle size can result from an increase in the cross sectional area of the muscle (hypertrophy) or an increase in the number of muscle fibers (hyperplasia). Initial strength, duration of training, and the training type influence the magnitude of the cross sectional area. In six to eight weeks of training, muscle strength gains can range from nine to fifteen percent depending on the muscle (Enoka, 1988). Additionally, Gillam (1981) looked at the effects of frequency and muscle strength enhancement in weight training. He suggested that along with an intense workout that the more frequent a stress occurs the greater the muscles adapt. However, without proper recovery from the stress, fatigue settles in quickly.

The central nervous system, peripheral nerve, neuromuscular junction, and the muscle fiber are the chain of sites for normal contraction and the potential sites for fatigue. Force can decrease if any of these sites are disturbed resulting in fatigue (Leiber, 1992). Many researchers have studied whether the decline in maximal force is centrally or peripherally located. Bigland-Ritchie et al. (1986) defines neuromuscular fatigue as any reduction in maximum force generating capacity, regardless of what type of work being is done. She and her colleagues found that in highly motivated athletes central fatigue is not likely. As the muscle was fatigued during maximal voluntary contraction, they tried to electrically stimulate the muscle. Bigland-Ritchie et al. (1986) hypothesized that if the central fatigue occurred, the muscle's force output would increase. However, they discovered there was no stimulated strength increase concluding that all the motor units were being recruited. In conclusion, the muscle was peripherally fatiguing at the actual muscle site.

OVERTRAINING SYNDROME

Sometimes muscle overload during workouts is beneficial for athletes especially before a period of reduced training preceding a major competition. Unfortunately, fatigue, a failure to sustain an expected or required muscular force, may result from overload during an athlete's workout. If fatigue is prolonged and becomes too great, recovery and adaptation may not occur in the appropriate amount of time. Resulting from this scenario, overtraining syndrome often compromises performance as well as affects physical and psychological well-being (Kuipers et al., 1988; Budgett et al., 1990). This can occur at all levels of performance in athletes. Fry et al.(1991) feel that there is a need for a systematic approach to research overtraining aiming at the development of methods for its identification and prevention.

Overtraining is very difficult to diagnose since there isn't a diagnostic test to determine overtraining. Kuipers et al. (1988) claims diagnosis of overtraining syndrome based on medical history, physiological, and psychological symptoms is difficult due to the susceptibility varying greatly among athletes. The major physiological symptoms are a decreased performance and muscular strength, a loss of coordination and appetite, a change in heart rate and blood pressure, and an inadequate immune system preventing infections. Feelings of depression, loss of desire to compete, decreased self-esteem, and overall changes in personality are the main psychological signs of overtraining (Fry et al. 1991). Unfortunately, there isn't a model yet that can predict overtraining and be used to prevent the symptoms of overtraining

Stone et al., (1991) feels overtraining is an inadequate adaptation of the central nervous system resulting from a lack of appropriate stimulation in terms of movement patterns. Researchers feel rest possibly up to eight weeks is the only way to recover from overtraining syndrome. Stone et al., (1991) state three possible ways to prevent overtraining: proper intensity changes in workouts, gradual changes instead of sudden changes in workouts, and periodization workouts. Budgett et al. (1990) recommends that a sudden increase in training load should be avoided. They feel it is best to increase the workload gradually at a steady pace of five percent per week for optimal training.

OVERTRAINING AND RESISTIVE TRAINING PROGRAMS

Strength trained individuals tend to respond differently to resistance training stresses than do endurance athletes. Anaerobic overtraining tends to occur more in young athletes. (Van Borselen et al., 1992) These researchers feel there is a four stage theoretical development of anaerobic overtraining: no effect on performance with altered neural function, probably no effect on performance with altered motor recruitment, probably decreased performance with altered motor coordination, and decreased performance with decreased motor coordination, respectively. Researchers feel intensity seems to contribute to overtraining more than duration.

A short-term near maximal intensity machine resistance training program was also developed to induce overtraining. Fry et al. (1994) completed this study before the above mentioned study. The researchers used nine volunteers who were currently recreational weight lifters. There were five in the overtraining group, and four in the control group. Both groups worked on the squat machine measuring repetition maximum. Both groups started out with the first two weeks being familiarization sessions which included a 1 RM test. The next three weeks were for training. The control group reported two days a week for a warm- up and a low volume and low intensity. The training group reported five days a week: two days the workout was the same as controls and the other three days the workout was an additional eight repetitions of ninety five percent of 1 RM. Both groups were tested four times: after familiarization weeks, after training weeks one, two, and three. Isokinetic torque was measured on the Cybex II in order to determine muscular strength.

After the training and the final test, Fry et al.(1994) determined that the training group displayed a significant increase in 1 RM strength on the squat machine by test two (after one week of training) and remained the same for the other two weeks. The controls achieved a significant increase also by test four which was taken at the completion of the study. However, the researchers felt that overtraining was not induced since the training group actually showed an increase in muscle strength performance. Fry et al. (1994) feel that despite improvements in the training groups one repetition maximum, that other performance tasks may show a different result. Therefore, they recommended for future studies an intensity- dependent resistance exercise overtraining program of greater intensity than their program perhaps as high as 100% 1 RM.

Only one study has attempted to experimentally induce an overtraining response during resistive training program. Fry et al. (1994) used seventeen weight trained males who were randomly divided into either an overtraining group (OT; N=11) or a control group (CON: N=6). The training consisted of a lower body workout performed on a squat resistance exercise machine. This activity primarily involved the hip and knee extensor muscle groups. The squat exercises were the only exercises allowed to be performed in the lower body during the three week study. The first week consisted of two familiarization sessions with the squat machine. Both familiarization sessions included an one repetition maximum (1 RM) assessment after a warm-up. During weeks two and three, the OT group performed a maximal relative intensity lift (100% 1 RM) but a low number of repetitions. Specifically, the workout for the overtraining group was a controlled warm -up followed by ten sets of one repetition at 100% 1 RM. There was two minutes of rest in between each set. If the subjects were unable to make the lift, the weight was lowered by 4.5 kg. The training protocol was repeated six days a week. The CON group reported one day a week to perform a low intensity exercise protocol. The subjects were assessed by measuring isometric strength of the quadriceps on the Cybex II, Also, the maximum number of repetitions at seventy percent of 1 RM was performed on the squat machine on the off day(i.e. the seventh day of the week). The CON group also reported once a week for the same assessments.

