EFFECTS OF ENDURANCE INTENSITY AND REST INTERVAL
ON SUBSEQUENT STRENGTH PERFORMANCE

THESIS

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

Gregory D. Books, B.A.
Denton, Texas
May, 1996
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ACKNOWLEDGEMENTS

The author would like to acknowledge Andrew Reyes for his help in data collection and methodology coordination, and Haley Hoss for her technical help and support in this project.

The purpose of this study was to examine the acute effects of cycling exercise at different intensities and rest intervals on strength performance. Ten males, engaged in concurrent training for at least one month prior to testing, comprised the subject group for this study. Results show only leg press torque and leg press work to be decreased after cardiorespiratory exercise of moderate intensity. Leg extension average power, chest press torque, chest press power, and chest press work after cycling were not decreased from pre-exercise values. No significant effects were found for exercise intensity, testing times, or intensity by testing times. These results indicate that lower body strength is decreased by cycling and that one hour is not sufficient to restore leg strength.
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CHAPTER I

INTRODUCTION

Training for both strength and cardiorespiratory endurance, or concurrent training, is important to a variety of individuals participating in athletics, rehabilitation, or fitness programs. As the health benefits of strength and cardiorespiratory endurance exercise are increasingly extolled and more individuals become involved in concurrent training, the need for knowledge about the effects of concurrent training also increases. Health related fitness is defined by the American College of Sports Medicine (ACSM) as developing and maintaining cardiorespiratory fitness, body composition, and muscular strength and endurance in the healthy adult. Strength and cardiorespiratory endurance training programs produce physiological and performance adaptations specific to their mode of training. Although adaptations to these two modes of training are well known when performed singularly, their combined effects are not yet clear. Information on how to maximize the results of both modes of training would be useful to concurrent trainers and exercise prescribers alike.
Strength training is done to increase the maximum force output of muscle. In the American College of Sports Medicine position paper on resistance training it is stated that "strength training should be an integral part of an adult fitness program," and "one set of 8-12 repetitions of eight to ten exercises that condition the major muscle groups at least 2 days per week is a recommended minimum" (The American College of Sports Medicine [ACSM], 1991, p. 265). Strength training has, however, been found to be most effective when four or five sets of 4-6 repetitions of a heavy resistance exercise are utilized (Atha, 1981).

Several physiological changes occur in the trained muscle which increase force production. Strength training causes hypertrophy of type I and II muscle fibers, and the adaptation of type II fibers to anaerobic fibers. Neurological improvements in motor recruitment patterns, the number of contractile proteins, the concentration of ATP and CP at rest, and the enzymatic capacity to resynthesize ATP from immediate energy sources are increased in the trained muscle.

Cardiorespiratory endurance training is done with a large number of submaximal contractions to increase aerobic power ($VO_{2\text{max}}$). ACSM recommends that cardiorespiratory exercise be performed continuously for 20-60 minutes 3-5 days per week at 50-85% $VO_{2\text{max}}$ or 60-90% heart rate maximum (ACSM, 1990, p. 265). Adaptations at the muscular level
include an increase in capillarization, as well as in the number and activity of mitochondria in the trained muscle. Cardiorespiratory training increases oxygen extraction from muscle, causes little or no hypertrophy of type II fibers, and acts to convert other fibers to aerobic fibers. Central (systemic) cardiorespiratory adaptations include an increase in stroke volume, maximum ventilation, cardiac output, and VO$_2$max, with a decrease in submaximal heart rate and blood pressure (McArdle, Katch & Katch, 1991).

In the past decade, several studies have involved subjects training concurrently for strength and endurance. While cardiorespiratory improvements appeared to be unaffected by concurrent training in these studies, strength improvements may have been compromised. The results for strength training are inconsistent, with Bell, Bagnall, Quinney, Peterson and Wessel (1991), Dudley and Djamil (1985), Hickson (1980), and Hunter, Demment and Miller (1987) finding a compromise in strength improvement, while McCarthy, Agre, Graf, Pozniak, and Vailas (1995), Nelson, Arnall, Loy, Silvester, and Conlee (1990), and Sale, MacDougall, Jacobs, and Garner (1990) found no strength inhibition. Some of the discrepancy in these findings may be accounted for in procedural differences. It now appears that the more specific the strength and cardiorespiratory endurance exercises are the less compromise of strength will occur. If training modes are not specific, or the recovery
between training sessions is inadequate, some strength compromise is likely. More research is necessary to determine optimal concurrent training parameters for strength improvement.

Acute studies, in which results are related to training applications, have focused on how endurance exercise intensity and muscle recovery time affect strength performance. Kroon and Naeiji (1988) found maximal biceps force to still be compromised 25 hours after endurance exercise. Abernathy (1993) found both high and low intensity cardiorespiratory endurance exercise decreased strength performance. However, differences in rest periods and subject groups make conclusions about this study difficult. Questions remain as to what level of aerobic intensity, and what rest intervals between exercise sessions are most appropriate for maximal strength performance.

The purpose of the current study was to examine the acute effects of cardiorespiratory endurance exercise intensity and rest interval on subsequent strength performance.

Hypotheses

1. Higher intensity endurance exercise results in a larger decrease in strength performance than lower intensity exercise.

2. Lower body strength performance is more negatively affected by leg cycling endurance exercise than upper
body strength performance.

3. Strength performance increases as rest intervals after cardiorespiratory endurance exercise increase.

Delimitations

This study will be delimited by the following factors:
1. Only males between the ages of 18 and 35 will be tested.
2. Bicycle ergometry will be the only method of cardiorespiratory endurance exercise. Strength testing will occur only on dynamometers.

Limitations

This study will be limited by the following factors:
1. The results of the study will only be generalizable to young adult males.
2. The study will use dynamometers for strength testing and cycle ergometry for cardiorespiratory endurance exercise, which may limit applications to other modes of cardiorespiratory endurance exercise and strength testing.

Definitions

Concurrent training: Training for both strength and endurance.

