San Fernando Valley State College

EFFECT OF FATIGUE ON THE DEVELOPMENT
OF ISOTONIC AND ISOMETRIC STRENGTH

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Arts in

Physical Education

by

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June, 1968
The thesis of Nicolas James Breit is approved:

[Signature]

Committee Chairman

San Fernando Valley State College

June, 1968
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ABSTRACT

EFFECT OF FATIGUE ON THE DEVELOPMENT
OF ISOTONIC AND ISOMETRIC STRENGTH

by

Nicolas James Breit

Master of Arts in Physical Education

June, 1968

The problem of this investigation was to determine if participation in strength developing exercises during a state of fatigue has a different effect on strength gains than when participating in the same exercises in a nonfatigued state.

Thirty-eight male volunteers enrolled at San Fernando Valley State College physical education activity classes served as subjects for the study. Prior to the beginning of the seven week training period each subject went through a group-equating test period. This consisted of one maximum repetition on the bench press three days a week for two weeks. The percentage of strength gain was determined between the first and sixth test. All subjects were then ranked according to their percentage of strength gains for this two week period and were then randomly assigned to Group I or Group II.

Group I trained on the hand dynamometer in a nonfatigued state, then became fatigued on a bicycle ergometer and immediately trained on the bench press while fatigued. Group II trained in the
reverse order, using the bench press exercise while in a nonfatigued state, then became fatigued on the bicycle ergometer, and immediately trained on the hand dynamometer. The training program consisted of two training sessions a week for six and one-half weeks. Each training session consisted of one bout of ten maximum repetitions on the bench press and one maximum six second isometric contraction on the hand dynamometer. The subjects became fatigued by exercising on a bicycle ergometer for five minutes with a resulting heart rate of 180 beats per minute.

The results of this study indicate that there was no significant difference in the strength development in exercises performed in a fatigued or nonfatigued state. It may be concluded that the state of fatigue does not influence the training effect of exercises designed to develop isometric and isotonic strength.
CHAPTER I
INTRODUCTION

One of the primary objectives in physical education is the development of physical fitness. An important component of physical fitness is that of muscular strength.

Programs designed to achieve gains in strength are commonly conducted when the students are in a "fresh" or nonfatigued state. Some programs provide for strength development exercises in a fatigued state following endurance type activities. Still other programs are conducted with little thought given to the sequence of participation in strength and endurance exercises. The effect of a fatigued or a nonfatigued state on the development of strength may be an important consideration in determining the most efficient and effective program for strength development.

For many years psychologists have conducted research in the area of fatigue and its effects on mental and verbal tasks. More recently, physical educators have investigated the effect of fatigue on motor performance and motor learning. (7, 24, 29, 30) In one study it was reported that fatigue improved the efficiency of learning novel skills. (29) In another study the investigator found that conditioning for endurance activities could be improved by training in a state of oxygen debt. (30) There has been little or no research, however, dealing with the relationship of strength
gains and fatigue. This investigation, therefore, has been designed to examine the effects of fatigue on strength development.

The Problem

Statement of the Purpose

The purpose of this study was to investigate the effect of fatigue on the development of isometric and isotonic strength.

Statement of the Problem

The problem of this study was to determine if participation in strength developing exercises during a state of fatigue has a different effect on strength gains than when participating in the same exercises in a nonfatigued state.

Hypothesis

The investigation was designed to test the following null hypothesis: Exercising in a state of fatigue will not affect the development of isotonic and isometric strength.

Importance of the Study

The effect of fatigue on the development of strength has not been determined. If fatigue has an effect on gains in strength, such information would serve as a valuable guide in the organization of the sequence of activities in physical education classes and body conditioning programs which deal specifically with the development of strength. Another desirable outcome could be that the findings
of this study would result in a greater understanding of the phenomena of strength.

Scope and Limitations

The study dealt with thirty-eight volunteer college men enrolled in physical education classes at San Fernando Valley State College. The study, which was conducted over a seven week period, was confined to the effect of the experimental condition on the strength gains acquired from arm extension and hand gripping exercises. All subjects were asked to refrain from any resistive work which might possibly influence the strength of muscles employed in the bench press and hand dynamometer exercises.

Assumptions

The study was based on the following assumptions: (1) that strength can be measured; (2) that exercise performed on the bicycle ergometer leading to a heart rate of 180 beats per minute is a sufficient work load to induce fatigue.

Definition of Terms

The following terms are used in the study and are defined specifically for their use in this investigation.

Fatigue. A condition indicated by a heart rate of 180 beats per minute resulting from exercising on a bicycle ergometer.

Maximum Isometric Strength. A single maximum isometric contraction made on a hand dynamometer.
**Maximum Isotonic Strength.** The maximum weight lifted through one complete repetition in the bench press exercise.