The most critical finding after the third week was that overtraining was induced after a high intensity resistance training program. After the final test, there was depressed muscular strength performances in the OT group. Specifically, the authors felt these changes were a direct result from the high intensity resistance training protocol. However, the CON group improved in muscle strength performance. Fry et al. believed this result was due to a learning effect. The OT group experienced an approximate twelve kilogram decrease in one repetition maximum strength. There was also a decrease in stimulated leg extension torque measuring isometric strength in the OT group by approximately fifteen percent. There was a increase in voluntary leg extension torque measuring isometric strength in the control group by approximately by twelve percent. Other than the decreased muscle strength performance in the OT group, there were no other apparent signs of overtraining such as changes in body weight, heart rate, sleep, or mood. Therefore, the investigators determined that was it possible to induce 1 RM performance decrements after using a high- intensity, low- volume resistance exercise overtraining program in weight trained males.

In the late eighties and early nineties, researchers started to realize that anaerobic overtraining needed to be investigated more thoroughly. Callister et al. (1990) looked at the physiological and performance responses to overtraining in elite judo athletes. The study lasted for ten weeks looking at the performance after an increased resistance training workout along with regular and increased judo workouts. Fifteen national judo athletes volunteered for this study. The study consisted of three phases during the ten weeks. Phase I (weeks 1-4) was considered a baseline phase were the judo athletes performed their regular workouts of judo, interval, and resistive training. Phase II (weeks 5-8) the volumes of interval and resistive training were increased fifty percent while the intensity remained the same. Phase III (weeks 9-10) the resistive and interval training were reduced to the phase I state, and the judo training was doubled. The experimental design allowed the investigators to look at the different effects of the training volumes increasing twice, but by different training modalities.

Testing was completed on the same day of each test week before daily training in weeks two, four, eight and ten. Isokinetic strength changes were assessed in the knee and elbow flexors and extensors using a Cybex II. Peak torque was measured at five different angular velocities. Isokinetic force output significantly increased during phase I, remained unchanged during phase II, and decreased during phase III in all four muscle groups. The decrease in isokinetic strength in all four muscle groups at all tested velocities proposed that the greatest impact of overtraining occurred during phase III. Despite the decreases in peak torque, there was no noticeable decrease or increase during all phases in repetition maximum strength. Callister et al. (1990) suggested that the difference between the failure to improve RM and the isokinetic strength decrements may represent a difference between the effect of overtraining on maximal force output and repeated muscular effort or muscle endurance. The researchers support the results of this study conclude that overtraining itself may have detrimental effects on performance without the development of the other symptoms of staleness.

Hakkinen et al. (1988) had eight elite Finnish weight lifters perform one week of very intense strength training looking at adaptive neuromuscular responses. The experimental design consisted of ten high intensity workouts. The weightlifters lifted at least once per day. In addition, the weightlifters performed two workouts every other day. An electromechanical dynamometer was used to measure neuromuscular performance; specifically, isometric maximal bilateral force of the leg extensors. Results showed no significant changes in isometric force before each morning workout when compared to the first morning workout. However, there was a significant decline in maximum force from morning to afternoon workout. This neuromuscular response was expected due to the high overall stress of the workout the weightlifters had to perform. The results indicated only a slight decrease in maximum force and neuromuscular activity during each training session. In fact, researchers stated no systematic changes were found at the basic level of neuromuscular performance during the one week study.

In another study, Hakkinen et al. (1988) recruited eight top-level weightlifters to perform a very intense workout twice in one day. The first workout consisted of the Olympic snatch, Olympic clean and jerk, and the front squat. In the second workout, four hours later, the subjects performed a similar tough workout. A dynamometer was used to measure bilateral isometric force, force-time, and relaxation-time parameters of the leg extensor muscles. Hakkinen et al. (1988) found significant decreases in neuromuscular strength from the beginning of the workout to the end of the workout in both sessions. In first workout the subject's maximal isometric strength decreased from 3914+/- 798 to 3640+/- 712 Newtons. The second workout followed a similar pattern of 3865 +/-812 to 3562+/- 678 Newtons, respectively. The researchers concluded the decreased in maximal strength was associated with decrease in neural activation of the exercised muscles.

REDUCED TRAINING AFTER OVERTRAINING

Falsetti et al. (1983) states that overload training is used by some coaches as a form of training. It is used as a large stimulus for adaptation to promote a fitness peak prior to a major competition. Decreases in performance for a short period of time commonly occur. But following an extended recovery period, commonly known as a taper period, an increase in performance capacity usually results.

There currently are no studies available that specifically investigate a reduced training program, often called a taper period, after inducing an overtraining effect. Only one study was available that looked at a taper period after attempting to induce overtraining in swimmers (Costill et al., 1991). However, they were unable to get a true overtraining effect in the swimmers. The swimmers trained together for four weeks once a day in the twenty five week study. The next six weeks the swimmers were broken into two groups: one trained twice a day and the other trained once a day. The next fourteen weeks, the swimmers trained once a day again. This study found that performance did not improve in the twice a day group anymore than the once a day group.

After the heavy training weeks, the investigators placed the swimmers on a taper period. This period lasted for two to three weeks before weeks thirteen and twenty five which were before major competitions. In order to assess the effects of the two types training sessions, the performances were compared from competition during nontapered and tapered periods. Both groups improved approximately a little over three percent after the tapered period. There was significant improvement after the taper period during performances versus nontapered performances.

SUMMARY

The effects of overtraining during resistive training is a new topic. Currently, only one study examines the role of resistance training and overtraining in the literature. Others have come close, but Fry et al. (1994) and other researchers have determined that overtraining is more dependent upon intensity than volume or frequency. In a subsequent study, Fry et al. (1994) was able to create an overtraining program during resistive exercise on a squat machine. Callister et al. (1990) was able to induce overtraining in judo athletes. However, it was during judo training, not during resistive or interval training. The resistive and interval training was only increased by fifty percent and the judo workouts were increased one hundred percent. Also, Costill et al. (1991) investigated a reduced recovery and found improvements after the attempt to overtrain the athletes. From these three studies, one could conclude that overtraining is more dependent upon intensity than volume.