Type I muscle fibers: Slow-twitch fibers which have a low glycogen content, high mitochondrial density, and a high resistance to fatigue, making them well-suited for long lasting low level force production.
Type IIA muscle fibers: Fast-twitch fibers which have high glycolytic and oxidative enzyme content, making them well-suited for prolonged high force output.

Type IIB muscle fibers: Fast-twitch fibers which have a high glycogen and low mitochondrial content making them best suited for short high-force production.

VO$_2$max: The maximal rate of oxygen that can be consumed during exercise at sea level, usually expressed in liter per minute (l*min$^{-1}$) or milliliters per kilogram bodyweight per minute (ml$^*$kg$^*$min$^{-1}$).
CHAPTER REFERENCES


CHAPTER II

LITERATURE REVIEW

Training for both strength and cardiorespiratory endurance is important for some sports, rehabilitation, and health benefits. Thus, knowledge of the effects of concurrent training has practical significance to a variety of people. Both training and acute studies, however, have yielded conflicting results. This chapter will discuss the importance of strength and endurance training and examine relevant literature from training and acute studies.

Importance

Regular physical activity is an important component of a healthy lifestyle, as it prevents disease and enhances health and quality of life. Evidence over the last decade indicates several benefits of regular exercise (American College of Sports Medicine & United States Center for Disease Control [ACSM & USCDC], 1993). Benefits of cardiovascular training include protection against coronary heart disease, adult-onset diabetes, hypertension, certain cancers, obesity, elevated blood cholesterol, and depression. Resistance training, by increasing muscular strength, connective tissue strength and bone mass, prevents
muscular atrophy with age, injury, and osteoporosis (ACSM & USCDC, 1993).

Sports such as rowing, rugby, skating and cycling require the production of high levels of muscular force for a length of time. In injury rehabilitation, it is necessary to strengthen as well as increase blood flow to the injured tissue in order to speed recovery. In these situations, the simultaneous use of both strength and endurance modes of training are necessary for improvement.

When strength and cardiorespiratory endurance training are combined, the possibility exists for the enhancement, compromise or compatibility of each fitness factor. While it now seems that endurance training is not hindered by strength training, the reverse is not yet clear. An understanding of the effects of combined strength and endurance training used for health, athletics, and rehabilitation programs are important in order to maximize the individual benefits from each mode of training.

Training Studies

Concurrent strength and endurance training studies have generated very different results (see Table I). Many studies have shown strength to be compromised (Bell, Bagnall, Quinney, Peterson & Wessel, 1991; Dudley and Djamil, 1985; Hickson, 1980; Hunter, Demment, & Miller, 1987), while others have not (McCarthy, Agre, Graf, Pozniak & Vailas, 1995; Nelson, 1990; Sale, MacDougall, Jacobs &
Garner, 1990b). In answering the question of strength compromise, it is necessary to examine the research in detail. Unfortunately, direct comparisons between studies are difficult due to the wide variations in training protocols. Examining these different parameters in terms of training design and degree of specificity is helpful in clarifying the research findings. This section will compare the literature in terms of appropriateness of strength and endurance training programs, specificity of training, volume, frequency and mode of training, upper and lower body differences, rest intervals and cardiorespiratory training intensity.

As mentioned previously, ACSM (1990) recommends a minimum of one set of 8-12 repetitions for strength maintenance and development. However, in order to maximally develop strength, a program of four to five sets of 4-6 repetitions per exercise should be used (Atha, 1980). Sale et al. (1990b) used a strength training program consisting of 15-20 repetitions. Dudley et al. (1985) had subjects perform as many repetitions as possible in 30 seconds. These protocols are inconsistent with ACSM minimal strength training recommendations and inappropriate for maximal strength gains, being better suited for muscular endurance. By not fully stressing the muscle, the adaptive response will be smaller, resulting in a smaller protein buildup and decreased neuromuscular facilitation.
A recommended endurance training program should be performed three or more days per week for at least 20 minutes at 50-85% of VO$_2$max. Sale et al. (1990b) and Dudley et al. (1985) use cardiorespiratory endurance programs involving several short near maximal bouts of exercise with brief rest periods in between. These protocols are inappropriate for cardiorespiratory endurance and do not isolate the aerobic system. A large anaerobic component is used in this type of training which probably represents anaerobic overtraining when combined with a strength program.

The goal of concurrent training is to produce optimal physiological adaptations for two very different modes of exercise. The better each of the strength and cardiorespiratory components are isolated, the more specific will be their resultant adaptations. McCarthy et al. (1995) trained subjects for strength using five sets of 5-7 repetitions and endurance for 50 minutes at 70% HRR. Both types of training were done on the same day, three days per week, on alternating days of the week. Results showed no decrement of strength increase with concurrent training. Nelson et al. (1990) utilized a program of three sets of six repetitions on weights and running for 60 minutes, each performed two days per week. Although training was done on alternating days, strength was not compromised. These results indicate that when appropriate training procedures
are utilized and overall volume is kept low, strength performance is not impeded. This could be due to the isolation of strength and endurance modes of training, a case in which the adaptive stimuli from the aerobic and anaerobic systems may be diverse enough to preclude mutual interference.

Overtraining, or allowing inadequate time for muscular recovery, is a potential cause of strength compromise during concurrent training. While boundaries for concurrent training have yet to be defined, they might be assumed to be the same or slightly less than the sum of their individual components. Strength training programs usually involve training the same muscle group two or three days per week, allowing 48 hours between training. Endurance training is usually performed three to six days per week. Hickson (1980) trained previously untrained subjects' legs five days per week for strength and six days per week for endurance. Hunter et al. (1987) trained subjects four days per week for strength and four days for endurance. While these studies found strength to be compromised, the training volumes were not practical and may represent overtraining. It should be noted, however, that no cardiorespiratory endurance compromise, which is also a possibility in overtraining, was found in the same studies.

Training frequency itself may be an important consideration in training regimen design. McCarthy et al.
(1995) notes "Hickson (1980), Dudley and Djamil (1985), and Hunter et al. (1987) report impairment in strength development when some type of training (strength, endurance or both) occurs six days a week" (p.434). McCarthy et al. (1995) and Sale et al. (1990) found strength to be unaffected when both strength and endurance training were performed on the same day three days per week. Nelson et al. (1990) trained strength and endurance on alternating days four days a week and also found no compromise. Thus, training more than a total of five days a week in a concurrent program appears to compromise strength gains.

