Cross Transfer Effects of Isometric Strength Measurement Schedules

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CROSS TRANSFER EFFECTS
OF ISOMETRIC STRENGTH MEASUREMENT SCHEDULES

being

A Thesis Presented to the Graduate Faculty
of the Fort Hays Kansas State College in
Partial Fulfillment of the Requirements for
the Degree of Master of Science

by

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Date July 27, 1962

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CROSS TRANSFER EFFECTS
OF ISOMETRIC STRENGTH MEASUREMENT SCHEDULES
(An Abstract)
by
Arthur L. Ray

The purpose of this study was to determine the effect of isometric strength testing of the wrist palmar flexion muscles on the strength of the contralateral muscle group in male high school students.

Twenty-two male high school students enrolled at the Oakley High School served as subjects for this investigation. Subjects were chosen who could meet with the investigator on five successive days and then, after a two day rest, meet with the investigator for another five consecutive days. These were students who could comply with the requirements of the investigation.

The measurement instrument, a cable-tensiometer, was incorporated into the testing equipment enabling a cable to pass through it and at a ninety degree angle to the forearm of the subject being tested. The subjects were given a one minute rest between each of the five trials on each of the days. Group "A" was instructed to pull with the right wrist palmar flexion muscle group the first week and then the second week to change to the left wrist. Group "B" was instructed to pull with the left wrist palmar flexion muscle group the first week and then to change to the right for the next week of testing. Subjects were measured near the same time each day.
The treatments by subjects design of analysis found group "B" to exhibit significant differences in daily mean strength measures. T-tests found days four and five significantly greater than day one, and day five significantly greater than day two in the analysis of the left hand. T-tests run on the right hand found days three, four, and five significantly greater than day one, and day five significantly greater than day two.

The comparison of daily mean scores of the right wrists of group "A" and group "B" show decidedly higher mean scores for group "B", which was tested the second week.

On the basis of the data and within the limitations of this study, the following conclusions seem warranted:

1. In group "B", left hand, there were significant increases between day one and days four and five and, also, between day two and day five.

2. In group "B", right hand, there were significant increases between day one and days three, four and five and, also, between day two and day five.

3. The significant daily increases might be attributed to strength development, learning, or a combination of strength development and learning.
ACKNOWLEDGEMENTS

The writer wishes to express his sincere appreciation to Dr. Walter Kroll for his interest, suggestions, and criticisms which aided materially in the successful completion of this work; to the other members of the committee, Dr. James Belisle, Dr. Gerald Tomanek, and Dr. B. W. Broach; and to the students of Oakley High School who willingly participated as subjects for the study.
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CHAPTER I

INTRODUCTION

Strength has been of interest to man for many years, but many questions still surround certain phases of the subject. Is additional strength beneficial to persons attaining skills? Is over-all body strength an aid to a skill which uses only one part of the body? Does movement of one part of the body build strength in another part of the body? These are only a few of the questions brought up concerning strength.

If these questions could be answered, it would be of benefit to people in many different areas of work: physical educators, coaches, athletes, doctors, and people teaching skills of any type.

Strength has been shown to be an important factor in motor coordination as reported by Willgoose,¹ and, of course, motor coordination is accepted as a prerequisite in the learning of most skills. There is now a question concerning the transfer of strength or skills from muscles being exercised. Persons working in physical education and rehabilitation are interested in this facet of strength and skills. Hellebrandt² has indicated in her study that there seems to be a


transfer of power and endurance from exercised muscles to their contra-
lateral muscles. This is of importance to people in physical education
and rehabilitation, in that it might shorten the recovery period for
certain injuries.

One of the questions concerning the reliability of this phase
of strength testing seems to be with the testing procedures. When
unilateral muscles are tested initially, does the measurement schedule
itself provide enough increase in strength at a later date? If there
is some increase in strength from this initial test, it would affect
the later test for cross education. In this area, much work is needed
before anything but hypotheses can be made.

Purpose of Study. The purpose of this study was to determine
the effect of isometric strength testing of the wrist palmar flexion
muscles on the strength of the contralateral muscle group in male high
school students.

Significance of Study. Cross education is an area of strength
measurement which has not been adequately studied. This is a relatively
new area of research in which varied and contradictory results have
been published. Many of the studies are concerned with the transfer
of strength due to dynamic exercises. The results from these studies
do seem to indicate the presence of cross transfer to the contralateral
muscle group. Some studies, such as Darcus and Salter and also

3H. D. Darcus and Nancy Salter, "The Effect of Repeated Muscular
Mathews, indicate the transfer of strength to the unexercised when using isotonic and isometric exercises, but their studies do not allow them to differentiate between the two.

The presence of cross education in relation to isometric exercises seems to be in negative form. The studies concerning isometric exercise directly have not produced the increase in strength of the contralateral muscle group; in fact, the study by Mayberry was not of sufficient intensity to produce an advance in the exercised muscle group.

It is thought by some that a pretesting schedule will affect the final test; however, most of the studies have incorporated some sort of pretest.

This study is significant in that the pretest was eliminated and the subjects were randomly assigned to either group "A" or group "B". The comparisons for strength increase were made between the two groups instead of a pretest and final test.

This study is also significant in the exercises used. The exercises are, in actuality, daily tests of strength. These are registered on a cable-tensiometer which is attached to a stabilized cable making this an isometric contraction. Any results noted would be due directly

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to these isometric exercises.

All subjects used in this study professed to being right handed, so there can be a comparison in strength development and transfer in relation to preferred and non-preferred hand.

**Procedures.** For a study of this type an accurate tool for the measuring of strength was needed. Clarke\(^6\) has done much research in the area of strength measurement and he found the cable-tensiometer to be an appropriate tool. Morris\(^7\) used this cable-tensiometer in a device of his own, designed to measure the strength of the right wrist palmar flexor muscle group. In this study, the device was altered to test right and left wrist palmar flexor muscle groups.

Twenty-two male high school students served as subjects. The subjects were divided randomly into groups "A" and "B". Group "A" exerted maximum pull with the right wrist palmar flexor muscle group five times a day, one minute apart, for five consecutive days while group "B" exerted a maximal pull with the left wrist palmar flexor muscle group five times a day, one minute apart, for five consecutive days. Both groups rested two days and then began again with the same procedure, but reversing muscle groups.