CHAPTER THREE:

METHODOLOGY

SELECTION OF SUBJECTS

Nine weight trained males between the ages of nineteen to thirty-seven years of age volunteered to be in an overtraining of the quadricep study through flyers posted on campus and at The Weight Club. The trained males that were selected had been lifting on a regular basis for at least six months.

Table 1. Subject Characteristics

Subjects	Age (yrs)	Height (in)	Weight (lbs)	Months Lifted
1	21	68	164	6
2	23	68	191	48
3	37	71	183	96
4	24	68	151	6
5	26	70	266	10
6	22	77	220	36
7	21	68	174	6
8	26	68	136	10
9	22	71	201	6

Prior to being included in the training investigation, the subjects completed a medical/health history questionnaire and signed an informed consent. Orthopaedic limitations requiring medications and major medical diseases (i.e. heart disease) were considered to be exclusion criteria. All subjects had met the inclusion criteria based on the completed medical/health history questionnaire. If the subjects had no discomforts or concerns with the testing and training procedure during the orientation week and was an appropriate candidate, he reported to the Human Performance Laboratory for pre-testing. The first week of the study was known as the familiarization week. The subject and investigator met twice and went through an orientation of the Biodex testing and leg extension exercises on the nautilus machine.

Before participation in the study, subjects were given a written and verbal explanation of the study, including benefits and potential risks of participation, freedom to terminate participation at any time, and signed an informed consent approved by the Institutional Review Board at Virginia Polytechnic Institute and State University to review and sign.

EXPERIMENTAL PROCEDURES

Week 1: Familiarization Week

After the informed consent was signed, the subject started week one of the four week study. Week one, the familiarization week, consisted of one or two meetings depending on the subjects' comfortability with the training and testing procedures. The subject was oriented with both the Biodex and the leg extension nautilus equipment. During the orientation of the Biodex, the subject became comfortable with the testing procedure at the speeds of 120, 240, and 360 degrees per second while conducting isokinetic concentric leg extension exercises. During the orientation of the nautilus equipment, the subject completed a 1 x 1-100% RM leg extension on each leg. This gave a basis upon what the controlled warm up will be for the first training session.

Weeks 2 & 3 - Training

Week two started the training program for the subjects. The subjects first reported to the Human Performance Laboratory for a pre-test to measure peak torque (ft-lbs) and power (watts) in the quadricep while performing a leg extension exercise on the Biodex. The pre-test started with the subject warming up on a cycle ergometer with no load for five minutes. While the subject was warming- up, the investigator calibrated and set up the Biodex. The subject was securely attached to the Biodex in order to prevent any possible movement that may enhance their results. Once comfortable and situated, the subject performed isokinetic concentric knee extension exercises on the Biodex at three different speeds. The subject completed the first speed with five repetitions at 120 degrees per second. The second speed was 10 repetitions at 240 degrees per second. The final speed of the knee extension pre-test was 15 repetitions at 360 degrees per second. Ninety seconds of rest was taken in between each speed and set. Subjects were instructed to concentrate on giving give their maximal effort during each knee extension lift, and not to focus on the flexion part of the lift. The test was conducted on both legs and lasted approximately thirty minutes.

Approximately 24 hours later, the training began for the subject. The subject reported to the Hokie Gym, the nautilus room in War Memorial Hall, or The Weight Club. The subject trained one leg six times a week, and the other leg only twice a week. The days that the training overlapped, the subject trained at the same time but only one leg at a time. The type of training was assigned randomly to each leg.

The training protocols for each leg are summarized in Table 2. For the (OT), the exercise session with a controlled warm- up of ten repetitions at 50 percent of one repetition maximum strength of the quadricep using the leg extension nautilus machine. It was based upon the repetition maximum strength measured during the familiarization week. At the conclusion of the warm- up, the overtrained leg 's 1x 1- 100% RM was reassessed. This required a few extra lifts. After the warm- up and the 100 percent repetition maximum assessment, the overtrained leg lifted 10, 1 RMs with 90 seconds rest in between each lift. If a lift was unsuccessful, the subject's lift did not count and the weight was reduced by 10 pounds. The subject completed the overtraining workout six days a week on the leg extension nautilus machine for two weeks. The seventh day of the first week served as an off day. Each training session lasted approximately 30 to 45 minutes.

After the two weeks of training, the subject completed a post-test on the Biodex measuring peak torque and power. The testing protocol was conducted exactly the same as the pre-test with both legs separately performing the isokinetic concentric leg extension exercise at the three speeds of 120, 240, and 360 degrees per second. The subject reported approximately the same time each testing session in order to maintain validity and reliability with the testing. Also, each testing and training day, the subject was asked to refrain from all caffeine, alcoholic beverages, nicotine products, and pain products for at least twelve hours. Finally, the subject rated leg soreness on a scale from 0- 10 everyday. Zero on the soreness scale meant absolutely no soreness, and 10 was considered to be very severe soreness. The scale helped screen the individual's soreness to try and prevent injury.

For the (TR), the same controlled leg extension warm-up of 10 repetitions at 50% maximum of the quadricep strength based upon the subject's familiarization weeks one repetition maximum strength. Following the warm-up, the subject 's a 1x 1-100% RM was retested. This required a few more lifts. Then, the subject performed a low volume, low relative intensity exercise session. The protocol was 1x 5- 30% RM, 2x 5- 40% RM, 3x 5- 50% RM based upon the most recent repetition maximum. The subjects rested for 90 seconds in between each set. This leg trained twice a week using the nautilus leg extension machine. Subjects were also asked to rate the soreness in the TR leg on the same zero to ten scale. The trained group lifted on every third day of the overtrained groups' schedule.

At the end of week three, the subject' s trained leg completed a post-test at the same time of the overtrained leg' s post-test for the subject's convenience. This test was also conducted exactly the same as the pre-test. The subject executed their maximal effort at 120, 240, and 360 degrees per second during the isokinetic concentric leg extension test. Once again, each testing and training day, the subject was asked to refrain from all caffeine, alcoholic beverages, nicotine products, and pain products at least 12 hours.