**Overload.** Demands placed upon the neuromuscular and cardiorespiratory systems which are greater than that to which the subject is accustomed. The 10 R. M. technique on the bench press exercise and a maximum effort on the hand dynamometer illustrate overload of the neuromuscular system. Increasing the resistance on the bicycle ergometer to develop a heart rate of 180 beats per minute illustrate overload of the cardiorespiratory system.

**10 R. M.** The 10 R. M. technique refers to the system of weight training used in this study. It represents a weight which is heavy enough to allow only ten repetitions.

**Organization of the Remaining Chapters**

The study is organized in five chapters. Chapter II contains a review of the literature which was deemed relevant to the present investigation. Chapter III describes the research methodology by which the study was conducted. Chapter IV includes the presentation and interpretation of the data, and a discussion relating to the study. Chapter V includes a summary, conclusions, and recommendations for future studies.
CHAPTER II
REVIEW OF RELATED LITERATURE

The purpose of this study was to investigate the effect of fatigue on the development of isotonic and isometric strength. The literature contains many studies in the areas of strength and fatigue, however, no attempt appears to have been made in the area of fatigue and its influence on gains in muscular strength. For purposes of this investigation, the literature was categorized and discussed under the following headings: Stimuli for Strength Development; Physiology of Strength; Overload; Psychological Aspects of Fatigue; and Related Studies.

Stimuli For Strength Development

There are several possible stimuli which have been theorized as having an influence on strength development. Among such considerations have been changes in the central nervous system, changes in blood flow within the muscle, and oxygen deprivation within the muscle. There is conflicting evidence regarding some of these considerations.

Role of Oxygen Deprivation and Blood Constriction in Strength

In 1953 Hettinger and Mueller reported that six second isometric contractions resulted in significant strength gains. They
attributed the gains in strength to oxygen deprivation in the muscle. In discussing their findings, as translated by O'Connell, Hettinger and Mueller stated:

One could not believe that whenever the oxygen demand of the muscles is not fully satisfied during exercise, a training effect results. If this hypothesis is correct, then static work, a form of work which creates particularly unfavorable vascularization conditions, ought to originate a training stimulus with a relatively small metabolism. (32:2)

We assumed that the not completely supplied requirement of oxygen coincides with the threshold values of the training stimulus. If so, then the training effect which increases above the threshold value with the training strength could be correlated with the correspondingly increasing deficit of the oxygen supply. However, this would not explain why above a certain range value the training effect does not increase any more although the oxygen deficiency becomes greater. But we could surmise that the crossing of the aerobic metabolism limit creates a constant training stimulus regardless of the intensity of the oxygen deficiency, in other words, the 'all-or-none-law' of the training stimulus applies to the muscle fibers. (32:10)

A study by Royce suggests that oxygen deprivation plays a role in isometric strength development. He investigated isometric fatigue curves in muscles with normal and occluded circulation. His findings lend support to the conclusions made by Hettinger and Mueller. (25:211)

These findings apparently did not agree with the findings of other researchers. O'Connell conducted a study to test the hypothesis of Hettinger and Mueller. He compared the isometric strength gains of two groups. The training stimulus for one group was isometric contractions and the training stimulus for the other group was artificial blood occlusion by use of a sphygmomanometer. He found that the artificially occluded group failed to develop
significant strength gains, thus demonstrating that oxygen depriv-
ation alone is not a significant training stimulus for muscular
strength. (22:44) These findings were supported by Morehouse, who
stated that changes in blood are insufficient to account for the
large gains sometimes made in strength. (5:196)

The findings of Maison and Broeker lend support to those of
Morehouse and O'Connell. They found that finger muscles with an
adequate blood supply, when worked to fatigue, were "more effective"
than those who trained to fatigue with an occluded blood supply.
(19:404)

Central Nervous System

The role of the central nervous system may be an extremely
important aspect of strength development as it appears that strength
is highly dependent on neuromuscular integration. (13:382) Maison
and Broeker have taken a slightly different approach regarding the
involvement of the central nervous system, for they suggest that
strength may involve "the building of resistance to fatigue in the
cells of the motor cortex of the anterior horn or a more economical
usage of motor discharge." (19:390)

The role of the central nervous system as an important factor
in strength development has also been discussed by Morehouse. He
cites Magoun in stating:

Recent studies of function of the reticular formation suggest
that the effect of training may be a reduction of the inhibi-
tory effects of the extra-pyramidal system on the anterior
horn cell discharges which produces contractions. (5:198)
Although the involvement of the central nervous system is primarily theory, DeVries suggests "until more conclusive evidence is available, it seems logical to hypothesize the existence of training in the central nervous system and in the muscle itself."