**Delimitations.** This study has been delimited by the size of the

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sample, which included twenty-two male high school students; the muscle
group investigated, which was the wrist palmar flexor muscle group;
the measurement instrument, which was the cable-tensiometer; the number
of days in succession in which each subject was measured totaled ten,
with a two-day rest after five; the number of trials each subject was
required to perform each day totaled five; the amount of rest between
each exertion, which was one minute; and the time of testing, which
was between 8:30 A.M. and 10:45 A.M., and between 2:15 P.M. and 4:00 P.M.

Limitations. The selection of subjects was limited to male high
school students who agreed to meet with the investigator on five
successive days to exert, for five trials spaced one minute apart, the
maximal force of their designated wrist palmar flexor group. After a
two-day rest period they were to change to the other wrist palmar flexor
group and exert maximum force five times a day for five more days.

This investigation, which was limited to a study of static
strength, was also limited by the control of body position and the
actions of the subjects. The one-minute rest period between trials
might also be a limiting factor.

No attempt was made to control variables other than those
specifically designated.

Summary. The purpose of this study was to determine the effect
of exercise (five trials a day, for five consecutive days) on the
contralateral muscle group of high school students.
Since strength is so important to the success of motor performance, some of the facts concerning a strength buildup are of importance to people associated with physical activity and the rehabilitation of injuries.

Twenty-two high school students served as subjects for this study. They were required to exert a maximal force of their wrist palmar flexor groups, five trials each day on five consecutive days, and then after a two-day rest period, test the contralateral muscle group five times a day for five additional days. The measurement instrument used in this investigation was the cable-tensiometer, which was found to be reliable in the study of human strength.
CHAPTER II

REVIEW OF RELATED LITERATURE

The actual value of strength in the active role of life has been in question for many a year. This chapter will present some of the pertinent material from many of the studies that have been done on this subject. These studies, for the most part, have been well organized with the results consisting of facts which will be of value in the quest for the truth about strength.

In the past, it was believed by many that strength building was of questionable value to the athlete who must be quick acting and fleet of hand and foot. The person who lifts weights has been thought of as a person with reflexes that have been slowed by hours of muscle building. Muscle building has also been thought of as a means of building muscles for the sole purpose of looks and not for their value in added strength.

There have been many types of devices made for the intricate business of measuring strength, some of which have been good and some of which were of questionable value. Along with this, there have been many different methods and techniques used in the search for the way to eliminate the erroneous factors involved when trying to isolate the true aspects of strength.

The question of strength having an effect on the actions and activities of the body is another question which has been considered by many. The effect of strength on endurance and athletic ability are also
factors which have been in question.

For the purpose of this review, the material will be divided into six areas: (1) types of tests and devices used; (2) weight training and its effects; (3) strength and its variables; (4) value of strength in athletics; (5) factors influencing accuracy in testing; and (6) cross education.

Types of Tests and Devices Used

A study by Hunsicker and Donnelly\(^1\) presents the following brief history of the various human strength measurement devices that have been used in the past 250 years. One of the first, and possibly the most crude, of the tests known today was a study done in 1699 by De La Hire, a French scientist. This test was, in part, a comparison of human strength to that of horses. An Englishman by the name of Graham was instrumental in developing the dynamometer. Two Frenchmen, Mathieu and Collin, further developed the dynamometer in the latter half of the nineteenth century. Sargent's work at Harvard was considered one of the first instances of the use of the dynamometer in the United States. Mosso was the first to introduce a device for the measuring of endurance instead of actual strength. This was done by using the ergograph. This early ergograph was, however, limited just to the testing of finger endurance.

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Bovard and Cozens\textsuperscript{2} developed "the leap meter", which was a device for the registering of the height of and frequency of jumps. A harness was worn on the head with a rope attached which ran through a pulley on the ceiling, and then attached to a graph-like device that registered each jump.

Clarke,\textsuperscript{3} in his study, compared the following: the cable-tensiometer, Watkins-Porter strain guage, spring scale, and Newman myometer. The tensiometer was found to be the most acceptable of the four for the testing of strength.

Glenn Kirchner\textsuperscript{4} used a battery of four items which seemed to be acceptable from the results obtained, and for the particular criterion used in his study. The purpose of this study was to find a battery of tests which would measure strength, endurance, power, and speed among boys of elementary school age. The four items which seemed to be best were: the five-second run, the standing broad jump, the chest raising, and the squat thrust.

Arthur J. Wendler\textsuperscript{5} used the dynamometer in testing a group of

\textsuperscript{2}John F. Bovard and Frederick W. Cozens, \textit{The Leap Meter}, University Press, Eugene, Oregon, 1928.


four hundred seventy-four men and women with an extensive test checking forty-seven different muscle groups to determine their individual strength. He then used the dynamometer for devising a battery of tests which could be easily and economically given, and would have a relatively high correlation with his extensive test results.

The hand dynamometer was also used in a study carried on by Jebens\(^6\) concerned with finding if the push and pull tests would be found to correlate highly with the test for chins and dips. It was found that these two tests did have a correlation of .864 which would indicate the push and pull tests could be substituted for the chins and dips.

H. Harrison Clarke\(^7\) began to substitute the cable tensiometer for the dynamometer and other devices for many phases of strength testing. This change took place in 1948 and was followed in 1952 by a study concerning the development of objective strength tests of muscle groups by cable tension.\(^8\) Research was done by Frank T. Kennedy\(^9\) in 1959.

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concerning the substitution of the cable-tensiometer for the dynamometer in back and leg lift testing for strength. This research showed clearly that the cable-tensiometer could be substituted for the dynamometer.

Edgar W. Everts\textsuperscript{10} did a study in 1938 which indicated that some of the problems of administration for the testing of leg strength could be eliminated by the use of a belt which held the cross bar in place before and during the lift. In 1953, however, Alfred W. Hubbard\textsuperscript{11} showed in his study that the reliability of the information found when testing leg strength with a belt was lower due to the erroneous components of the measurement, such as a backward lunge and the lack of the necessity for hanging onto the crossbar itself.

Four devices were tested by H. Harrison Clarke\textsuperscript{12} to see which would fulfill the needs of a varied strength testing program. Those tested were the spring scale, tensiometer, myometer, and the strain gauge. The tensiometer and the spring scale were used on all tests; however, the strain gauge was limited in its conclusions due to its sensitivity and distortion of the aluminum ring used in construction. The spring scale was limited to one hundred pounds which did not


\textsuperscript{12}Clarke, Bailey and Shay, \textit{loc. cit.}
adequately measure all tests. The myometer showed the lowest mean scores, apparently due to the necessity of pressing instead of pulling. This device was limited to sixty pounds pressure which was, of course, inadequate for some of the tests.