Week 4- Reduced training

During the week after the post- test, the subject trained both legs at the same low intensity workout for one week that the TR leg performed during weeks two and three. However, both legs trained separately based upon their one repetition maximum strength to continue the isolation of each leg. During week four, the subject performed the workouts twice like the TR leg's exercise sessions during weeks two and three. One 100 percent repetition maximum was measured each day similar to weeks two and three. After the reduced training week, approximately 24 hours later, the subject completed a final test on the Biodex. The same test was run as the previous two tests measuring peak torque and power at the three speed levels. The subjects were reminded to give their maximal effort during the isokinetic concentric leg extension part of the test only. Once again, he refrained from all caffeine, alcoholic beverages, nicotine products, and pain products at least twelve hours. Upon completion of the study, to insure compliance standards with most of the responsibilities, all subjects were asked to complete an anonymous questionnaire (Appendix C).

Table 2. Subject's Training Schedule

	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
Week 1	**fam. w/eq.			**fam. w/eq.			pre-test
Week 2	OT only	OT only	OT &TR both legs	OT only	OT only	OT &TR both legs	off
Week 3	OT only	OT only	OT &TR both legs	OT only	OT only	OT &TR both legs	post-test
Week 4			TR both legs			TR both legs	final test

** fam. w/eq.= familiarization week with equipment (Biodex and knee extension machine)

STATISTICAL ANALYSIS

After the data was collected, a two way ANOVA with repeated measures was computed between conditions and between time within each condition from the measurements taken on the Biodex. Statistical significance will be chosen at an alpha level of .05 for all data.

CHAPTER FOUR:

RESULTS

This study was a four week study consisting of three evaluations (pre-, post-, and final) on the Biodex. The pre-test was conducted before training started. The post- test was conducted after the two weeks of training. The final test was completed after a week of reduced training. The purpose of the reduced training was to look at the recovery phase. Each leg (OT & TR) was tested separately performing an isokinetic concentric leg extension at three speeds: 120, 240, and 360 degrees, respectively. Peak torque, relative torque, and average power of the leg extension were studied during testing. Finally, the subject's leg extension one repetition maximum was assessed every training day.

PEAK TORQUE

Peak torque (ft/lbs) was evaluated in all three speeds during each of the three tests. In order to see an overtraining effect in the quadricep of each subject's leg, a significant decline in force output needed to be measured. There were no significant statistical differences ($p>0.05$) between OT and TR at any of the three speeds from pre-test to the final test.

Figure 1 demonstrates the mean peak torque values for the overtrained and trained legs during each evaluation at 120 degrees per second. In the OT leg at 120 degrees, the mean peak torque (ft-lbs) value decreased from pre- to post-test. Following the reduced training period, the subjects generated more force output in their final test by increasing the peak torque above the original pre-test mean. The TR leg demonstrated a decrease in peak torque performance throughout the pre-, post-, and final, respectively.

Peak torque at 240 degrees did not vary too much throughout the study in the OT and TR leg. Figure 2 displays that there actually was a very slight but insignificant increase from pre- to post-test in the overtrained leg. A very slim but not statistical decrease below the initial mean was measured in the mean peak torque during the last test. In the TR leg, the peak torque at 240 degrees decreased from pre- to post-test, then increased to a higher peak torque in the final test than the pre-test, respectively. To further support that overtraining was not achieved, there were no statistical significant differences ($p>0.05$) in peak torque at 240 degrees.

Peak torque at 360 degrees also showed no statistical differences at the $p>0.05$ level. A seen in Figure 3, both legs showed a decrease in their mean value from pre- to post-test. In addition, both legs increased from post- test to the final test. However, unlike the TR leg, the OT leg's final test did not increase above the initial force output's mean value.

RELATIVE TORQUE

Since relative torque (ft-lbs-lb TBW^{-1}) is peak torque (ft-lbs) divided by total body weight (lb TBW^{-1}), relative torque for all three speeds followed a very similar pattern. Due to no changes in body weight, there was no statistical significant difference ($p>0.05$) in relative torque at 120 degrees on the Biodex between legs or time periods. As shown in figure 4 , the relative torque mean decreased from pre- to post-test. And relative torque increased from post- to final test in the OT leg during week four of the study. Also shown in figure 4, the TR leg's relative peak torque mean decreased slightly throughout the whole study.

Figure 5 shows the OT leg's relative peak torque increasing only slightly throughout the study. The TR leg decreased from pre- to post-test, and increased in relative force output above the initial mean value also displayed in figure 5. Once again, no significant difference ($p>0.05$) was seen in relative torque at two hundred forty degrees per second.

Additionally, no significant effect ($p>0.05$) of overtraining was seen in the quadricep performing the leg extension on the Biodex at 360 degrees per second. Figure 6 shows the relative torque means for all three evaluations in the OT and TR legs. A continuing decreasing effect was seen in all three tests in the OT leg. In the TR leg, the mean value decreased from pre- to post-test but increased minisculely above the first test's mean value.

AVERAGE POWER

An overtraining effect was not seen peak torque, relative torque, nor average power (Watts). No significant differences ($p>0.05$) in average power were shown in any of the three speeds during the study. The mean average power at 120 degrees decreased in the OT leg from the pre- to post-test, and recovered somewhat by test three. The TR leg decreased during the four week study in mean average power. At 240 degrees per second on the Biodex, the OT leg displayed a small increase from the beginning to end of the overtraining period. After recovery, the OT leg decreased in average power. The TR leg had no change in the pre- to post-test period. However, the average power fell after the reduced training period. Both legs decreased in average power throughout the study when being evaluated at 360 degrees.

ONE REPETITION MAXIMUM

One repetition maximums were assessed everyday during overtraining for the OT leg and every training day for the TR leg. The evaluation of the one repetition maximum was completed after the warm-up. The overall means were calculated from everyday that a one repetition maximum was performed for each leg.(Appendix D) Throughout the study, the OT legs' one repetition maximum increased from 157.8 lbs on the first day to 188.9 lbs on day thirteen. During the recovery week, the one repetition maximum decreased slightly to 187.8 lbs. The TR leg increased from the beginning of the study to the post test, (163.3 - 177.8 lbs). A similar pattern to the OT leg, there was a decrease in the one repetition maximum after the final week of the study, (174.4 lbs). In conclusion from the results of the Biodex testing and one repetition maximums, an overtraining effect did not occur.