(2:306)

**Physiology of Strength**

Researchers have devoted much time to understanding the stimuli for strength and the resulting physiological changes. It is generally agreed that certain changes occur in the muscles as a result of increased strength.

The increase in muscle size is a result of an increase in the diameter of each muscle fiber. There is also an increase in the number of myofibrils in each muscle fiber. Other causes of hypertrophy are an increase in the number of capillaries, thickening of the sarcolemma, increase in the amount of phosphocreatine, glycogen, and non-nitrogenous substances. (6:199, 201)

**Overload**

It is a known fact that training with light workloads will not bring about improvements in strength or endurance. For this reason, when individuals are training with weights or trying to build up endurance, it is necessary to impose increasingly heavy demands on the body. (2:330) Whether an individual is concerned
with strength, muscular endurance, or cardiorespiratory functions, improvement will come about only when the system primarily involved is overloaded or challenged. Improvement, therefore, will occur only when the workload is greater than that to which an individual is accustomed. (2:218)

There are several methods which have been commonly used to impose forms of overload on the body in order to develop strength. In general, this overload can be accomplished in four different ways:

1. Walters states that exercising against resistance at a "speed which produces fatigue" is an appropriate form of overload. (28:1) Hellebrandt and Houtz state that this increase in the speed and pace will "progressively overload the neuromuscular system and augment functional capacity." (14:322)

2. Overload may be produced by gradually increasing the total load to be moved. (31)

3. Overload may be imposed by progressively increasing the number of performances (31) or the frequency of sessions. (13:382)

4. Overload may be imposed by progressively increasing the total time that a given position may be held. (31)

In evaluating common methods of training, Hellebrandt and Houtz conclude that "the amount of work done per unit of time is the critical variable on which extension of the limits of performance demands." (13:382)

It is apparent that various forms of stress can create an overload situation since the body is forced to make compensations which help indirectly to increase systematic output. Some research suggests that it is advantageous to work while tired because the
explanation given by the writer dealt with blood chemistry changes as a result of the hypoxia conditions. (30:1, 24)

Clarke studied the immediate effects of cardiorespiratory fatigue on strength decrement. His subjects exercised on a treadmill at seven miles per hour for ten minutes until a "high heart rate" was attained and then they were tested for strength changes in various muscle groups. Two muscle groups showed significant strength decreases, five muscle groups showed nonsignificant strength decreases, and five muscle groups showed strength increases. He suggested that warm-up may have accounted for the increase in the strength of five of the muscle groups. (10:96, 99)

Implications for Present Study

The findings of Hettinger, Mueller, and Royce suggest that oxygen debt and blood occlusion act as a training stimulus for strength. Latimer found that training in a state of hypoxia significantly improved endurance performance, while Benson found that practicing while fatigued improved the efficiency of learning novel skills. In view of these facts it appears that strength development may be positively related to fatigue, and, therefore, the hypothesis of this study is worthy of investigation.
CHAPTER III
RESEARCH PROCEDURES

The purpose of this investigation was to determine the effect of fatigue on the development of isometric and isotonic strength. Included in this chapter will be a discussion of the selection and assignment of subjects, the orientation of the subjects, the general design of the study, the familiarization period, the testing procedures, the instrumentation, a description of the experiment, and the statistical design.

Selection and Assignment of Subjects

Thirty-eight volunteers from San Fernando Valley State College were used as subjects in this study. The volunteers were students enrolled in general education physical education classes. The criteria for being accepted as a volunteer were: "unrestricted" medical classification, willingness to dress in physical education apparel each day of the training program, having no outside activities which would influence the gains in strength during the training period, being able to participate for nine consecutive weeks, and not having been enrolled in a body conditioning class within the last year.

All subjects received six tests on the bench press prior to the beginning of the study. Since these tests were needed to equate
the groups, they were defined as the group-equating tests. The subjects were ranked and paired according to the percentage of strength gains made on the group-equating tests and were then randomly assigned to Group I or Group II by a flip of a coin.

**Orientation of Subjects**

The subjects were informed of the nature of the study at the time they volunteered. At this time they were told that they would be participating in a fatigue and strength developmental metabolic study, and that it would consist of five minutes of strenuous exercise on a bicycle ergometer, ten maximum lifts on a bench press, and a six second isometric contraction on a hand dynamometer. (Appendix A)

Prior to the beginning of the study, each subject was telephoned to confirm his interest and determine the days on which he could exercise. At this time each subject was told of the type of exercise he would be doing, the number of weeks he would be exercising, and the number of strength tests he would take.

Following the end of the week of familiarization, a general information letter was mailed to each subject. (Appendix B) The purpose of this letter was: to explain any muscle soreness or physical discomforts that may have been experienced; that warming up, if desired, should be done prior to their exercise period; that breakfast and lunch should be eaten at a particular time in relation to their exercise time; and a reminder to limit any outside activity
involving muscles of the shoulder or forearm.