Mode of endurance training may potentially effect strength outcome. The three training studies which have not found a compromise of strength improvements in concurrent training all utilized leg cycling (McCarthy et al., 1995; Nelson et al., 1990; Sale et al., 1990b). Studies using continuous running (Hunter et al., 1987) and rowing (Bell et al., 1991), have found a strength compromise. These findings indicate cycling may be a preferential alternative to running for improving strength while training for cardiorespiratory endurance.

Upper and lower body strength may be differentially affected by endurance training. Craig et al. (1991) found only upper body strength to be improved in a ten week concurrent running program. Although the differences were not found to be significant, other concurrent studies have
also shown a greater increase in upper body strength than in lower body strength (McCarthy et al., 1995; Hunter et al., 1987). The literature indicates a larger decrement of strength gains may result in muscles which are concurrently being endurance trained. This indication supports the idea that antagonistic physiological changes inhibiting strength increases may occur specifically in the trained muscle during concurrent training.

The amount of rest needed between modes of exercise is not yet clear. Studies finding no strength compromise have used as little as 10 minutes between modes, and alternated the order of the modes (McCarthy et al., 1995), while others have used two hours and still found a compromise (Hickson, 1980). Further complicating the issue, Sale et al. (1990a) found leg extension torque to be increased significantly more when strength and cardiorespiratory endurance are trained on alternating days than when trained on the same day.

No training studies have examined the effect of cardiorespiratory training intensity on strength improvement. Although different intensity cardiorespiratory training components have been used in studies finding strength compromises and those which did not, comparisons are not possible due to the large procedural differences between studies.
## Concurrent Training Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Days/Week</th>
<th>Strength Program</th>
<th>Endurance Program</th>
<th>Compromise</th>
</tr>
</thead>
<tbody>
<tr>
<td>McCarthy 1995</td>
<td>3: combined (alternated order)</td>
<td>4 sets 5-7 reps (total body)</td>
<td>50 min cont. cycling at 70% HRR</td>
<td>NO</td>
</tr>
<tr>
<td>Craig 1991</td>
<td>3: combined (end. then strength)</td>
<td>3 sets 6-8 reps (total body)</td>
<td>35 min cont. running at 75% HRRmax</td>
<td>YES: lower body NO: upper body</td>
</tr>
<tr>
<td>Nelson 1990</td>
<td>4: combined (strength then end.)</td>
<td>3 sets 6 reps knee flex/ext</td>
<td>60 min cont. cycling at 85% MHR</td>
<td>NO</td>
</tr>
<tr>
<td>Sale 1990</td>
<td>3: combined (end. then strength)</td>
<td>6 sets 15-20 reps leg press</td>
<td>8-3 min bouts cycling</td>
<td>NO</td>
</tr>
<tr>
<td>Hunter 1987</td>
<td>6: total 2: combined (4end/4str)</td>
<td>3 sets 10 reps (total body)</td>
<td>40 min cont. running at 75% HRR</td>
<td>YES</td>
</tr>
<tr>
<td>Dudley 1985</td>
<td>6: alternated (3end/3str)</td>
<td>30 sec timed knee extensions</td>
<td>5-5 min bouts cycle at VO2max</td>
<td>YES</td>
</tr>
<tr>
<td>Hickson 1980</td>
<td>6: combined (6end/5str) (?order)</td>
<td>3 sets 5 reps (legs)</td>
<td>6-5 min bouts cycle at VO2max</td>
<td>YES</td>
</tr>
</tbody>
</table>
Acute Studies

Acute studies attempt to link their results with those of chronic studies. The drawback of these studies is that strength performance findings cannot be directly compared to strength training increases. Rather, improvements over time must be inferred. An advantage of acute studies is a better ability to isolate the immediate physiological occurrences than their chronic counterparts. Of the three studies to date, the first two mentioned contain methodological anomalies which limit the validity of the results, and the third represents a cardiorespiratory exercise component too large to be applicable to concurrent training.

Kroon and Naeije (1988) found the biceps brachii to have not fully recovered twenty-five hours after endurance exercise, which consisted of submaximal contractions of the left biceps muscle to exhaustion. This finding would seem to lend itself to the finding that training six days a week has a strength compromise, where three-day per week protocols do not. However, the protocols in question (McCarthy et al., 1995; Nelson et al., 1990) used strength training after endurance training within twenty-four hours, so these results disagree with Kroon and Naeije (1988). The biceps, however, is a small muscle not normally used for aerobic work, and may not be comparable with a larger muscle group such as the quadriceps.
Abernathy (1993) found both low and high intensity endurance exercise to decrease subsequent leg extension strength performance. High intensity cycle exercise consisted of five 5-minute repetitions at which the work rate was progressively increased from 40-100% of VO$_2$peak, whereas low intensity exercise consisted of cycling continuously at 35% of VO$_2$peak for 150 minutes. However, rest intervals and subject ability were not held constant in this study. Additionally, this study used the 5 near-maximal bouts protocol previously noted as not specific to cardiorespiratory endurance exercise. These problems make any conclusion about the study difficult.

Sherman et al. (1984), found maximal peak leg extension torque had not returned to baseline seven days after completing a marathon. While this represents a cardiorespiratory exercise extreme, a volume inappropriate for concurrent training, it demonstrates that both exercise intensity and rest duration have an effect on subsequent strength performance. More research in the areas of acute endurance intensity level and rest intervals are necessary before conclusions concerning acute physiology and its relation to training studies can be drawn.