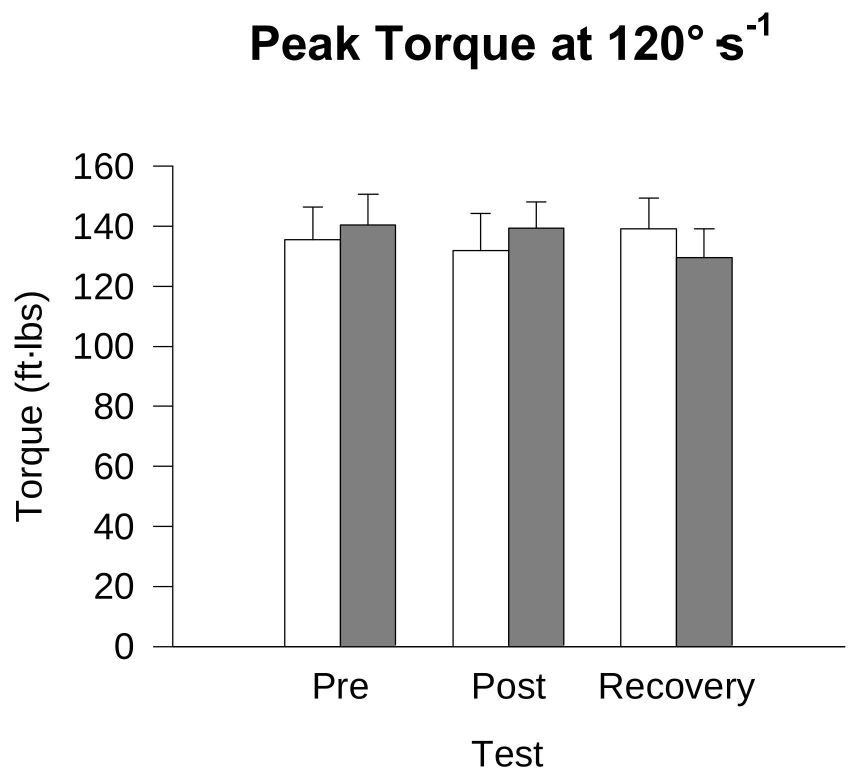

Figure 1. Peak torque in OT and TR legs. Open bars represent the OT leg, and hatched bars represent TR leg.

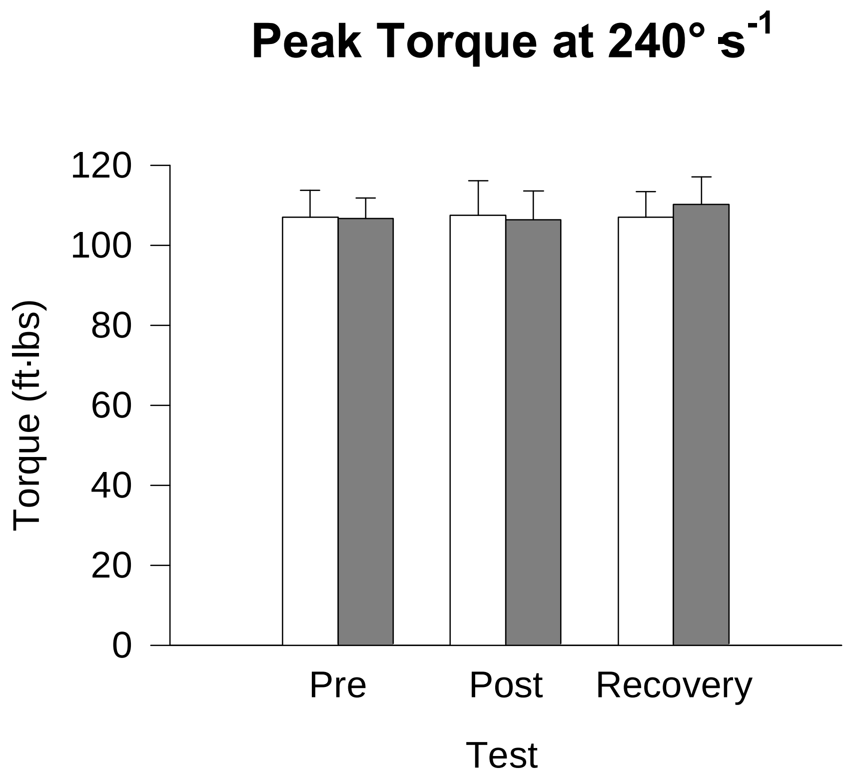

Figure 2. Peak torque in OT and TR legs. Open bars represent the OT leg, and hatched bars represent TR leg.

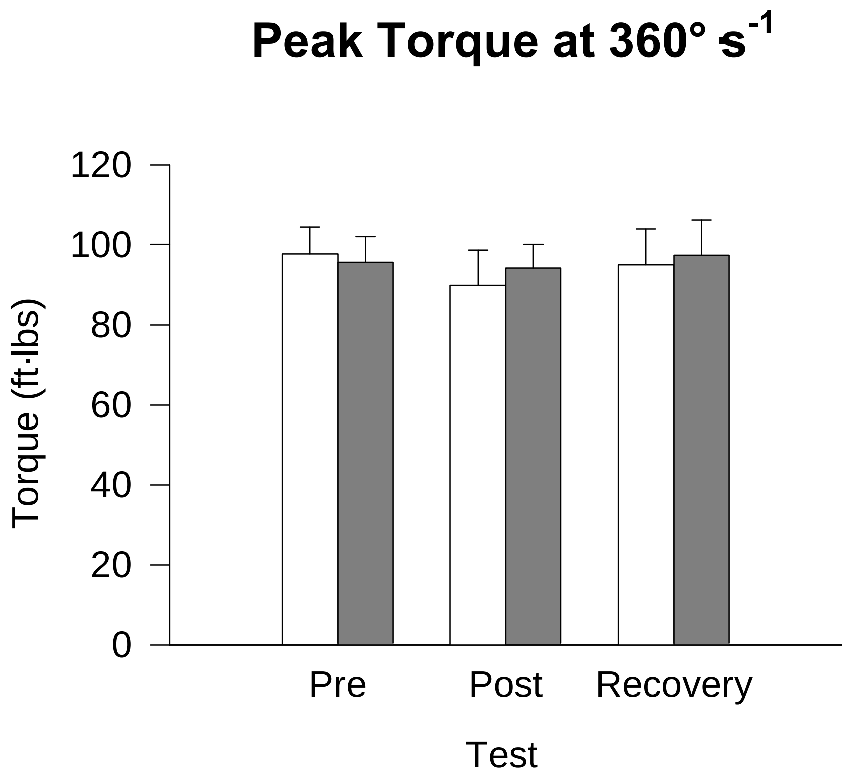

Figure 3. Peak torque in OT and TR legs. Open bars represent the OT leg, and hatched bars represent TR leg.