**General Design**

The study, excluding one week of familiarization and the group-equating test period, lasted seven weeks. Subjects trained twice a week at the same time of day throughout the study, except for week six in which case only one training day was allowed because of Thanksgiving Vacation. Each subject was handled individually on an appointment basis and was allotted approximately a seven minute period to complete each training session.

Group I trained with the hand dynamometer in a nonfatigued state, then became fatigued on the bicycle ergometer and immediately trained on the bench press in a fatigued state. Group II trained in the reverse order using the bench press exercise while in a nonfatigued state, then became fatigued on the bicycle ergometer, and immediately trained on the hand dynamometer.

**Familiarization Period**

Prior to the group-equating tests, one week was devoted to familiarization of the subject with the equipment. This week was intended to allow the subject to become proficient with the bench press and hand dynamometer, and to eliminate major fluctuations in performance on this equipment.

During this week each subject exercised three days on the
hand dynamometer. Each day the subject exerted three maximum isometric contractions and between trials the handle of the hand dynamometer was adjusted until the most comfortable grip had been secured.

Following the third trial on the hand dynamometer, each subject exercised on the bench press. In most cases the subjects began lifting 125 pounds and were allowed up to three lifts per day providing each lift was an improvement over the previous one. Increments ranged from two and one half pounds to twenty pounds, depending on the subject and the case in which he made each lift.

**Testing Procedure**

**Group-equating tests.** The group-equating tests, which followed the week of familiarisation, were designed to provide a basis on which the two groups would be formed. The basic criterion was the percentage of strength which was gained on the bench press over a period of two weeks. For example, a subject bench pressed 130 pounds on test number one and 155 pounds on test number two. There was an improvement of twenty-five pounds and a strength gain of nineteen per cent. Another subject may bench press 150 pounds on test number one and 175 pounds on test number two; he too improved twenty-five pounds, but only gained sixteen and one half per cent.

The group-equating test period consisted of three tests per week for all subjects and was conducted for two weeks prior to the beginning of the study. Each subject reported to the testing room
on Monday, Wednesday, and Friday, or Tuesday, Thursday, and Friday. Each day the subject did one maximum repetition on the bench press until the end of the second week. At this time the percentage of strength gain between test one and test six was calculated. All subjects were ranked according to their percentage of strength gains and were then randomly assigned to Group I or Group II.

**Pre-tests.** Pre-tests were given to each subject on the bench press and hand dynamometer exercises. Test number six on the hand dynamometer and bench press of the group-equating test period served as the pre-test for the hand dynamometer and bench press.

**In-training tests.** In-training tests were conducted on Friday of weeks two and four of the training program. These were given to determine any trends in the strength gains and to determine if differences between the two groups existed during the training program. These tests were identical to those given in the pre-test and post-test.

**Post-test.** Post-tests for both the bench press and the hand dynamometer were conducted on Friday of week seven of the training program. The tests were identical to those given in the pre-test and in-training tests.

**Procedures followed for testing.** The test on the hand dynamometer consisted of the best of three maximum contractions. The grip was adjusted to the same size as that used during the training sessions. The subject was given chalk for his hand if desired. Following the first and second contraction a rest interval of
CHAPTER IV
FINDINGS OF THE STUDY

The problem of this study was to determine if participation in strength developing exercises during a state of fatigue has a different effect on strength gains than when participating in the same exercises in a nonfatigued state. The subjects were equated on the basis of their percentage of strength gain during a two week period prior to the beginning of the experimental training program. The program consisted of training two times a week for a period of seven weeks. Group I exercised using the hand dynamometer in a nonfatigued condition, became fatigued on a bicycle ergometer, and immediately exercised on the bench press. Group II performed the same exercises except in reverse order. They trained on the bench press in a nonfatigued condition, became fatigued on a bicycle ergometer, and immediately exercised on the hand dynamometer. Both groups were given a pre-test and post-test and two in-training tests.

The reliability of the testing procedure was determined by the use of Pearson's product moment correlation coefficients. The correlations between the fourth and fifth trials, and the fifth and sixth trials were both .99 for the bench press, and .96 and .95 for the hand dynamometer. These particular trials were used because they were taken during the first week of the group-equanting period. The first three trials were taken during the week of familiarization and therefore did not serve as good data for reliability tests.
The hand dynamometer, which was calibrated with known weights before each test, showed a consistent decrease in the amount of resistance of the "inner spring" to the external weight being applied. Reliability of the internal resistance of the hand dynamometer to known weights was computed using Pearson's product moment correlation. The correlation of the hand dynamometer calibration readings between the pre-test and post-test was .99, indicating the hand dynamometer became proportionally and very consistently weaker.