WEIGHT TRAINING AND ITS EFFECTS

Repeated exertion of maximum effort usually results in improved performance. Output may be doubled in three weeks. The key to strength seems to be tension. The action should be duplicated in movement and, also, in posture to attain the greatest development. These are some factors pointed out by Dr. Laurence E. Morehouse in a paper presented at the Colloquium on Exercise and Fitness pertaining to weight training. As shown by Hunsicker and Greey, strength is intricately associated with such factors as body type, age, position of the body when testing, and types of exercise.

Edward Chui prepared a study relating to strength building and its correlation to ability to jump, ability to put the shot, and ability related to sprinting. Two groups were tested as to their abilities in these particular events and then the groups were exposed to separate

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programs for a period of three months. One group was put on a weight training program while the other group participated in an ordinary physical education program. The results show that the group which participated in the physical education program made no significant gain in the events which they had been tested on, while the group which had been participating in the weight training program made advances in all events tested, indicating an increase in potential power.

Some parts of weight training seem to be irrelevant, as indicated by studies in jumping height in relation to varied weight training schedules. Robert J. Brown\textsuperscript{16} showed about the same amount of improvement in vertical jump, using just the heel raise, as did Paul O. Knudtson\textsuperscript{17} using six different exercises designed for increasing arm, shoulder, and leg power. This would indicate a small, if any, advantage in strong arm and shoulder muscles in relation to vertical jump.

Philip E. Ness and Charles L. Sharos\textsuperscript{18} indicated that a weight training period of four weeks is sufficient to show an increase in leg strength and jumping ability. The idea was introduced in a study by

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Melvin M. Lorback,\textsuperscript{19} that a comparable increase in strength can be produced by six-second contractions of each muscle group. This study indicated that this method of exercise is just as productive as the more common method of exercising against an overload of weights. This particular type of exercise for the building of power was also indicated to be effective by Wolbers and Sills.\textsuperscript{20}

Masley, Hairabedian and Donaldson\textsuperscript{21} showed indications of a strength, speed, and coordination increase for a group participating in six weeks of weight training, while two other groups did not increase in any of these areas. One of the groups participated in volley ball while the other was inactive. This would indicate, at least, that weight lifting is not detrimental.

A progressive weight training program was carried on for eight weeks with one group of college age boys, while a comparable group participated in regular physical education classes. A battery of tests relating to physical fitness and circulatory-respiratory functions was given before and after participation in these activities. It was found

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by Kusinitz and Keeney\textsuperscript{22} that significant gains were made, both in muscular power and in the improvement of circulatory-respiratory functions, by the experimental group. The control group did not advance significantly in any of these areas.

**STRENGTH AND ITS VARIABLES**

Many methods have been used for the building of strength. Capen\textsuperscript{23} experimented with four different weight schedules to find the one that would be superior in the building of strength. According to his findings, a schedule involving maximum effort for one lift, then a rest, then maximum effort again followed by another rest, and ending in a third maximum effort, is superior over schedules involving near maximum effort for several continuous repetitions.

It has been thought that strength and endurance do not necessarily go hand in hand. Tuttle\textsuperscript{24} worked with these two factors and his results verified this line of thought. He found that a person with a greater amount of initial strength maintains a smaller per cent of his maximum strength throughout a sequence of work than a person with a lesser


degree of initial strength.

The correlation of strength and anthropometric measurement is relatively low. The highest correlation in this type test seemed to be body weight. Body height, hand width, and length of limbs had relatively little to do with strength; however, body types are a factor in the strength of an individual. Mesomorphs are superior to endomorphs and ectomorphs in strength, speed, agility and endurance. These factors were stated in studies by Clarke, Everett and Sills. Marilyn Flint made a study concerning college age women who had chronic back aches and a similar group who had no trouble with backaches. It was found that relief from chronic backache was indicated when the strength imbalance between trunk flexor and back extensor was reduced.


The value of strength in athletics is a very controversial subject substantiated on both sides by studies. Carl E. Willgoose\textsuperscript{30} shows in the results of his study that motor coordination does seem to improve with muscular strength. It was evident that weight lifting increased the speed of movement of the arm, as indicated in a paper reporting the findings of Zorbas.\textsuperscript{31} This, of course, would tend to increase the capability of a person in certain athletic activities.

C. H. McCloy\textsuperscript{32} reports an analysis of eight studies concerning strength and its ability to predict athletic ability. According to McCloy, the most important muscle group for the prediction of athletic ability is the arm and shoulder girdle. This is evidenced by the fact that, unless this muscle group is exercised in some type of athletics or physical education activities, it is relatively weak. The other important muscle groups, such as the back muscles and the leg muscles, are fairly well developed due to every day use in such activities as walking, bending, stooping, dancing, or running.


Cozens\textsuperscript{33} studied strength and its ability to predict general athletic ability. His testing of athletic ability consisted of activities from football, baseball, track and field, and dips. The test which was used for the testing of strength involved back lift, leg lift, arm push, chins and dips. The correlation was .982. This indicates that, using his criterion, strength can be used to predict general athletic ability. These findings were substantiated in a study concerning body structure, muscular strength, and explosive power as associated with success in college athletics.\textsuperscript{34}

On the other hand, Meisel\textsuperscript{35} did a study concerning the building of strength and speed of running. In this paper it was reported that after six weeks of weight training the runners were inferior to the initial trial. This test, however, could be considered inadequate because of the distance which was timed. The test consisted of timing the runner for the distance of ten yards. This would be very difficult to time accurately.

\textsuperscript{33}Frederick W. Cozens, "Strength Tests as a Measure of General Athletic Ability in College Men," \textit{Research Quarterly}, 11:45-52, March, 1940.


Glen Cunningham\textsuperscript{36} studied some factors relating to middle and long distance runners. One of these factors was right and left grip strength. It was shown, as would be suspected, that there was no correlation between strength and middle and long distance running.

Some of the material which has been written was found to be inaccurate due to factors that had been overlooked or factors that could not be accurately measured. One such study was carried on concerning the testing of athletic ability, but was found to be irrelevant due to the criteria used.\textsuperscript{37} A study pertaining to velocity of a thrown ball was also considered inadequate due to the lack of devices for accurate timing of the thrown ball.\textsuperscript{38} Another baseball study was done by Hooke.\textsuperscript{39} He attempted to predict baseball ability from strength and also from body structure. There was found to be a high correlation between strength and baseball ability, but relatively little relating to body structure.

\textsuperscript{36}Glen Cunningham, "The Relation of Selected Cardiovascular and Strength Measures to Physical Fitness of Outstanding Athletes," (Unpublished Doctoral thesis, New York State University, 1938).