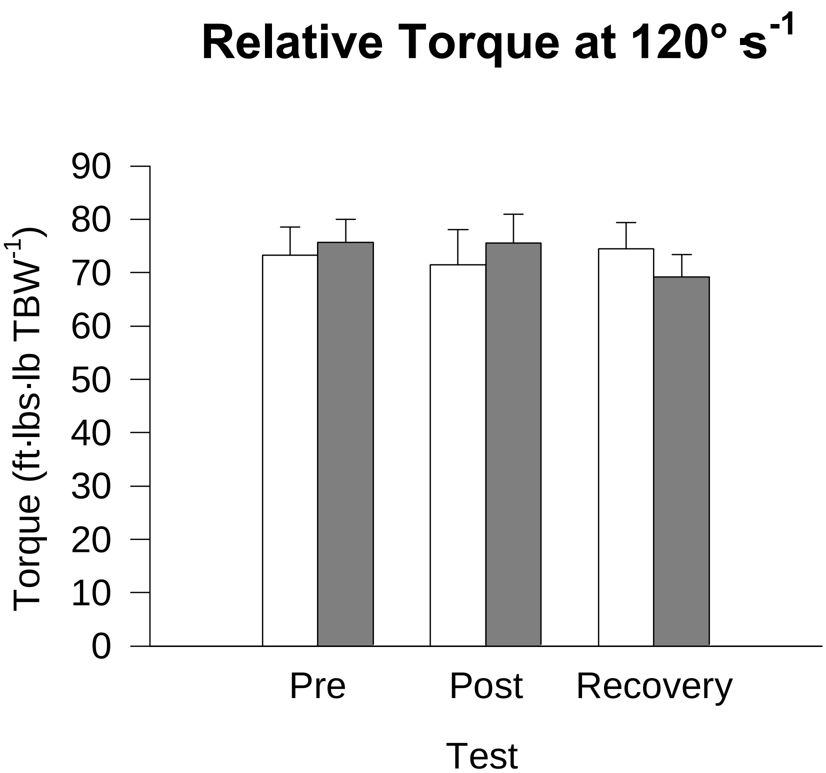

Figure 4. Relative torque in OT and TR legs. Open bars represent the OT leg, and hatched bars represent TR leg.

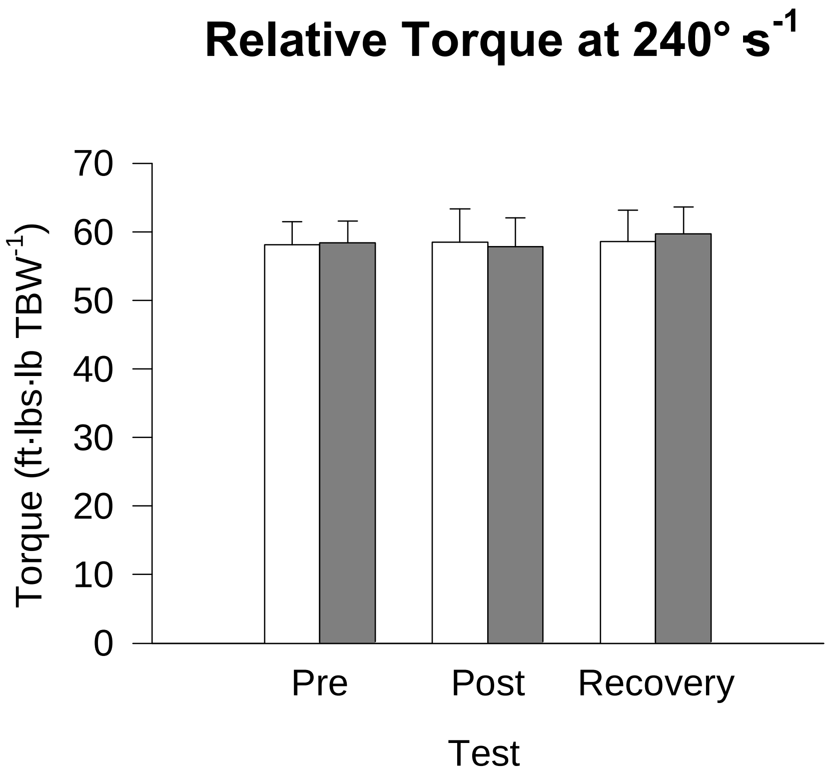

Figure 5. Relative torque in OT and TR legs. Open bars represent the OT leg, and hatched bars represent TR leg.

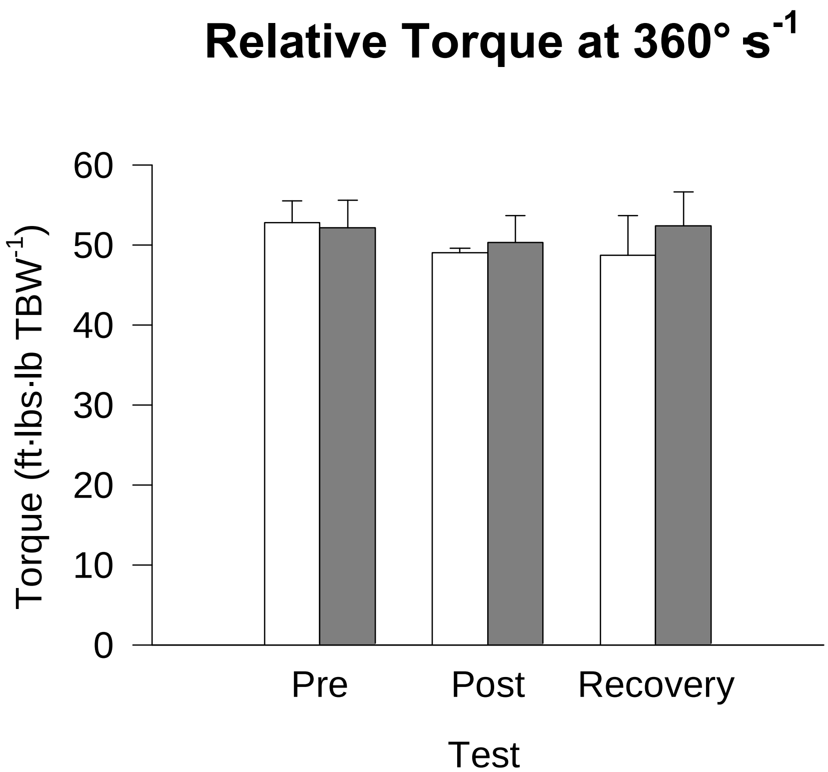

Figure 6. Relative torque in OT and TR legs. Open bars represent the OT leg, and hatched bars represent TR leg.