Individual results of the bench press tests for Groups I and II and individual results of the hand dynamometer tests will be found in Tables 6 and 7 in Appendix E.

**Statistical Analysis**

The findings obtained from the bench press tests for Group I and II are summarized in Table 1. Both groups gained consistently throughout the study with Group I averaging a 3.2 pound gain every two weeks and Group II averaging a 3.7 pound gain every two weeks.

The greatest gains for both groups were made during the last two weeks in which Group I had a mean gain of 4.6 pounds and Group II a mean gain of 5.1 pounds.

Analysis of the mean gains for the bench press are summarized in Table 2. The resulting t values indicate no significant gains occurred within either group.

The findings obtained from the hand dynamometer tests for
TABLE 1
SUMMARY OF MEANS AND STANDARD DEVIATIONS ON BENCH PRESS TESTS

<table>
<thead>
<tr>
<th>Group I</th>
<th>Pre-Test</th>
<th>Test I</th>
<th>Test II</th>
<th>Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>156.44</td>
<td>158.55</td>
<td>161.44</td>
<td>166.05</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>21.60</td>
<td>21.60</td>
<td>21.52</td>
<td>20.57</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group II</th>
<th>Pre-Test</th>
<th>Test I</th>
<th>Test II</th>
<th>Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>170.52</td>
<td>172.36</td>
<td>176.71</td>
<td>181.84</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>32.19</td>
<td>32.36</td>
<td>31.98</td>
<td>31.64</td>
</tr>
</tbody>
</table>

TABLE 2
SUMMARY OF t TESTS ON BENCH PRESS TESTS WITHIN EACH GROUP

<table>
<thead>
<tr>
<th>Group I</th>
<th>Mean Difference</th>
<th>t Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Test and Test I</td>
<td>2.10</td>
<td>.29 *</td>
</tr>
<tr>
<td>Test I and Test II</td>
<td>2.89</td>
<td>.40 *</td>
</tr>
<tr>
<td>Pre-Test and Test II</td>
<td>5.00</td>
<td>.69 *</td>
</tr>
<tr>
<td>Test II and Post-Test</td>
<td>4.60</td>
<td>.65 *</td>
</tr>
<tr>
<td>Pre-Test and Post-Test</td>
<td>9.60</td>
<td>1.36 *</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group II</th>
<th>Mean Difference</th>
<th>t Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Test and Test I</td>
<td>1.84</td>
<td>.17 *</td>
</tr>
<tr>
<td>Test I and Test II</td>
<td>4.34</td>
<td>.40 *</td>
</tr>
<tr>
<td>Pre-Test and Test II</td>
<td>6.18</td>
<td>.57 *</td>
</tr>
<tr>
<td>Test II and Post-Test</td>
<td>5.13</td>
<td>.48 *</td>
</tr>
<tr>
<td>Pre-Test and Post Test</td>
<td>11.31</td>
<td>1.06 *</td>
</tr>
</tbody>
</table>

*Not statistically significant - .05 level.
Groups I and II are summarized in Table 3. As can be seen the mean pre-test score on the hand dynamometer for Group II was 11.4 pounds greater than Group I. This difference is significant at the .05 level. Since the groups were only equated on bench press performance there was no way to control this difference on the hand dynamometer. Group I improved on all but the second in-training test with an average gain of .38 pounds every two weeks and a mean gain of 1.14 pounds during the study. Group II lost consistently on all but the post-test with an average loss of .83 pounds every two weeks and a mean loss of 2.49 pounds during the study.

Table 4 includes the results of the t tests which were used to determine whether significant changes were made within each group on the hand dynamometer. The resulting t values indicate no significant gains occurred within Group I. The losses recorded within Group II were also nonsignificant.

The analysis of the difference of mean strength gains between Groups I and II on both bench press and hand dynamometer are summarized in Table 5. The difference between Groups I and II in mean strength gain due to the bench press exercise was found to be nonsignificant. The difference between Groups I and II in mean strength gains due to the hand dynamometer exercise was also found to be nonsignificant.

It will be recalled that the groups were equated according to the percentage of strength gains made on the bench press during the first two weeks of the investigation. The percentage of strength
### TABLE 3
SUMMARY OF MEANS AND STANDARD DEVIATIONS ON HAND DYNAMOMETER TESTS

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-Test</th>
<th>Test I</th>
<th>Test II</th>
<th>Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>109.55</td>
<td>117.47</td>
<td>108.47</td>
<td>110.69</td>
</tr>
<tr>
<td>StDev</td>
<td>17.02</td>
<td>15.76</td>
<td>15.15</td>
<td>12.94</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-Test</th>
<th>Test I</th>
<th>Test II</th>
<th>Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>121.04</td>
<td>117.33</td>
<td>115.68</td>
<td>118.55</td>
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<td>StDev</td>
<td>15.26</td>
<td>14.50</td>
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### TABLE 4
SUMMARY OF t TESTS ON HAND DYNAMOMETER TESTS WITHIN EACH GROUP