Thompson\(^\text{40}\) investigated the possibility of strength improvement showing up in swimming ability. It was found that weight training alone did not significantly change the subject's ability to perform in this activity.

In wrestling, Gross\(^\text{41}\) indicated that individuals high in strength seem to learn the fundamentals of wrestling more quickly than those low in strength. Kroll\(^\text{42}\) indicated, however, that strength is not a factor in wrestling success as shown by a study of wrestlers from eight Illinois high schools. Age and experience, however, did have some bearing on their success.

These findings indicate that strength alone is not an important factor in athletics. Neither is strength shown to be a deterrent to athletics. Strength plus other qualities does seem to insure some success at most athletics.

**FACTORS INFLUENCING ACCURACY IN TESTING**

A grip strength study was reported by Verna Wright\(^\text{43}\) indicating

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the time of day when grip is the greatest and the least. It was found that the time of greatest grip was at five P.M. and the time of least grip at four A.M. Work was also done with body temperature and immobilization of the person for a determined length of time. The only factor showing some relationship to strength was body temperature. When body temperature raised two degrees their strength increased appreciably.

Several studies have been done concerning angle of limbs when testing strength of that limb. Clarke\textsuperscript{L44} indicated that for ankle plantar flexion, ninety degrees seemed to be the best angle, while Carpenter\textsuperscript{L45} indicated that the most consistently high correlations come from angles of one hundred fifteen to one hundred twenty-four degrees. Rasch\textsuperscript{L46} experimented with the position of the forearm in elbow flexion. It was shown in his results that more could be lifted with the forearm in mid position than with supine or pronated. The supine was next in power over the pronated forearm.

The unreliability of the testing program does not seem to lie in the test itself, but the variance of the subjects from day to day. In a

\begin{itemize}
\item \textsuperscript{L44}H. Harrison Clarke, "Recent Advances in Measurement and Understanding of Volitional Muscular Strength," \textit{Research Quarterly}, 26:263-273, October, 1956.
\item \textsuperscript{L45}Aileen Carpenter, "A Study of Angles in the Measurement of the Leg Lift," \textit{Research Quarterly}, 9:70-72, October, 1933.
\end{itemize}
study by Henry, dealing with vertical jump, the data indicates a measurement error of fifteen per cent, which would account for some of the day-to-day variance.

The matter of objectivity was approached by Cousins and Mathews in two different studies. Mathews worked with the Physical Fitness Index and found it to be only as reliable as the person or persons administering the test. Cousins worked with right grip and left grip only, and his findings seem to indicate that the testers in this test were consistent in their measurement. The objectivity of grip testing was high.

CROSS EDUCATION

The actual existence of cross education has been in question for many years. Slater-Hamel found that exercising the right arm improved the endurance of the left arm. This investigation was carried out by holding a weight in the hand while flexing and extending the arm.

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Hellebrandt\textsuperscript{51} found that a limb which has been worked until fatigued will recuperate to one hundred per cent of capability if simultaneous work is done with the contralateral limb. This recuperation will last only a short time; however, this indicates there is a cross transfer of strength from one limb to another. In a later study she found that the preferred hand, while sustaining a load, is affected by rhythmical activity of the non-preferred hand.\textsuperscript{52} This was not the case when the non-preferred hand was sustaining a load and the preferred hand was participating in rhythmical activity.

Static or dynamic training showed an increase in both isotonic and isometric strength of pronation and supination in the contralateral limb. This study by Darcus and Salter\textsuperscript{53} did not isolate either isotonic or isometric, but worked with them together. This leaves the question to be answered: was this due to isotonic or isometric or the combination of both types of training. Mathews\textsuperscript{54} also worked with these two factors and found there to be an increase in strength in both the exercised arm and


\textsuperscript{52}\textit{et al.}, "Physiological Effects of Simultaneous Static and Dynamic Exercise," \textit{American Journal of Physical Medicine}, 35:106-117, 1956.


the contralateral arm, but he, too, was unable to distinguish between isotonic and isometric. There was no increase indicated in connection with the transfer of endurance to the contralateral arm.

Cross transfer has been studied using the electromyograph, a device for registering electrical stimuli, in connection with the contralateral limb while the exercising limb is actively engaged in work. Gregg\textsuperscript{55} found that there was a definite cross transfer in the form of stimuli when the exercising arm was worked under a heavy load, and this stimuli increased as the load increased. At the peak of the load, when it became isometric, the cross transfer stopped. Sills and Olson\textsuperscript{56} found, also, that transfer of strength was indicated during a period of exercise with a heavy load. There was, however, no reference made to any change in stimuli as the load reached isometric measures.

Rasch and Morehouse,\textsuperscript{57} while working with elbow flexion, found that there was a slight increase in the strength of the contralateral, unexercised elbow, but credited this to a transfer of skill rather than a transfer of strength.


A study concerning one isometric contraction of the wrist flexor found that one contraction was not adequate to produce strength development in either the exercised wrist or the contralateral muscle group.\textsuperscript{58}

Information gained from studies concerning isometric training seems to indicate there is no transfer factor involved. There has not been adequate research done, however, to signify the absolute absence of cross transfer in relation to isometric training.

\textbf{SUMMARY}

Many phases of strength development and its relationship to various activities have been investigated. These studies have come up with some of the answers pertaining to strength and have also uncovered new and varied areas in which research needs yet to be done.

The development of more valid and reliable strength tests and testing devices is making it possible to acquire more pertinent data from these studies. This is an area of much research which should improve the standard of measurement of strength even more in the years to come.

When studying human strength, there are many factors which may play a part in the results. Fatigue, learning, attitude, order effect and many others will have to be considered.

\textsuperscript{58}Robert P. Mayberry, "Isometric Exercise and the Cross-Transfer of Training Effect as it Relates to Strength," Proceedings of the College Physical Education Association, December, 1958, pp. 155-158.
There is much to be done in the area of cross education. There are indications of positive cross transfer and of negative results when concerned with the transfer of strength to the contralateral limb. Even when there is agreement on the attainment of cross transfer, there is a question as to the factor, or factors, which caused this transfer.
CHAPTER III

METHODS AND PROCEDURES

The purpose of this chapter is to present the methods and procedures employed in this investigation. To simplify discussion, this chapter has been divided into subtopics which include description of subjects, testing equipment, testing procedures and the analysis of data.

Description of Subjects. Twenty-two male high school students enrolled in the Oakley Consolidated School System served as subjects for this study. Subjects were chosen who could meet with the investigator on the five school days for the two consecutive weeks of April 30, 1962 through May 11, 1962, and who could comply with the requirements of the investigation.