To summarize, a variety of individuals participate in both strength and endurance training today for their beneficial health and fitness effects. Knowledge of the physiological consequences of concurrent training is
important to exercise prescription for health, athletics and rehabilitation. The amount of strength impairment that occurs during concurrent training probably depends upon the appropriateness of the strength and endurance programs, training volume, frequency, intensity, mode, muscles trained, and initial training status of the subjects. With the exception of Sale et al. (1990b), studies which have not found strength antagonism have used programs specific for strength and cardiorespiratory endurance (McCarthy et al., 1995; Nelson et al., 1990). Conversely, studies which do not use specific strength or cardiorespiratory endurance programs show an antagonism of strength (Bell et al., 1991; Dudley and Djamil, 1985; Hickson, 1980; Hunter et al., 1987). These findings indicate that when appropriate strength and endurance modes of training are used judiciously in terms of frequency and volume, strength gains may be unhindered. However, the intensity of cardiorespiratory exercise possible and amount of rest necessary before strength is compromised, as well as underlying physiological mechanisms of antagonism must be determined by future research.


CHAPTER III

METHODS

This chapter will present the methods and procedures used in the investigation. Specifically, subject selection, experimental design, and methods of measurement will be presented.

Subjects

Ten healthy male volunteers between the ages of 21-28 years were recruited from the Dallas/Fort Worth metroplex. Subjects were involved in both regular strength and endurance training programs at least twice per week within one month prior to testing. Subjects were asked not to engage in any exercise within 48 hours of each testing session. On testing days, subjects were asked not to take any drugs or caffeine prior to testing, and not to have eaten for two hours prior to testing. Other than these requirements, subjects were asked to maintain their normal daily routine during the testing period. Subjects were told the purpose of the study and asked to complete Physical Activity Readiness Questionnaire, health risk appraisal, and informed consent forms before testing began. Subjects answered "no" to each item on the first two forms used in
this study (see Appendix A). Height, weight, blood pressure
and ECG readings were obtained for each subject prior to
testing. Institutional Review Board approval was obtained
before testing commenced.

Tests

The maximal incremental test was performed by each
subject on a Monarch Ergometric 814E cycle ergometer to
determine VO$_2$ peak. Subjects maintained a rate of 60
revolutions per minute by use of a metronome and digital rpm
display. After a two-minute warm-up period at 0.5 kg (30
watts), the test was initiated by adding 0.5 kg, making the
starting work rate 60 watts. Resistance was then increased
by 0.5 Kg at two minute intervals until subjects could no
longer continue. Subjects were given verbal encouragement
to "go as long as they could". Testing was terminated when
subjects could no longer maintain 50 revolutions per minute
for a period of 10 seconds. Subjects breathed through a
mouth piece while wearing a nose clip to allow measurement
of VO$_2$ via a MedGraphics CPX metabolic cart. The metabolic
cart was calibrated immediately prior to the testing of each
subject.

Maximal isokinetic strength testing consisted of three
right leg extensions at 45°·sec$^{-1}$ on the Biodex System 2
isokinetic dynamometer and three chest presses at the
highest hydraulic resistance setting (10) on the
Hydrafitness Omnitron. Prime movers for the right leg
extensions were the quadriceps muscles. For the chest press, prime movers were pectoralis major, pectoralis minor, anterior deltoid and triceps muscles.

Strength equipment was set for the subject prior to testing. For the Omnitron machine, subjects were seated, the right patella aligned with the pivot point of the power arm, and the ankle pad situated directly anterior and superior to the right lateral malleolus. Subjects were strapped into the Biodex at the right ankle, right thigh, waist and chest. The right leg was then weighed and range of motion for the leg extension set. Next, subjects walked approximately 15 feet to the Omnitron, where the seat back was adjusted to align the subjects knee with the end of the seat.

Strength testing was performed as follows: First, subjects sat on the Biodex chair and were strapped at the ankle, thigh, waist and chest. Subjects were then told to perform three leg extensions, pushing "as hard as possible" when they saw the green light, the final light in the Biodex stoplight sequence. Subjects grasped the bottom of the seat with their hands. At the end of the third repetition, subjects were unstrapped, walked to the Omnitron, sat down, and fastened a seat belt around the waist. After performing one slow repetition to set the range of motion, subjects were instructed to perform three chest presses, pushing "as hard as possible". In all cases, the time required from the
start of strength testing on the Biodex to completion at the
Omnitron was less than 90 seconds.

Subjects performed strength testing in the same manner
at time intervals of zero, twenty and sixty minutes after
the initiation testing. Subjects sat quietly and were
allowed water and reading material between strength tests.

The Biodex and Omnitron machines generated reports of
torque and work in ft*lbs and power in watts. For the
Biodex machine, "torque" represented the peak torque on the
highest of the three individual repetitions performed,
"work" represented that of the maximum repetition of the
three performed, and "power" represented the average power
of all three repetitions. On the Omnitron machine, in each
case "torque", "work", and "power" represented the value for
the highest individual repetition of the three performed.
By using the two different machines the "lag" time between
the measurement of leg extension and chest press was
minimal.

Procedures

Testing of each subject was completed in four sessions.
In the first session, after height, weight, heart rate and
ECG measurements were taken, subjects were familiarized with
testing procedures on the Monarch cycle ergometer, and
VO₂peak was determined. In the second session, after a
three repetition learning trial on the Biodex and Omnitron
machines, which subjects were told to perform at 50% of
maximal effort, subjects sat quietly for 5 minutes. Maximal strength was then tested at zero, twenty, and sixty minutes after timing was begun.

The remaining two sessions were done by subjects in random order. At one session, a 20 minute exercise bout was done on the cycle ergometer at 65% of the workload at which the subject achieved VO$_2$peak. At the other session, a 32.5 minute bout was done on the cycle ergometer at 40% of the workload associated with VO$_2$peak. Utilizing the above exercise periods allowed work volume to be kept constant in the two sessions. At completion of the exercise bout, subjects cycled an additional 30 seconds at 30 watts to "cool-down". The amount of resistive force applied to the cycle ergometer and monitoring of the 60 rpm pedal cadence determined exercise percentage of VO$_2$peak. It should be noted that the 40% and 65% of work at which VO$_2$peak was achieved actually represented higher percentages of VO$_2$peak. Heart rate measurements of 5 subjects indicated exercise intensities of approximately 66% and 83% of maximal heart rate (220-age) for the 40% VO$_2$peak and the 60% VO$_2$peak intensities, respectively. In both exercise sessions, strength testing was conducted at zero, twenty, and sixty minutes after exercise completion.