CHAPTER 5:

DISCUSSION

SUMMARY

Overtraining is a common occurrence when athletes are suffering from prolonged fatigue (Budgett et al., 1990). Fry et al. (1994) claim that overtraining can result from an increase in training volume or intensity, leading to decreased performance. There is no single diagnostic test that defines overtraining since the symptoms, susceptibility, and severity varies among the individual. For the above mentioned reason, researchers have an overall belief that there is no “gold standard” in order to diagnose overtraining syndrome. Fry et al. (1994) conducted the only published study that has been able to produce an overtraining effect resulting in a performance decrement with high intensity resistance exercise. This investigation attempted to replicate Fry et al. (1994) closely in order to understand more about overtraining with anaerobic exercise. Therefore, this study attempted to identify overtraining as a significant performance decrement from pre-test to post-test.

Specifically, nine subjects volunteered to participate almost everyday of the four week study. The first week served as a familiarization week in order for the subjects to feel comfortable with the leg extension exercise on the nautilus and the Biodex at the testing speeds. Day one of week two was the pre-test on the Biodex. Each leg was assigned as an overtrained leg or a trained leg. The overtrained leg performed the high intensity workout six days a week for two weeks. The trained leg performed a low intensity workout every third day of the overtrained leg ’s workout. Day 21 of the study, the subjects completed another test identically to the pre-test known as the post-test. A recovery week was allowed with a low intensity workout in case there was an overtraining effect. Another identical test (the final test) measured how much the overtrained leg recovered.

From the questionnaire given, seven out of nine subjects claimed they complied with all of the responsibilities in the study. The remaining two stated they complied with most of the responsibilities. At the end of the study, a two-way repeated measures analyses of variance were used to examine the differences between the pre-test and the post-test in order to determine if there was a significant overtraining effect. The data showed a nonsignificant effect of overtraining on peak torque, relative torque, and average power. To further support this nonsignificant effect, the subjects’ one repetition maximums increased in both legs during training. The results of this study suggest that overtraining was not achieved after a two weeks of high intensity resistance training.

GENERAL DISCUSSION

Many studies have looked at the effects of overtraining in aerobic conditioning, but few have looked the effects of overtraining in anaerobic conditioning. The exact mechanisms behind overtraining is not known. Signs and symptoms in the athlete that might implicate overtraining vary tremendously. A decrease in performance generally is the first sign that overtraining has resulted from the athlete’s hard work. More severe symptoms generally show up later in the training regimen. (Van Borselen et al., 1992) Complete rest is the only thing that allows the athlete to recover from overtraining.

Researchers tend to think that overtraining is mostly intensity related. Recently, one study has been able to see an overtraining effect through high intensity resistance training. Fry et al. (1994) performed a short-term, heavy resistance training program with weightlifters with four and a half years experience performing a maximal squat workout for two weeks. They stated that an overtraining effect was seen due to a significant decrease in peak torque (Cybex II dynamometer) and in one repetition maximum. A goal purpose of this study was to replicate Fry et al.'s (1994) study in order to learn more about overtraining during weight training. This study used a similar warm-up and the same high intensity workout except performing a leg extension versus a squat. Unfortunately, this study did not see the same significant results that Fry et al. (1994) did. Therefore, it is suggested that overtraining did not result from the high intensity workout protocol.

Unlike Fry and colleagues, the one repetition maximums did not decrease from pre- to post-test. During the leg extension one repetition maximum's, the quadricep's maximum strength tended to increase rather than decrease. Also, Fry et al. (1994) saw significant decreases in isokinetic force output. Whereas, with this study, there were no significant decreases in force output on the Biodex in any of the speeds throughout all the tests.

To further support that overtraining was not seen in the subjects, there were no signs of overtraining in most of the subjects. Four out of ten subjects complained of knee pain in the medial area in their overtrained leg. After a few days of the study, one subject dropped out and felt he had previously injured his knee. When asked to rate their pain on a scale of zero to ten, the highest number of five was recorded once. Generally, the few with knee soreness rated it at a two or three. It is suggested that this was due to the extreme amount of weight and pressure the subjects were putting on their joint. These three subjects were lifting with one leg on an average of at least twenty to thirty pounds over their body weights. Throughout the whole study, no subjects complained of feeling fatigued at any time.

Fry's subjects also reported no signs of feeling fatigued despite decreasing in performance. It was noted that Fry's subject's had been lifting a mean of four and a half years. The subjects in this study had been resistive weight training for a mean of two and a half years. It may be possible that the subjects in this study had not been lifting long nor intense enough previously to reach an overtraining effect. Despite the requirement in this study of having been weight trained for at least six months, there were no specific requirements with regards to history of intensity or frequency in performing leg extension exercise in order to participate in this study. Whereas, with Fry, the subject's had to be able to squat at least one and a half their body weight. The relatively short training history may be a possible reason that overtraining was not achieved in this investigation.

Another likely reason that overtraining did not occur is due to the mode of exercise being performed. Leg extension exercises are known as being a fairly easy exercise when compared to squat exercises. Also, leg extensions primarily isolate the quadricep muscles. Whereas the squat works not only the quadricep, but also, the hamstrings, gluteal, and lower back muscles. One theory may be that overtraining occurs first in the small group muscles before larger muscles. It may be possible that in Fry's study that the smaller muscles became overtrained first. Therefore, they failed to assist the larger muscles during the squat exercise. If this process occurred, that would lead to the larger muscles having to work harder and developing more substantiated overtraining effect. Since this investigation only looked at one large muscle, it is difficult to evaluate the performance of a small muscle group. In order to achieve an overtraining effect with a large muscle group, a more intense workout may need to be designed.