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean Difference</th>
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<tr>
<td>Group I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Test and Test I</td>
<td>1.92</td>
<td>.35 *</td>
</tr>
<tr>
<td>Test I and Test II</td>
<td>-3.00</td>
<td>-.58 *</td>
</tr>
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<td>Pre-Test and Test II</td>
<td>-1.08</td>
<td>-.20 *</td>
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<tr>
<td>Test II and Post-Test</td>
<td>2.22</td>
<td>.47 *</td>
</tr>
<tr>
<td>Pre-Test and Post-Test</td>
<td>1.14</td>
<td>.22 *</td>
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</table>

<table>
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<th>t Ratio</th>
</tr>
</thead>
<tbody>
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<td>Pre-Test and Post-Test</td>
<td>-2.49</td>
<td>.51 *</td>
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</table>

*Not statistically significant - .05 level.
gains for the bench press were further calculated every two weeks following the introduction of the experimental variable. The percentage scores of both groups have been plotted and are shown in Figure I. Analysis of the curve shows that Group I exceeded Group II for the first two weeks of the experimental period and in the last four weeks Group II exceeds Group I.

**TABLE 5**

**COMPARISONS OF MEAN GAINS BETWEEN GROUPS I AND II**

<table>
<thead>
<tr>
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<td>.89 *</td>
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<td>-2.49</td>
<td>3.63</td>
<td>1.72 *</td>
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*Not statistically significant - .05 level.

**Discussion**

One of the major considerations in this study was the determination of the fatigue state. Heart rates have been validly used as an index of work output and as an indication of the level of fatigue caused from muscular work. (18:275) Balke, in attempting to determine what the normal cardiorespiratory limitations are in man, has concluded that an attainment of 180 beats per minute represents a physiological point where cardiorespiratory limitations become evident. He stated that as a heart rate of 180 beats per
FIGURE I

PERCENTAGE GAINS ON BENCH PRESS—
TWO WEEK INTERVALS
minute is approached there is a sudden rise in anaerobic work, decreased pulse pressure, decreased stroke volume, decreased oxygen pulse, and a disproportionate use in ventilation as compared to the amount of oxygen consumed and heart rate. (22:363) For these reasons a heart rate of 180 beats per minute was used as the criterion of fatigue in this study.

The method used to equate the groups in this study appears to be a new concept in strength studies. The original principle of equating groups on percentage of strength gains was formulated by Müller and Rhéamart. (20) Although their method related to isometric strength development, it was based on trends in the strength development curve, which was indicated by rapid gains at first, followed by continued and slower increases. Previous strength studies have either equated groups randomly or have matched groups according to the amount of weight initially lifted. The concept of equating groups on percentage of strength gains was thought to be superior to the random sampling technique, and to overcome the weaknesses in matching groups on the initial amount lifted.

When matching subjects on initial lifts, it is assumed that two subjects who lift a similar weight are equal in strength. This cannot be assumed, for one subject may have never worked with heavy resistance before, while the other may have trained previously with heavy resistance. The latter subject will have less opportunity to improve since he is already at a greater level of strength development, while the former subject will show much greater gains since
weights. There is no doubt that the spring in the hand dynamometer became consistently weaker throughout the study. For example, at the beginning of the study it took 116.5 pounds of known weights to register a score of 50 kilograms. Two weeks later it took only 111.5 pounds of known weights to register a score of 50.5 kilograms. Therefore a subject was able to attain a higher kilogram reading without really improving his strength. Psychologically the subject felt he was getting stronger, while in reality he was not. The investigator was aware of this, and although he did not tell the subjects the spring was getting weaker, he consistently encouraged them to achieve a higher score in an attempt to off-set this problem of instrumentation. If instrumentation were the only reason for the strength loss of Group II, then Group I would also have tended to lose strength. The reliability coefficients of .99 for comparisons of different hand dynamometer calibrations on the pre-test and post-test indicate a very consistent weakening of the spring throughout the scale.

The strength findings related to the isometric training on the hand dynamometer were not found to be consistent with the findings reported by Mueller. Mueller states that one can expect twenty percent gain in isometric strength in five weeks. (21:310) Since the subjects exercised on the hand dynamometer during the group-equating test period, it is possible that this two week period accounted for much of the gains, however, this would not appear to explain the small gains in strength during the experimental phase of the study.
specificity of this nature did not occur with Group I on the bench press who trained while fatigued and tested while "fresh".