In Table I the range, mean, median, and standard deviation of the age, height and weight of the subjects investigated is reported.

TABLE I

<table>
<thead>
<tr>
<th>Age, Height and Weight of Subjects (N = 22)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AGE</strong> (Years)</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td><strong>MEAN</strong></td>
</tr>
<tr>
<td><strong>MEDIAN</strong></td>
</tr>
<tr>
<td><strong>STANDARD DEVIATION</strong></td>
</tr>
<tr>
<td><strong>RANGE</strong></td>
</tr>
</tbody>
</table>
The measured height and weight of each subject was recorded on the first experimental day. Each subject was requested to note his present age on the data sheet. As Table I illustrates, the subjects were average high school students with regard to age, height and weight. Subjects ranged in age between fourteen years and eighteen years; in height between five feet, one inch and six feet, two inches; in weight between one hundred eleven pounds and one hundred eighty-five pounds.

**Testing equipment.** A reliable instrument for the measurement of strength was needed if this study was to produce any information of value. Clarke\(^1\) compared the effectiveness of four instruments for measuring human strength: (1) the cable-tensiometer, (2) the Watkins-Porter strain gauge, (3) the spring scale, and (4) the Newman Myometer. An over-all evaluation of the four instruments found the cable-tensiometer to have the greatest reliability for strength testing. The cable-tensiometer was the most stable and generally useful of the instruments tested, and was free of most of the faults of the other devices.

Morris\(^2\) used the cable-tensiometer in his study, which was concerned with the effect of order upon the wrist palmar flexion muscles,

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and found it adequate for purposes of strength measurement. Based on Clarke's findings and the results obtained in Morris's study, the cable-tensiometer was chosen for the measurement instrument to be used in this study.

The cable-tensiometer was originally designed for testing the tension of aircraft control cable. It is a small, compact unit (4" x 4" x 1¼") which records on a dial the amount of tension created against an offset (riser) in the cable between the fixed points, the sectors. Cable-tension may be converted into pounds by reference to a prepared calibration chart attached to the cover of the tensiometer case.

A table was constructed by Morris,3 incorporating the tensiometer and restraining board, according to the standardized procedure developed by Clarke.4 This table was used by Morris in the testing of the right wrist palmar flexion muscle group. It was altered to consist of two vertical restraining boards for the purpose of restricting movement of muscle groups other than the ones being tested. The cable-tensiometer is aligned horizontally at a ninety-degree angle to the forearm. The forearm was strapped snugly to a vertical restraining board to immobilize it at all times during the experiment. Foam rubber was attached to the restraining board and to the inside of the straps that secured

3Morris, loc. cit.

the forearm to the restraining board to insure comfort for the subjects. Figure I illustrates the equipment used and shows the proper alignment of the cable-tensiometer with the right forearm of the subject. The restraining board for the measuring of the left wrist palmar flexion muscle group can also be seen in this figure.

Adjustments in the length of the 1/16 inch aircraft cable that passed through the cable-tensiometer and attached to the handle on which the subjects exerted their effort was made possible by the use of several links on welded link chain. This entire apparatus was adequately secured to a table to prevent any movement of the restraining board and the device holding the cable-tensiometer. A sturdy folding chair with rubber covered legs was used to seat the subject comfortably in front of the measurement device. A stop watch was used to time the one-minute rest interval between trials.

**Testing procedures.** An attempt was made to measure each subject at a similar time each experimental day in an attempt to eliminate any deviation in the amount of strength of the subject due to the time of testing. This was generally possible to the point of testing each subject within the same hour each day. The data was collected between eight thirty A.M. and four P.M. on each testing day. Testing was begun on April 30, 1962 and ended on May 11, 1962.

On the first of the ten days in which each individual was tested, the investigator recorded the measured height of each subject to the nearest inch while the subject stood in stocking feet. The measured
FIGURE I

POSITION OF SUBJECT DURING EXERTION
OF RIGHT WRIST
weight of each individual was recorded to the nearest pound. Each subject was requested to record his age at that time.

Each subject was requested to roll the appropriate shirt sleeve to a position above the elbow. The subject was then seated in a comfortable position in front of the testing apparatus. The subjects arrived each day in groups of three or four. The following instructions were then read to each group on the first day:

First day: This study is being conducted to determine certain measures of strength of the wrist muscles. For this study to be a success, each subject must exert an all-out effort of the wrist muscles on each trial.

1. You will be seated in a comfortable position in the chair directly in front of the testing apparatus with both legs inside the legs of the table.

2. The non-exerting arm will remain in your lap at all times.

3. The arm to be tested will be strapped to the apparatus and your hand will grasp the handle attached to the cable. I will adjust the length of the cable so the handle fits in your hand.

4. A one-minute rest will be allowed between each of five trials. Relax your grip on the handle when you have exerted your maximal force.

5. Are there any questions?

On the nine remaining days of the study the following instructions were read to each group of subjects:

Nine remaining days: Today we will continue with the study as before. Sit down comfortably with both legs between the legs of the table, laying your arm on the restraining board. Remember that each exertion must be an all-out effort using a slow, steady pull. Relax your grip on the handle between each trial.

If there were no questions, the subject was then strapped into the
padded restraining board with the medial aspect placed firmly against the vertical portion of the restraining board. Figure II shows the subject in the position assumed during an exertion. Note the forearm being pulled away from the restraining board even though the subject was fastened in firmly before the exertion had begun. The wrist is in the position of hyperextension and the arm is in such a position as to make a ninety-degree angle with the cable which is running through the cable-tensiometer.

The cable was adjusted to permit the subject to pull with the wrist in a position of hyperextension while grasping the handle in a comfortable manner. The cable was adjusted by limiting the number of chain links used in attaching the handle to the cable. The number of links used in the adjustment of the length of the cable during the first test day for each subject was recorded on the data sheet and remained the same for the succeeding nine days of testing of that individual.

Subjects were instructed to pull until they felt they had exerted their maximal strength on each trial and then to relax. When the subject released the handle the investigator started timing the minute on the sweep hand of the investigators watch. He then registered the tensiometer reading on the data sheet. The tensiometer score was used in the analysis of the data. At the end of each one-minute rest period, the tester informed the subject to "exert your maximum pull." The tone of voice was normal and unexcited for each trial of each subject. Five
FIGURE II
POSITION OF SUBJECT DURING EXERTION OF LEFT WRIST
trials, one minute apart, for each of the nine days remaining were executed by each subject.