CONCLUSION

Overtraining is the imbalance between training and recovery. This study was designed to replicate and support Fry et al. (1994) results. They showed that a decrease in performance following a short-term, heavy resistance training program produced an overtraining effect as evidenced by decreased knee extension torque. It is hypothesized that overtraining did not occur in this study due to the possibility that the subjects had not been training long enough before they participated in the study. Also, the mode of exercise, the intensity of the workout, and the type of muscle exercised were contributing factors. In summary, this investigation demonstrated that overtraining in the quadricep did not result from the two weeks of high intensity resistance training. Due to this, it was impossible to address the notion that decreased performance was due to central and peripheral mechanisms or to examine performance changes during recovery.

SUGGESTIONS FOR FUTURE RESEARCH

The relationships between overtraining, exercise and the individual is very difficult to understand. Researchers have not found a point in exercise that actually leads to the overtraining effect. This results from the variability in the athlete's signs and symptoms. There is only one study that has actually seen an overtraining effect resulting in decreased performance during an resistive training workout. In order to increase the knowledge about weight training and overtraining, a few areas should go under further investigation.

Researchers feel intensity is the main reason overtraining occurs. However, in this study a high intensity workout was replicated, and the subjects did not decrease in their performance. Mode of exercise probably plays a stronger role in overtraining than once thought. A study should be conducted with the same high intensity workout but two different exercises concentrating on two different muscle groups (i.e. small versus large muscle group). This may possibly support the theory that small muscle groups fatigue first resulting overtraining quicker than large muscle groups.

Another way to possibly investigate overtraining better is to have more similar subject characteristics. A high intensity resistance training protocol could possibly be designed to involve a specific team that has performed unified workouts for awhile before actually starting the overtraining study.

Finally, overtraining is an imbalance between workout and recovery. Since this seems to be the key, a high intensity workout with less rest in between sets for a longer period of time would likely result in overtraining. A study that recruits experienced weightlifters to perform a specific exercise at a high intensity with little rest in between sets for approximately two to four weeks might produce an overtraining effect. In addition, a study similar to Hakkinen et al.'s (1988) needs to be designed so there are multiple training sessions in one day for one group and daily heavy training for another group and possibly concentrating on the recovery process. These ideas may produce some significant results that can help investigators get a better grasp on this complicated problem.

BIBLIOGRAPHY

Bigland-Ritchie, B., Jones, D.A., Hosking, G.P., Edwards, R.H.T. (1978) Central and peripheral fatigue in sustained maximum voluntary contractions of human quadriceps muscle. Clinical Science of Molecular Medicine. 54. 609- 614.

Bigland-Ritchie, B., Bellemere, F., Woods, J.J., (1986) Excitation frequencies and sites of fatigue. Human Muscle Power. Champaign, IL.: Human Kinetics. 197-213.

Budgett, R., (1990) Overtraining Syndrome. British Journal of Sports Medicine. 24.

Callister, R., Callister, R., Fleck, S., Dudley, G., (1990) Physiological and performance responses to overtraining in elite judo athletes. Medicine and Science in Sport and Exercise. 22. 816- 824.

Costill, D., Thomas, R., Robergs, A., Pascoe, D., Lambert, C., Barr, S., Fink, W., (1991) Adaptations to swimming training: influence of training volume. Medicine and Science in Sport and Exercise. 23. 371- 377.

Enoka, Roger, (1994) Neuromechanical Basis of Kinesiology. Champaign, IL.: Human Kinetics. pp. 319-321, 328, 332-333.

Falsetti, H., (1983) Overtraining in athletes- a round table., Physician and Sportsmedicine. 11: 93- 110.

Fry, A., Kraemer W.J., Lynch, J., Triplett, N., Koziris, L., (1994) Does short term near maximal machine resistance exercise training induce overtraining? Journal of Strength and Conditioning Research. 8. 188- 191.

Fry, A., Kraemer, W., Van Borselen, F., Lynch, J., Marsit, J., Ro, E., Triplett, N., Knuttgen, H., (1994) Performance decrements with high intensity resistance exercise overtraining. Medicine and Science in Sport and Exercise. 26. 1165-1173.

Fry, R., Morton, A., Keast, D., (1991) Overtraining in elite athletes. An update. Sports Medicine. 12. 32- 65.

Gillam, G.M., (1981) Effects of frequency of weight training on muscle strength development. Journal of Sports Medicine. 21. 432- 436.

Hakkinen, K., Pakarinen, A., Alen, M., Kauhanen, H., Komi, P.V., (1988) Neuromuscular and hormonal response in elite athletes to successive strength training sessions in one day. European Journal of Applied Physiology. 57. 133-139.

Hakkinen, K., Pakarinen, A., Alen, M., Kauhanen, H., Komi, P.V., (1988) Daily hormonal and neuromuscular responses to intensive strength training in one week. International Journal of Sports Medicine. 9. 422-428.

Kuipers, H., Keizer, H., (1988) Overtraining in elite athletes. Review and directions for the future. Sports Medicine. 6. 79- 92.

Leiber, Richard. (1992) Skeletal Muscle Structure and Function. Baltimore: Williams and Wilkens. pp.196, 204-206.

Sale, Digby. (1986) Neural adaptation in strength and power training. Human Muscle Power. Champaign, IL.: Human Kinetics. 289-307.

Sale, D.G. (1988) Neural adaptation to resistance training. Medicine Science in Sports and Exercise. 20. S135- S145.

Staron, R.S., Karapondo, D.C., Kreamer, W.J., Fry, A.C., Gordon, S.E., Falkel, S.G., Hagerman, F.C., Hikida, R.S. (1994) Skeletal muscle adaptations during early phase of heavy resistance training in men and women. Journal of Applied Physiology. 76. 1247-1255.

Stone. M, Keith, R., Kearney, J., Fleck, S., Wilson., G., Triplett, N. (1991) Overtraining: A review of signs, symptoms, and possible causes. Journal of Applied Sport Science Research. 5. 35- 50.

Van Borselen, F., Vos, N., Fry, A., Kraemer, W., (1992) The role of anaerobic exercise in overtraining. National Strength and Conditioning Association Journal. 14. 74- 79.