The insignificant strength gains made on the bench press support the hypothesis of the study. It appeared somewhat unusual that neither group made significant strength gains during the seven week training period. One possible reason for this occurrence may be that the seven week training period was too short for significant gains to occur. It also appears to be quite likely that the group-equating test period was too long as indicated by the large gains made during the first two weeks of the investigation. In calculating the strength gains made over the entire nine week period of the study significant gains (.05 level) were achieved in both Groups I and II. In light of this finding it is recommended that future strength studies employing the "percentage of strength gain" technique for matching subject, either extend the length of the experimental part of the study or shorten the group-equating period.

In view of the initial discomfort reported by some subjects, it was interesting to see how well Group I adjusted to exercising on the bench press while in a state of fatigue. Only two subjects, on several occasions, were unable to perform anywhere near their ten repetitions because of the effects of fatigue. This observation along with the finding of no significant differences between the groups suggest that training in a state of fatigue is not detrimental to strength development.
CHAPTER V  
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The problem of this study was to determine if participation in strength developing exercises during a state of fatigue has a different effect on strength gains than when participating in the same exercises in a nonfatigued state.

Thirty-eight male volunteers enrolled in San Fernando Valley State College physical education activity classes served as subjects for the study. Prior to the beginning of the seven week training period each subject went through a group-equating test period. This consisted of one maximum repetition on the bench press three days a week for two weeks. The percentage of strength gain was determined between the first and sixth test. All subjects were then ranked according to their percentage of strength gains for this two week period and were then randomly assigned to Group I or Group II.

Group I trained on the hand dynamometer in a nonfatigued state, then became fatigued on a bicycle ergometer and immediately trained on the bench press while fatigued. Group II trained in the reverse order, using the bench press exercise while in a nonfatigued state, then became fatigued on the bicycle ergometer, and immediately trained on the hand dynamometer. The training program consisted of two training sessions a week for six and one half weeks. Each
training session consisted of one bout of ten maximum repetitions on the bench press and one maximum six second isometric contraction on the hand dynamometer. The subjects became fatigued by exercising on a bicycle ergometer for five minutes with a resulting heart rate of 180 beats per minute.

The findings of this study indicate that there was no significant differences in the strength development in exercises performed in a fatigued or nonfatigued state.

Conclusions

Since the null hypothesis tested in this study was found to be tenable, the following general conclusion appears justified: The state of fatigue does not influence the training effect of exercises designed to develop isometric and isotonic strength.

Recommendations for Future Studies

As a result of this study two recommendations for future studies appear evident:

1. The concept of equating groups on the basis of percentage of strength gains is new. The success of this concept in this study was only indirectly answered. To truly test this concept, there should be two groups equated on the percentage of strength gain technique, followed by having both groups receive the identical training stimulus.

2. In view of the calibration difficulty encountered with the hand dynamometer used in this investigation, perhaps the isometric phase of this study should be repeated with a new hand dynamometer.
BIBLIOGRAPHY

Books


Periodicals


Unpublished Materials


APPENDICES
APPENDIX A

APPLICATION BLANK
APPLICATION BLANK

Mr. Briat of the physical education department will be conducting a study in the area of human fatigue and strength this semester. Approximately forty male subjects are necessary for this investigation. It is hoped that some students in your class will be interested in this experiment and submit their names as possible subjects.

Volunteers chosen for the study will be asked to meet for approximately ten minutes per appointment, three days a week for a period of ten weeks. The study will end the week prior to Christmas Vacation. Those who are chosen as subjects will dress in physical education apparel and meet in P.E. 107. The experiment will consist of a five minute ride on a bicycle ergometer, a six second isometric contraction on a hand dynamometer, and ten lifts on a bench press.

If you are interested and willing to volunteer as a possible subject, please fill out the form below and return it to your instructor. Unfortunately, it is impossible to give financial assistance for your help, but each subject will benefit from an increase in arm and shoulder strength as well as increased cardiorespiratory fitness. You will be contacted by Mr. Briat if you meet the qualifications as a subject.

Name_________________________ Age____ Major_____________________

Last First Initial

Address____________________________________ Home phone_____________________

# and Street City Work phone_____________________

Weight_______ Height_______ Medical Classification_______ Year______

Activity class currently enrolled in: Title____ Teacher Time-Day____

Have you had any body conditioning classes within the last year?____

Circle your current state of condition: Excellent Good Average Poor

I would be willing to meet regularly scheduled ten minute appointments three times a week for a period of ten weeks. Please check the hours during which you could meet and start your most desirable hours.