Twenty-two male high school students completed this study as subjects. The subjects were divided into two groups by simultaneously drawing a name from a hat and also by drawing a red or white poker chip from another hat. The subjects who drew the red poker ships were in group "A", and those who drew white poker ships were in group "B". A pretest to equate group "A" and group "B" was not given due to the possibility of confounding the results of the actual training schedules. Group "A" exerted maximal force with their right wrist palmar flexion muscle group for five times each day and for five consecutive days. After a two-day rest period they exerted maximal force with their left wrist palmar flexion muscle group five times each day for five consecutive days. Group "B" exerted force with their left wrist the first week and their right wrist the second week.

The data was collected in the stadium of the Oakley High School. There was some moving about of other people and a certain amount of talking in the same room where the testing was being done.

Analysis of data. Tables and graphs were constructed to aid in the analysis of data and the interpretation of results. The treatments by subjects design described by Lindquist⁵ was used in the analysis of data. This design is applicable in studies in which the treatments

are all administered in succession to the same subjects as occurs in this experiment. The reason for using the treatments by subjects design was to increase the precision of the experiment by eliminating intersubject differences as a source of error. Thus, the treatment by subjects design provides substantial control over one of the most important sources of variation in a study of this nature, that is, intersubject variation.

The measure analyzed to assess the effect of testing one muscle group in relation to the contralateral muscle group was the mean tensiometer score for each subject for each day.

Prior to an analysis of the data, the .05 per cent level of significance was decided upon as the test of the null hypotheses considered. All conclusions and interpretations are based upon this significance level.

Summary. Twenty-two male high school students enrolled at Oakley High School served as subjects for this study. They were required to exert the maximal strength of their wrist palmar flexor muscle groups for five trials spaced one minute apart upon five consecutive days. Then, after a two-day rest period, they were to exert maximal force with the contralateral wrist palmar flexor muscle group for five trials spaced one minute apart upon five consecutive days.

The cable-tensiometer was incorporated in a device which aligned it at a ninety-degree angle with either the right or left forearm of the subject. This device was secured to a table in front of which the
subject was seated in a sturdy folding chair.

The effect of testing the wrist palmar flexor group in relation to its contralateral muscle group was analyzed by using the treatments by subjects design described by Lindquist. The .05 per cent level of significance was used in interpretation of the data.
CHAPTER IV

RESULTS AND DISCUSSION

The results and discussion of the effect of isometric training schedules upon the strength of the wrist palmar flexor muscle group which was actively engaged in training, and its contralateral muscle group, is presented in this chapter. Subtopics include the effect of days, a discussion of results, and the conclusions.

The effect of days. Table II presents the mean, standard deviation, and range of all scores on each of the five test days for each of the four testing situations.

An increase in the mean scores was found for each day in three of the four testing situations. The standard deviation of scores ranged 8.97 tensiometer units in group "A" with the right hand, 1.75 tensiometer units in group "A" with the left hand, 1.01 tensiometer units in group "B" with the left hand, and 1.95 tensiometer units in group "B" with the right hand. In three of the four testing situations both extremes of the observed range of scores for each day increased between day one and day five.

Figure III illustrates the means of the five test days of group "A" first week, with the right hand, in comparison to the same group second week, with the left hand. The increase in mean strength from day to day may be noted and also the comparison of left hand with right hand.

Figure IV illustrates the means of the five test days of group
<table>
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<tr>
<th></th>
<th>Group &quot;A&quot;</th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Day I</td>
<td>Day II</td>
<td>Day III</td>
<td>Day IV</td>
<td>Day V</td>
</tr>
<tr>
<td>right wrist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mean</td>
<td>56.27</td>
<td>56.72</td>
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<td>61.90</td>
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<td>8.39</td>
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<td>44-75</td>
<td>45-76</td>
<td>49-80</td>
<td>48-89</td>
</tr>
<tr>
<td>left wrist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
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<td>52.54</td>
<td>53.45</td>
<td>54.36</td>
<td>55.45</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>6.72</td>
<td>7.26</td>
<td>7.49</td>
<td>5.74</td>
<td>6.90</td>
</tr>
<tr>
<td>Range</td>
<td>42-66</td>
<td>42-68</td>
<td>39-47</td>
<td>47-67</td>
<td>47-70</td>
</tr>
</tbody>
</table>

|               | Group "B" |               |               |               |               |
| left wrist    |          |               |               |               |               |
| Mean          | 49.09    | 51.27         | 51.81         | 53.81         | 54.54         |
| Range         | 32-65    | 34-66         | 33-66         | 34-69         | 39-69         |

| right wrist   |          |               |               |               |               |
| Mean          | 58.36    | 60.90         | 62.36         | 63.81         | 66.00         |
| Standard Deviation | 11.42   | 10.53         | 9.78          | 10.93        | 11.73         |
| Range         | 41-79    | 43-77         | 44-76         | 46-85         | 48-87         |
FIGURE III
MEAN STRENGTH TENSIO METER SCORES
OF GROUP "A"
FIGURE IV

MEAN STRENGTH TENSIOMETER SCORES
OF GROUP "B"
"B" first week, with the left hand, in comparison to the same group second week, with the right hand. A comparison of left hand with right hand may be noted and also the increase in mean strength from day to day.

Figure V illustrates the means of the five test days of group "A" first week, with the right hand, and group "B" second week, with the right hand. This figure enables a comparison between the means of the right hand of the two groups. Figure VI illustrates the means of the five test days of group "A" second week, with the left hand, and group "B" first week, with the left hand. A comparison of left hands is afforded.

To determine whether or not the observed increase in daily mean strength measures was significant, an analysis of variance by the treatments by subjects design was made. This analysis of variance was run on each of the four different testing situations. With 4 and 40 degrees of freedom, an F of 2.61 was required for significance at the five percent level of confidence. The results of the analysis for the four different situations are found in table III.