Data Analysis

Independent variables were exercise intensity (pre-exercise, 40% VO$_2$peak, and 65% VO$_2$peak) and rest interval (0
min, 20 min, 60 min). Dependent variables were leg press and chest press torque, power and work. The statistical analysis was a 3x3 ANOVA with repeated measures. Alpha level was set at .01. Means and standard deviations were calculated for each dependent variable under each experimental condition. Results were reported in tables which follow the format of the sample table shown below.

Table II
Experimental Design

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>0</th>
<th>20</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensity %VO$_{2}$peak</td>
<td>no exercise</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
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<td>20</td>
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</tr>
<tr>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>
CHAPTER IV

RESULTS

This chapter provides the descriptive statistics of the subject characteristics and presents the results of the 3X3 ANOVA (exercise intensity X time) with repeated measures for each dependent variable measured.

Subjects

The subjects' age ranged from 21 to 28 years with a mean age of 24 ± 2. Height ranged from 162 to 183 cm with a mean of 177 ± 6 cm. Weight ranged from 71.8 to 83.4 kg with a mean of 77.1 ± 3.9 kg. VO₂peak ranged from 36.3 to 61.3 l*min⁻¹ with a mean of 48.7 ± 7.5 l*min⁻¹. Respiratory exchange ratio at VO₂peak was 1.23 ± .08.

Data Analysis

Statistical analysis indicated significant findings for only two of the six dependent variables, leg extension torque and work. The intensity (pre-exercise/ 40% intensity/ 65% intensity) main effect (p<.01) was significant for both variables. No time or time by intensity effect was found for any dependent variable (p>.01). Post hoc analysis indicated that pre-exercise leg extension torque and work values were higher than those of the 2 exercise intensities.
### TABLE III

**LEG EXTENSION TORQUE**

(ft*lbs)

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Pre-exercise</th>
<th>40</th>
<th>65</th>
</tr>
</thead>
<tbody>
<tr>
<td>%VO_peak 0</td>
<td>186.63 ±32.30</td>
<td>161.30 ±25.76</td>
<td>161.58 ±35.87</td>
</tr>
<tr>
<td>20</td>
<td>182.47 ±32.57</td>
<td>167.18 ±26.79</td>
<td>169.00 ±35.99</td>
</tr>
<tr>
<td>60</td>
<td>184.50 ±30.10</td>
<td>167.81 ±33.72</td>
<td>168.89 ±29.64</td>
</tr>
</tbody>
</table>

The average pre-exercise versus exercise intensities effect size for leg extension torque performance was .575. Leg extension torque performance decreased 10% between pre-exercise and the exercise intensities. No time (p=.410) or intensity by time (p=.409) effects were found for leg extension torque.
TABLE IV

LEG EXTENSION WORK
(ft*lbs)

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Intensity %VO$_2$peak</th>
<th>0</th>
<th>20</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pre-exercise</td>
<td>155.71 ± 25.90</td>
<td>149.66 ± 33.41</td>
<td>150.04 ± 25.96</td>
</tr>
<tr>
<td>40</td>
<td>135.02 ± 17.51</td>
<td>138.54 ± 18.27</td>
<td>138.56 ± 33.92</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>137.23 ± 28.60</td>
<td>147.70 ± 24.95</td>
<td>145.92 ± 30.05</td>
<td></td>
</tr>
</tbody>
</table>

The average pre-exercise versus exercise intensities effect size for leg extension work performance was .436. Leg extension work performance decreased 7% between pre-exercise and exercise intensities. No time (p=.762) or intensity by time (p=.201) effects were found leg extension work.
 CHAPTER V

DISCUSSION

Concurrent training is a very popular concept in American fitness today. Health and fitness enthusiasts, athletes and rehabilitation patients utilize both strength and endurance training. Training studies have found cardiorespiratory endurance training to be unaffected by concurrent training, but have yielded conflicting results about strength training improvements. Training studies with appropriate strength and cardiorespiratory endurance programs, using moderate volume and frequency, tend to show optimal strength improvements (McCarthy, Agre, Graf, Pozniak & Vailas, 1995; Nelson, Arnall, Loy, Silvester, Conlee, 1990). Additionally, training studies have found no gender effect in strength improvements, and indicate cycling to be a preferential endurance training mode for strength development. Acute studies have focused on exercise intensities and rest intervals, but have not yielded clear results. A better knowledge of how these exercise parameters affect strength improvements may yield exercise applications and insight into the potential physiological mechanisms of strength training antagonism.
This study was conducted under the hypothesis that higher intensity cycling and less rest would decrease strength performance, as muscle would have a greater workload to recover from and less time to recover. Additionally, it was hypothesized that lower body strength would be compromised to a larger degree than upper body strength, as the legs underwent the cardiorespiratory exercise and the upper body did not. Results showed that leg extension torque and work were significantly decreased at both the 40% or 65% VO₂peak cycling intensities. Leg extension power did not show any significant effect. Thus the prior cycling was detrimental to leg torque and work performance, but the intensity of cycling did not increase the effect. Time of rest interval showed no effect for any of the conditions. For both the significant and insignificant dependent variables, strength performance was consistent 0, 20, and 60 minutes after exercise. This indicates that even a rest interval of one hour after moderate or intense cycling is not sufficient for recovery.

As predicted, lower body strength was decreased more than upper body strength. Leg extension torque and work decreased 10% and 7% respectively, while upper body measures were not affected by the exercise. Since only the legs underwent the cardiorespiratory endurance exercise, this finding supports the idea that local intramuscular physiology is responsible for strength antagonism, rather
Comparison of Results to the Literature

Sherman et al. (1984) provided an extreme example of acute cardiorespiratory endurance exercise effects on subsequent strength performance. Leg extension torque performance did not return to baseline within seven days after completing a marathon. While a marathon would be an excessive exercise volume in a concurrent program, it illustrates that endurance activity may decrease subsequent strength performance.