___ 9-10 MW & Fri. between 8-1:30
___ 12-1 MW & Fri. between 8-1:30
___ 1-1:30 MW & Fri. between 8-1:30
___ 8-9 TTh & Fri. between 8-1:30
___ 9-10 TTh & Fri. between 8-1:30
___ 12-1 TTh & Fri. between 8-1:30
___ 1-1:30 TTh & Fri. between 8-1:30
APPENDIX B

GENERAL INFORMATION SHEET
GENERAL INFORMATION SHEET

TO: ALL SUBJETS
FROM: N. BREIT

Dear ________________________:

I would like to inform you that the first week of the study has progressed very well. There have been many questions asked regarding various phases of the study, and for this reason I have included the following information to help clarify any questions you may have.

MUSCLE SORENESS. Do not be disturbed by general soreness in the shoulder and chest muscles. This is a normal by-product of heavy muscular work and can be expected in any individual who has not exercised for a given period of time. The first few days on the bicycle ergometer may also be followed by a stiffness in the thigh and calf muscles. Again, this should not disturb you, in spite of how miserable you may feel. Keep in mind that the best way to combat this sore feeling is to continue to exercise.

WARMING UP. No time will be devoted to warming or loosening up after you have entered the research laboratory. Warming up does not necessarily result in a stronger muscle contraction. If you desire to loosen up, please do so on your own prior to your appointment.

RECOVERY FROM EXERCISE, MEALS. Until you have become conditioned to the bicycle ride and the bench press, certain feelings of discomfort may be evident. Do not be surprised if you feel generally weak and perspire heavily for a few minutes following your appointment. This is merely a sign of lack of conditioning. A few of you may experience a temporary feeling of nausea. These symptoms are only temporary. If you are not in the habit of eating any breakfast, I would certainly recommend your doing so. The bicycle ride and bench press performance are demanding on the body and without an adequate source of energy the uncomfortable symptoms may be more prevalent. If you have a noon time appointment, be sure to eat lunch at least one hour before your meeting or eat following your exercise.

OUTSIDE ACTIVITY. Unfortunately, some of you have to partially modify your activity in which you participate. It is imperative that you abstain from heavy exercise involving muscles of the chest and upper extremity. The study is attempting to increase your performance on the bench press and hand dynamometer, and if you have been working the shoulder muscles in heavy exercise outside the study, we will not know whether the experiment contributed to the increase in strength or whether it may be attributed to your outside exercising. More specifically, PLEASE do not do push ups, lifting of heavy weights over your head, or heavy work with your non-dominant hand. I hate to restrict anyone's activity, but it is essential
that any strenuous muscular work be kept at a minimum. If your job calls for heavy lifting, or if you have any questions regarding an activity in which you participate, please check with me.

PURPOSE OF STUDY. Several subjects have asked me what I am trying to prove in this study. I regret that at this stage of the study I cannot tell you what I am attempting to do. It has been found that one's performance can be swayed or influenced by their personal interpretation of what is being attempted. All I can tell you is that you will be participating in a fatigue and strength developmental metabolic study. Following termination of the study there will be an opportunity for all subjects to meet with me and discuss the findings of the study.

NEXT TWO WEEKS. For the next two weeks we will continue to do one maximum lift on the bench press and three maximum contractions on the hand dynamometer. These two weeks are a very important part of the investigation, for the experimental groups will be formed on the basis of your performance during this time. We will also begin to condition you on the bicycle ergometer and determine your heart rate during exercise. Once these two weeks are over we will begin a different training program. Two days a week you will do ten repetitions on the bench press, one six second contraction on the hand dynamometer, and five minutes of exercise on the bicycle ergometer. Every second Friday you will be tested on one maximum repetition on the bench press and three single contractions on the hand dynamometer.

In general I am very pleased with everyone's performance and their promptness in making their appointments on time. Keep up the good work!!

Mr. Nick Breit
Physical Education Department
San Fernando Valley State College
DAILY EXERCISE SHEET

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Grip Size

HAND DYNAMOMETER

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<td></td>
<td></td>
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APPENDIX D

BICYCLE ERGOMETER DATA SHEET
### BICYCLE ERGOMETER DATA SHEET
#### GROUP I

| Name | Seat | Grip | WEEK I | | WEEK II | | WEEK III |
|------|------|------|--------| |--------| |--------|
|      |      |      | 1st min. 20/1 | | 1st min. 20/1 | | 1st min. 20/1 |
|      |      |      | 2nd min. 30/2 | | 2nd min. 30/2 | | 2nd min. 30/2 |
|      |      |      | 3rd min. 30/ | | 3rd min. 30/ | | 3rd min. 30/ |
|      |      |      | 4th min. 30/ | | 4th min. 30/ | | 4th min. 30/ |
|      |      |      | 5th min. 30/ | | 5th min. 30/ | | 5th min. 30/ |
|      |      |      | Post bench press | | Post bench press | | Post bench press |
TABLE 6
INDIVIDUAL RAW SCORES OF THE
BENCH PRESS STRENGTH TESTS

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Table 6—Continued

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