In group "A" the first week, which was the testing of the right hand, an F of 2.51 was found not to be significant. This would indicate that there was no significant difference between the means of the daily

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FIGURE V

MEAN STRENGTH TensiOMETER SCORES
OF RIGHT WRISTS
FIGURE VI

MEAN STRENGTH Tensiometer scores
OF LEFT WRISTS
### TABLE III
ANALYSIS OF VARIANCE OF THE EFFECT OF DAYS UPON WRIST FLEXION STRENGTH

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<tr>
<td>Days</td>
<td>4</td>
<td>24.91</td>
<td>62.47</td>
<td>2.51</td>
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<td>Subjects</td>
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<td>399.95</td>
<td>399.09</td>
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<tr>
<td>Residual</td>
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<td>992.89</td>
<td>24.82</td>
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<tr>
<td>Total</td>
<td>54</td>
<td>5,233.75</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Days</td>
<td>4</td>
<td>28.06</td>
<td>7.01</td>
<td>.77</td>
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<td>Subjects</td>
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<tr>
<td>Residual</td>
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<td>364.34</td>
<td>9.10</td>
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<tr>
<td>Total</td>
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<td>2583.35</td>
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<tbody>
<tr>
<td><strong>Group &quot;B&quot;</strong></td>
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<td><strong>left wrist</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days</td>
<td>4</td>
<td>206.24</td>
<td>51.56</td>
<td>4.20*</td>
</tr>
<tr>
<td>Subjects</td>
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<td>4390.15</td>
<td>439.01</td>
<td></td>
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<tr>
<td>Residual</td>
<td>40</td>
<td>490.96</td>
<td>12.27</td>
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<tr>
<td>Total</td>
<td>54</td>
<td>5087.35</td>
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<tbody>
<tr>
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</tr>
<tr>
<td>Days</td>
<td>4</td>
<td>367.70</td>
<td>91.92</td>
<td>4.33*</td>
</tr>
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<td>Subjects</td>
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<td>564.29</td>
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<tr>
<td>Residual</td>
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<td>848.70</td>
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<tr>
<td>Total</td>
<td>54</td>
<td>6859.35</td>
<td></td>
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</tr>
</tbody>
</table>

*Significant at the five per cent level of confidence.
strength measures. Daily strength scores for group "A" the second week, left hand, was also found to be insignificant as the F was .77. This indicates that group "A" did not make a significant strength increase from day to day with either hand.

Group "B" the first week, left hand, was found to have an F of 4.20 which is above the minimum for significance. This indicates the presence of significant differences among the daily mean strength measures. The significant F suggests the necessity for application of the t-test to individual pairs of means. The t-test can account for the significant F in terms of day by day comparison to find which pair or pairs of means are significantly different. Table IV presents the results of the individual t-tests for the effect of days upon the strength of the wrist palmar flexor muscles of group "B".

With 40 degrees of freedom a t of 1.96 is required for significance at the five per cent level of confidence. The t between day one and day four and day one and day five was significant along with the t between day two and day five. This would indicate that the mean strength scores for both days four and five, were significantly greater than day one. The mean strength for day five was also significantly greater than the mean strength of day two. The comparisons of mean strength for the remaining days were not significant.

Group "B" the second week, right hand, was found to have an F of

2Lindquist, op. cit., 91.
TABLE IV

RESULTS OF t-TESTS FOR THE EFFECT OF DAYS UPON WRIST FLEXION STRENGTH (Group "B")

<table>
<thead>
<tr>
<th>Day I</th>
<th>Day II</th>
<th>Day III</th>
<th>Day IV</th>
<th>Day V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day I</td>
<td>-</td>
<td>1.46</td>
<td>1.82</td>
<td>3.17*</td>
</tr>
<tr>
<td>Day II</td>
<td>-</td>
<td>-</td>
<td>3.6</td>
<td>1.70</td>
</tr>
<tr>
<td>Day III</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.34</td>
</tr>
<tr>
<td>Day IV</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Day I</th>
<th>Day II</th>
<th>Day III</th>
<th>Day IV</th>
<th>Day V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day I</td>
<td>-</td>
<td>1.29</td>
<td>2.04*</td>
<td>2.78*</td>
<td>3.90*</td>
</tr>
<tr>
<td>Day II</td>
<td>-</td>
<td>-</td>
<td>.74</td>
<td>1.48</td>
<td>2.60*</td>
</tr>
<tr>
<td>Day III</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>.74</td>
<td>1.85</td>
</tr>
<tr>
<td>Day IV</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.11</td>
</tr>
</tbody>
</table>

*Significant at the five per cent level of confidence.
4.33 which is significant at the five per cent level of confidence. This called for t-tests to indicate which pairs of days were significant. The results indicate the mean strength scores for days three, four and five are all significantly larger than the mean strength of day one. The mean strength for day five in comparison to the mean score of day two is also significant at the five per cent level of confidence. Other mean strength score comparisons were not significant.

Discussion of results. The F for days was significant in both situations involving group "B". The F for days for group "A" was not significant in either situation. These findings would indicate that in both instances group "B" had a significant variation between the day by day mean strength scores. Group "A" did not show significant differences in the day by day mean strength measures for either the right or left wrist flexion muscle groups. This data was not analyzed further.

The t-tests run on group "B" show that the left hand mean strength for days four and five are significantly different from day one. Day five is also significantly greater than day two.

The results of the data concerning group "B", both left and right wrist flexor muscle groups indicate an increase in their ability to perform the training schedules observed in this study. This increase might be due to strength development of the kind reported Darcus and Salter. They worked with a combination of isotonic and isometric

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exercises and did show a significant strength increase. Five maximum exertions daily for five days might make it possible for the development of strength.

Morris,\(^4\) in a study concerned with the wrist flexion muscle group, indicated an improvement in the daily mean score; however, he did consider the factor of learning involved in using the training device for the testing device. Petersen\(^5\) indicates that studies using the same device for training and testing may produce results which could be attributed to an improvement in skill. In order to state the reason for the improvement in mean test scores there must be a method devised for eliminating erroneous factors in order to isolate either strength or learning.

In comparing the trends of the right wrist palmar flexion muscle groups, between group "A" and group "B", we find that group "B" starts 2.09 tensiometer points higher than group "A". The difference increases until at the finish of the five day period there is a difference of 4.10 tensiometer points. This comparison does not hold true for the two left wrist palmar flexor muscle groups. In this case group "A" started 4.54 points above group "B" but finished only 0.91 tensiometer point above group "B". From the comparison of the mean scores for the five days we

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might infer there is little difference between the left wrist palmar flexor muscle groups. A possibility might be that the two groups were of near equal strength before testing, or there was a transfer of strength from the dominant right wrist to the non-dominant left wrist. The original strength of the left wrist, of group "A", might have been much lower before the testing started and then improved to a level with the left wrist of group "B". Since a pretest was not given, due to the possibility of confounding the results of the actual test, there is no way of knowing the level of initial strength of group "A" left wrist.

In the comparison of group "A" and group "B" right wrist palmar flexor muscle groups the results seem to indicate agreement with Hellebrandt,⁶ who found that there seems to be a transfer of strength from the non-dominant hand to the dominant but not in reverse. The results of the data in this study show that the higher ranking group "B" right wrist palmar flexor muscle group had been preceded the week before by training of the non-dominant left hand.