Abernathy (1993) compared strength performance after low and high intensity endurance exercise. The low intensity exercise consisted of cycling 150 minutes at 35% $V_{O_2}\text{peak}$, high intensity exercise consisted of 5 5-min bouts of cycling starting at 40% $V_{O_2}\text{peak}$ in the first bout, and increasing to 100% $V_{O_2}\text{peak}$ in the final bout. He found that leg extension torque decreased significantly for both groups, and the decrease was similar between the groups. The current study used exercise intensities of 40% $V_{O_2}\text{peak}$ and 65% $V_{O_2}\text{peak}$ and found leg extension torque, but not chest press torque to be decreased, thus supporting Abernathy's (1993) results. The training literature used a variety of training intensities, but are difficult to compare due to their methodological dissimilarities. The findings of acute literature, however, indicate that prior cardiorespiratory exercise and not the specific exercise
intensity is important in causing a performance decrease in the exercised muscle. It is possible, however, that different length rest intervals may be necessary for strength recovery with higher intensity exercise than with lower intensity exercise.

Kroon and Naeije (1991) found that the biceps muscle required more than 25 hours after exhaustive exercise to return to baseline values for biceps curl maximal voluntary contraction. This is in agreement with Sherman et al. (1984), finding that leg extension strength requires more than seven days to fully recover after running a marathon. These cases utilized exhaustive exercise, which represents an exercise extreme, not an appropriate volume for a concurrent study. Abernathy's (1993) study used four hours rest between high intensity exercise and strength measurement, and one hour between low intensity exercise and strength measurement, and found similar strength decrements at each intensity. In the current study, leg extension torque strength had not fully recovered one hour after exercise. These studies are in agreement that a recovery period is necessary after cardiorespiratory endurance exercise in order to achieve maximal force production. Length of the rest period after moderate exercise has not been determined, but appears to be longer than one hour.

Since larger force production is associated with greater strength improvement, when a decrease in acute
strength performance is translated to longitudinal training it would be thought to lead to decreased strength improvements. Sale et al. (1990a) found strength production to be significantly greater when cardiorespiratory and endurance programs were done 3 days a week each on alternating days rather than on the same day. Both strength and cardiorespiratory endurance programs used in this study, however, have been noted as inappropriate. McCarthy et al. (1995) and Nelson et al. (1990) found strength production to be improved even with a rest period of ten minutes or less after cycling. Thus, the finding of the current study that more than one hour after cycling is necessary for maximal strength production is in agreement with Sale et al. (1990a), but appears to disagree with the findings of McCarthy et al. (1995) and Nelson et al. (1990). Three possibilities exist for the discrepancy between the decreased strength findings that Abernathy (1993), Kroon and Naeije (1991), Sale et al. (1990a), Sherman et al. (1984), and the current study have shown, and the strength improvements that McCarthy et al. (1995) and Nelson et al. (1990) have found. First, acute decrements do not relate to training studies. Second, the decrement in strength production, found in endurance exercised muscle which has not fully recovered, causes relatively minor strength antagonism in relation to strength improvements. Third, perhaps a mental or motivational factor is responsible for
some part of these discrepancies.

Craig et al. (1991), using a same-day concurrent protocol, found upper body strength to be significantly more improved than lower body strength. McCarthy et al. (1995) shows the same trend, although not significant, lower body strength improvements were smaller than upper body strength improvements. The current study found leg extension torque and work to be decreased and upper body strength to be unaffected by previous cycling. This finding supports Craig et al. (1991) as well as the theory that cardiorespiratory endurance exercise affects subsequent strength of the specific muscles utilized more than other muscle groups.

Many theories have been proposed to account for the varied findings of the literature. Three main categories exist for the potential categories for strength compromise.

A physiologically based compromise is supported by findings that cardiorespiratory endurance training causes the conversion of type II muscle fiber characteristics to those of type I (e.g. decreased myofibrillar protein content and altered enzyme concentrations), which have lesser force production capabilities. It is not supported by findings that glycogen depletion (Sherman, 1984) and androgenic hormone levels (Craig, 1991), and anaerobic enzymes (Sale, 1990) do not diminish strength improvement during concurrent training. A morphologically based compromise is not supported by Sale (1990) finding no difference in muscle
diameter between strength in compromised and non-compromised muscle.

A neurological basis for a potential compromise is perhaps the least contradicted in the literature. Cardiorespiratory endurance training is known to change motor recruitment patterns to preferentially use type I fibers during exercise. This is directly antagonistic to strength training, which develops a faster recruitment of a greater proportion of type II fibers, resulting in greater degree of strength production (Sale, 1992).

A fourth possible mechanism of differing strength results, may be the mental and emotional conditions created by the stresses of dual training. Different protocols, or fatigue could elicit different attitudes toward the training, causing changes in effort and therefore performance.

The current study, which found strength to be compromised after cycling only in endurance exercised muscle, then, supports a local muscular compromise, which could result from a local physiological antagonism other than glycogen depletion and enzyme changes, some neural facilitation compromise, or mental fatigue.

Summary
The following represent the findings of this study:

1. Cycling prior to strength measurement decreased leg extension torque and work significantly.
2. Cycling intensity and rest interval had no effect on strength produced.

3. Lower body (leg extension torque and work) strength was decreased more than upper body strength (chest press).

Conclusion

Cycling within one hour prior to strength performance will decrease leg strength but not upper body strength. This indicates that those involved in concurrent training should train for strength before endurance in order to maximize performance of each form of exercise.

Recommendations for future study

The following studies are recommended:

1. Conduct a study similar to the present investigation, in which strength testing is conducted from one hour until twenty-four hours after strength training.

2. Conduct a training study which compares the strength development of two same day concurrent protocols in which one trains strength before endurance, and the other trains endurance prior to strength.
CHAPTER REFERENCES


Preconditions of Subjects

1. I understand that I am not to eat for two hours prior to any testing.

2. I understand that I am not to take any drugs or caffeine prior to any testing done on testing days.

3. I understand that I am not to engage in any aerobic or anaerobic exercise in the 48 hours prior to any testing.

4. I understand that, other than the conditions mentioned above, I am to follow my normal patterns of eating, sleeping, and exercise.

Subject Signature ___________________________________________

Witness Signature ____________________  Date_________
CONSENT TO ACT AS A HUMAN SUBJECT

Subject Name (print): ___________________________ Date: __________

1) I hereby volunteer to participate as a subject in laboratory testing. I understand that this testing is part of a study entitled: "Effects of endurance exercise intensity on subsequent measures of strength." The purpose of this study is to investigate the effect of performing aerobic exercise before heavy-resistance exercise. I understand that my participation will include four days of testing in the Exercise Physiology Lab. I will receive a copy of this consent form. I can contact David W. Hill in his office in the Department of Kinesiology at (817) 565-2252 if I have any questions.

I hereby authorize David Hill and/or assistants selected by him to perform on me the following procedures:

a) day 1, to have me perform an incremental test to volitional exhaustion on a cycle ergometer, using either only arms or legs, with the work rate increased every two minutes until I feel that I can no longer continue, cannot maintain the required cadence, or am told to stop by the investigator; I understand that during this test my nose will be pinched shut and I will be breathing through a mouthpiece;

b) day 2, to have me perform a strength test that involves three all-out contractions of my knee extensors (thigh muscles) and three all-out contractions of my shoulder flexors (chest and shoulder muscles); resistance will be provided by a computerized strength-measuring machine (Biodex); the strength test will be repeated, with a 20 minute rest after the first test and a 40 minute rest after the second test;

c) days 3 and 4, to have me exercise on a bicycle ergometer using either only arms or only legs on two separate occasions, on one day for 30 minutes at an intensity equal to 60% of what I achieved in the incremental test (item "a" above) and on the other day for 20 minutes at an intensity equal to 90% of what I achieved in the incremental test (item "a" above); following each exercise bout, to have me repeat the strength testing described in item "b" above.

2) The procedures outlined above have been explained to me by David W. Hill and/or assistants selected by him.
3) I understand that the procedures outlined above involve the following risks and discomforts: temporary muscle pain and soreness, possibility of abnormal changes in my heart beat or blood pressure, or even heart attack; however, I understand that my heart rate will be monitored during testing and that I can terminate any test at any time at my discretion.

4) I have been advised that the following benefits will be derived from my participation in this study: other than learning about aerobic and strength testing and about fitness level, there are no benefits to me.

5) I understand that David W. Hill and/or assistants selected by him will answer any inquiries that I may have at any time concerning these procedures and/or investigations.

6) I understand that all data concerning myself will be kept confidential and available only upon my written request. I further understand that in the event of publication, no association will be made between the reported data and myself.

7) I understand that there is no monetary compensation for my participation in this study.

8) I understand that in the event of physical injury directly resulting from participation, compensation cannot be provided. Medical treatment will be available at the University Health Center. the laboratory has an outside telephone line to the city of Denton emergency services.

9) I understand that I may terminate participation in this study at any time without prejudice to future care or any possible reimbursement of expenses, compensation, or employment status.

10) I understand that I may contact the chairperson of the Kinesiology Department's Committee on the Use of Human Subjects in Research, Dr. Noreen Goggin on any matters concerning my participation in this study or if I feel that there is infringement on my rights.

Subject Signature: ________________________________

Witness Signature: ___________________________ Date: __________

The project titled “Effects of endurance exercise intensity on subsequent measures of strength” has been reviewed and approved by the UNT Committee for the Protection of Human Subjects (817-365-3940). The primary investigator in the study, Dr. David W. Hill, can be reached at 817-365-2232.
UNIVERSITY OF NORTH TEXAS
MEDICAL HISTORY FORM

All information is private and confidential. Please print.

Today's Date __/__/__

Name

First      Middle      Last

Home Address

Number and Street       Telephone Home

City            State        Zip Code

Permanent Address (if different from above)

Number and Street       Telephone Home

City            State        Zip Code

Social Security Number Date of Birth Age __

---/--/     ___/___    ___

Sex M ___ F ___

Marital Status

___ Single   ___ Married   ___ Divorced   ___ Widowed   ___ Separated

How long have you been this marital status? ________________________
PRESENT HISTORY

Check (✓) the blank in front of those questions to which your answer is yes. Leave others blank.

Has a doctor ever said that your blood pressure was too high? ____________

Has a doctor ever said that your blood pressure was too low? ____________

Do you ever have pain in your heart or chest? ____________

Do it happen at rest? ____________

Does it happen during exertion? ____________

Are you often bothered by a thumping of the heart? ____________

Does your heart often race like mad? ____________

Do you ever notice extra heart beats? ____________

Do you ever notice skipped heart beats? ____________

Are your ankles often badly swollen? ____________

Does the swelling improve when off your feet? ____________

Do cold hands or feet trouble you even in hot weather? ____________

Has a doctor ever said that you had or have heart trouble? ____________

Has a doctor ever said that you had or have an abnormal electrocardiogram (ECG or EKG)? ____________

Has a doctor ever said that you have had a heart attack or coronary? ____________

Do you suffer from frequent cramps in your legs? ____________

Do you often have difficulty breathing? ____________

Do you get out of breath long before anyone else? ____________

Do you sometimes get out of breath when sitting still? ____________

Do you sometimes get out of breath while sleeping? ____________

Has a doctor ever told you your blood fats (cholesterol or triglycerides) level was high? ____________

List any medications or supplements you are now taking, the date you started taking each drug, and how much you take (dosage), if known:

<table>
<thead>
<tr>
<th>Medication</th>
<th>Date started</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>month year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>month year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>month year</td>
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<td>month year</td>
<td></td>
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<tr>
<td></td>
<td>month year</td>
<td></td>
</tr>
</tbody>
</table>

List any drug allergies: ____________________________
PAST HISTORY

Do you **presently** have or have you **ever had** any of the following? (if yes, please specify approximately when and if it is still active).