The daily mean scores of group "A", left and right wrist, improved significantly. This indicates a possibility that strength improvement is more readily attained if the non-dominant limb is trained before the dominant. In group "A", the training of the dominant hand preceded the training of the non-dominant hand and there was no significant change made in either of the wrists daily mean scores.

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Since the accurate knowledge concerning learning effects and strength development has not been attained it can not be established that the increase of the mean scores in this study represents strength development or training effects or the combination of the two.

Until more knowledge is attained in cross transfer, especially pertaining to dominant and non-dominant transfer, a definite conclusion pertaining to this study cannot be made.

Conclusions. On the basis of the data and within the limitations of this study the following conclusions seem warranted:

1. In group "B", left hand, there were significant increases between day one and days four and five and also between day two and day five.

2. In group "B", right hand, there were significant increases between day one and days three, four and five and also between day two and day five.

3. The significant daily increases might be attributed to strength development, learning, or a combination of strength development and learning.

Summary. There were indications of strength improvement in group "B" in that an increase of daily mean scores was significant at the five per cent level of confidence. This increase could have been due to the order in which the muscles were trained, non-dominant and then dominant.

The transfer of strength from the non-dominant left hand to the dominant right hand might explain the higher mean scores of group "B" in the comparison of right wrist palmar flexor muscle groups. In the comparison between left hand daily mean scores there was little difference which might be explained by showing that the training for group "A"
had been from dominant to non-dominant muscle group or that the starting strength of group "A" was lower and an increase of strength did occur. Group "B" was exerting the left hand the first week which would mean there was no training preceding this test.
CHAPTER V

SUMMARY

The purpose of this chapter is to summarize this investigation which dealt with the effect of isometric training schedules upon the contralateral muscle group. This summary includes the purpose, significance, methodology, results, conclusions and recommendations.

**Purpose.** The purpose of this study was to determine the effect of isometric strength testing of the wrist palmar flexion muscles on the strength of the contralateral muscle group in male high school students.

**Significance of study.** An increase of strength in the contralateral muscle group of muscles being trained by dynamic exercise is indicated in several research articles. This is of importance to all persons concerned with the physical aspect of education or training. It is of particular importance to the people dealing with rehabilitation of injuries; hence, stimulation of injured muscle tissue may be brought about by exercising the contralateral muscle group. Atrophy of an injured muscle might be delayed due to activity of the contralateral muscle group.

This study was concerned with the training of the wrist palmar flexion muscle group with the aid of a device designed to test the strength of this muscle group. This device afforded training in the form of isometric exercises. The studies which have been done have not been
able to isolate the cross transfer of strength from a muscle group using isometric exercises. This problem concerning cross transfer when related to isometric exercises was the basis for this investigation.

**Methodology.** Twenty-two male high school students enrolled at the Oakley High School served as subjects for this investigation. Subjects were chosen who could meet with the investigator on five successive days and then after a two day rest meet with the investigator for another five consecutive days. These were students who could comply with the requirements of the investigation.

A table constructed to test the right wrist palmar flexion muscle group was modified to test either right or left wrist palmar flexion muscle groups. This table had incorporated into it a cable-tensiometer, which is an intricate device for the measurement of strain on a cable. A cable which can be adjusted to facilitate different hand sizes was used to absorb the strain from each muscle contraction.

The height and weight of each subject was measured the day of the first testing. At this time, the age of each subject was recorded on the data sheets.

Each day standardized instructions were read to each subject before being strapped into the testing device. After being strapped to the padded restraining board, the cable was adjusted as to linkage that had been determined the first day of testing. Subjects were instructed to pull until they had exerted their maximal strength and then relax for one minute before completing the next of the five contractions.
The data was analyzed by the treatments by subjects design. The F test, a method of supplying a test of significance simultaneously to the observed differences for all possible pairs of treatments was used. When the F was found to be significant, t-tests were used to determine which pair, or pairs, of daily mean scores were significant in this study.

Results. In group "A", neither the daily right nor the daily left wrist palmar flexion strength measures were found to be significant. Both the daily left and the daily right wrist palmar flexion strength measures of group "B" were significant. T-tests were run on the left wrist, and the results indicated a significant increase in the mean strength of days four and five over day one and, also, day five was significant over day two. The t-tests for the right wrist indicated a significant increase of days three, four and five to day one, and also day five to day two. The lack of significant increases in daily mean scores in group "A" might be of importance when compared with the significant results of group "B". This might indicate a definite variation of strength development depending on the order in which the muscles are trained. This would indicate a greater strength increase when the non-dominant limb is exercised first and followed by the dominant limb, than when the dominant limb is trained first and followed by the non-dominant.

In comparing group "A" and group "B", it was noted that the daily mean scores for the right wrist of group "B" was exceedingly higher than
the daily mean scores for the right wrist of group "A". These findings may indicate cross transfer in group "A", as it was preceded by a five day training period of the non-dominant left hand. The left hand of group "B" was not preceded by any training.

The daily mean scores for the left wrists of the two groups were nearly equal. This might indicate equal grouping of subjects as to strength, if group "A", left hand, had not increased their initial strength; however, the initial strength was not known since a pretest was not given.

Conclusions. The following conclusions seem warranted on the basis of the data and within the limitations of this study:

1. In group "B", left hand, there were significant increases between day one and days four and five and, also, between day two and day five.

2. In group "B", right hand, there were significant increases between day one and days three, four, and five and, also, between day two and five.

3. The significant daily increases might be attributed to strength development, learning, or a combination of strength development and learning.

Recommendations. Many problems pertaining to accurate analysis of material relative to strength measurement still exist. Does a significant difference between daily strength measures indicate strength development or learning? Is the transfer effect due to stimulation of the muscle fibers causing an increase in strength or a transfer of skill enabling the subject to more efficiently perform the skill? These are
questions which, if answered, would aid a great deal in this study of human strength. From results of this investigation, certain recommendations seem warranted.

1. A series of investigations seem necessary to determine the true cause for cross transfer effects.

2. A series of investigations using a pretested group to determine the existence, or non-existence, of cross transfer when concerned with dominant and non-dominant limbs would be valuable in the quest for knowledge pertaining to cross education.

3. A series of investigations are needed to attempt to isolate either the strength development aspect or the training effect, in order to insure positive identification of one or the other in terms of significant analysis of data.
A. BOOKS


B. PERIODICALS


C. UNPUBLISHED MATERIALS