- Heart attack
- Rheumatic fever
- Heart murmur
- Disease of the arteries
- Varicose veins
- Arthritis or joint pain:
- Diabetes Mellitus (if yes, are you on medication?)
- Abnormal blood sugar test
- Phlebitis
- Dizziness or fainting episodes
- Epilepsy or seizures
- Stroke
- Diphtheria
- Scarlet fever
- Infectious mononucleosis
- Anemia
- Hypothyroidism
- Hyperthyroidism
- Pneumonia
- Bronchitis
- Asthma:
  - Allergy induced
  - Exercise induced
  - Stress (psychologic) induced
- Abnormal chest X-Ray
- Emphysema
- Other lung diseases
- Jaundice or gallbladder problems
- Kidney stones
- Prostatic problems
- Diseases of the Central Nervous System
- Emotional problems
- Cancer
- Broken bones-specify:

Comments:
PAR-Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people, physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check (✓) the “YES” or “NO” opposite the question if it applies to you.

YES  NO
1. Has your doctor ever said you have heart trouble?
2. Do you frequently have pains in your heart and chest?
3. Do you often feel faint or have spells of severe dizziness?
4. Has a doctor ever said your blood pressure was too high?
5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise or might be made worse with exercise?
6. Is there a good physio reason not mentioned here why you should not follow an activity program even if you wanted to?
7. Are you over age 65 and not accustomed to vigorous exercise?

YES to one or more questions  NO to all questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness appraisal. Tell your physician what questions you answered “YES” to on PAR-Q or present your PAR-Q copy.

If you have a temporary minor illness, such as a common cold, postpone your activity program.

Answered if you answered PAR-Q accurately you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM — a gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort
- A FITNESS APPRAISAL — the Canadian Standardized Test of Fitness (CSTF)

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness appraisal. Tell your physician what questions you answered “YES” to on PAR-Q or present your PAR-Q copy.

After medical evaluation, seek advice from your physician as to your suitability for:

- A GRADUATED EXERCISE PROGRAM — a gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort
- A FITNESS APPRAISAL — the Canadian Standardized Test of Fitness (CSTF)

If you have a temporary minor illness, such as a common cold, postpone your activity program.

Answered if you answered PAR-Q accurately you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM — a gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort
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- A FITNESS APPRAISAL — the Canadian Standardized Test of Fitness (CSTF)

If you have a temporary minor illness, such as a common cold, postpone your activity program.

Answered if you answered PAR-Q accurately you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM — a gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort
- A FITNESS APPRAISAL — the Canadian Standardized Test of Fitness (CSTF)

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness appraisal. Tell your physician what questions you answered “YES” to on PAR-Q or present your PAR-Q copy.

After medical evaluation, seek advice from your physician as to your suitability for:

- A GRADUATED EXERCISE PROGRAM — a gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort
- A FITNESS APPRAISAL — the Canadian Standardized Test of Fitness (CSTF)

If you have a temporary minor illness, such as a common cold, postpone your activity program.
APPENDIX B

RESULTS
TABLE V

Leg Extension Power
(watts)

\begin{tabular}{|c|c|c|c|}
\hline
Intensity & 0 & 20 & 60 \\
\hline
\hline
pre-exercise & 97.47 \pm 13.50 & 93.69 \pm 23.05 & 98.00 \pm 17.17 \\
\hline
40 & 92.61 \pm 19.16 & 95.30 \pm 21.46 & 98.12 \pm 25.76 \\
\hline
65 & 96.07 \pm 25.61 & 100.83 \pm 22.04 & 96.81 \pm 20.03 \\
\hline
\end{tabular}

No intensity (p=.934), time (p=.688), or intensity by time (p=.587) effects were found for leg extension power.

TABLE VI

Chest Press Torque
(ft*lbs)

\begin{tabular}{|c|c|c|c|}
\hline
Intensity & 0 & 20 & 60 \\
\hline
\hline
pre-exercise & 178.90 \pm 19.05 & 180.60 \pm 23.23 & 178.60 \pm 21.50 \\
\hline
40 & 183.60 \pm 21.16 & 183.00 \pm 22.43 & 183.80 \pm 25.20 \\
\hline
65 & 187.20 \pm 21.04 & 187.00 \pm 21.30 & 184.50 \pm 20.02 \\
\hline
\end{tabular}

No intensity (p=.159), time (p=.709), or intensity by time (p=.885) effects were found for chest press torque.
### TABLE VII

**Chest Press Power**  
(watts)

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Pre-exercise</th>
<th>40</th>
<th>65</th>
</tr>
</thead>
<tbody>
<tr>
<td>%VO&lt;sub&gt;2&lt;/sub&gt;peak</td>
<td>47.90 ± 17.68</td>
<td>155.60 ± 25.51</td>
<td>150.00 ± 26.30</td>
</tr>
<tr>
<td>20</td>
<td>149.8 ± 32.70</td>
<td>150.70 ± 20.58</td>
<td>159.50 ± 23.70</td>
</tr>
<tr>
<td>60</td>
<td>142.00 ± 28.00</td>
<td>156.20 ± 21.10</td>
<td>161.40 ± 26.87</td>
</tr>
</tbody>
</table>

No intensity (p=.287), time (p=.771), or intensity by time (p=.243) effects were found for chest press power.

### TABLE VIII

**Chest Press Work**  
(ft*lbs)

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Pre-exercise</th>
<th>40</th>
<th>65</th>
</tr>
</thead>
<tbody>
<tr>
<td>%VO&lt;sub&gt;2&lt;/sub&gt;peak</td>
<td>202.80 ± 30.88</td>
<td>209.00 ± 28.52</td>
<td>208.00 ± 30.76</td>
</tr>
<tr>
<td>20</td>
<td>202.70 ± 37.72</td>
<td>207.20 ± 30.29</td>
<td>214.80 ± 32.10</td>
</tr>
<tr>
<td>60</td>
<td>205.40 ± 35.09</td>
<td>205.40 ± 35.09</td>
<td>217.20 ± 30.04</td>
</tr>
</tbody>
</table>

No intensity (p=.181), time (p=.130), or intensity by time (p=.599) effects were found for chest press work.
REFERENCES


