A COMPARISON OF THE DIFFERENCE

AMONG SELECTED SIT-UPS

WITH REGARD TO STRENGTH

by

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This study was undertaken to compare different variations of sit-ups for increasing the strength of the abdominal musculature, and to compare the results with a previous electromyographic study.

Thirty-one subjects, chosen from the University of North Carolina at Greensboro, were divided into four experimental groups and one control group. Groups A, B, and C were given a five-week period of training, and Group D was given a three-week period of training between the initial and the final test. The exercises performed were isotonic and isometric contractions. All groups used the overload principle except Group D which performed one single six-second contraction daily. The effects were determined in terms of scores on the tensiometer. In treating the data, means, standard deviations, tests of significance, and an analysis of covariance were used to analyze the results.

The results showed a significant difference between the means of the initial and final tests within all experimental groups. There was no significant improvement between the groups, and results of the present study conflicted with the results of the electromyographic study.

These findings resulted in the following conclusions:

Both isotonic and isometric contractions were equally effective in increasing abdominal musculature. One six-second contraction performed daily was just as effective as performing isometric contractions using

the overload principle. No one exercise was better than the other for increasing the strength of the abdominal musculature. Five weeks training was sufficient to increase the strength of the abdominal musculature. The present study was in disagreement with the electromyographic study in relation to gravity factors, eccentric and concentric contractions, and assisting of subjects during a sit-up exercise.

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CHAPTER I

INTRODUCTION

The age of automation has had a far-reaching effect upon the amount and kinds of physical activity in which persons engage today. Helping the individual to maintain optimal physical fitness, in spite of the tendency to decreased activity, is a major concern of physical educators. These educators have the task of finding various methods of evaluating fitness, of providing effective and meaningful forms of physical activity, and of motivating individuals to take advantage of opportunities to be active in order to maintain fitness for the necessary activities of daily life.

Professional leaders in physical education have also been confronted with the task of defining physical fitness. Though there have been varying opinions on this subject, most are inclined to agree that the fitness of an individual is dependent on his muscular performance which envelops speed, strength, coordination, flexibility, and endurance.

Karpovich (14:244) defines physical fitness as "...a fitness to perform some specified task requiring muscular effort." He evaluates various aspects of physical fitness in terms of speed, strength, and endurance.

Oberteuffer and Ulrich (21:103) believe that the individual who is fit gains in muscular strength and endurance. They state that, "...as man gets stronger he can do more and thus continue to increase his strength."

According to Oerhmann, et al: (22:7)

> Fitness is characterized by man's ability to function effectively within his potentialities and evidence on all sides indicates that it cannot be attained or maintained without physical activity.

The President's Council on Physical Fitness (23:5) views physical fitness as a measure of the body's strength, stamina, and flexibility. The council describes physical fitness as:

> ...a reflection of the ability to work with vigor and pleasure without undue fatigue, with energy left for enjoying hobbies and recreational activities and for meeting unforeseen emergencies.

Balke (10) believes that a determining factor of physical fitness is the individual's general adaptability to great physical demands. He asserts that a good test of physical fitness would be man's ability to survive under extraordinary biological demands. Massey, et al, (16:44) define physical fitness as one part of total fitness or good health. They say:

> Physical fitness is the condition of the body that permits the body to perform a physical task efficiently and the capacity of the person to perform his tasks without undue bodily fatigue.

The maintenance and improvement of muscular strength and endurance are necessary components in the development of physical fitness and are important objectives in the physical education program. Strength is desirable for attractive appearance, capable performances in skills and serves as a contributory safeguard against illness and injury (17:52, 34:15). Mohr (59:342) says, "strength implies the ability of the whole body or a part of the body to exert force by means of muscular effort."

There is general agreement among physical educators and physiologists that adequate strength is a personal asset in daily living, that developing strength can increase and improve an individual's capabilities of performance, and that high scores obtained from general ability relate significantly to high scores obtained from strength (10, 11, 18).

According to Morehouse and Rasch (20:119) the development and improvement of muscular strength is one of the greatest weapons against joint injuries. Oberteuffer and Ulrich (21:109) define muscular strength as a "...mark of muscular development and muscular development comes through activity--in work and play." They, too, agree if muscles are kept firm and strong through the use of exercise in work or play, injury is less likely to occur (21:111).

The development of muscular strength is important because when one is in good physical condition life is more enjoyable and activities are less fatiguing. If muscles are kept in a state of good muscle tonus and used efficiently, the overall effectiveness of the individual's well-being is greatly enhanced.

Since physical fitness is one of the immediate and vital concerns in physical education today, the author is concerned with one of the aspects of physical fitness, namely; muscular strength. Therefore, this investigation is directed toward the possible determination of the most effective and efficient exercise for increasing the muscular strength of the abdominal wall.

CHAPTER II

STATEMENT OF PROBLEM

An Electromyographic study (68) was previously conducted involving different forms of sit-ups varying in degree of difficulty which are used in practically all exercise routines for developing strength in the muscles of the abdominal wall. The ultimate purpose of this limited study was to examine the sit-ups electromyographically to determine, if possible, which variations would be most useful in developing and/or testing the strength of the abdominal musculature. Determination was based on the fact that the amount of electrical activity recorded from a contracting muscle is directly related to the number of motor units contracting in that muscle. The results of this study indicated that:

(1) the greatest amount of abdominal muscular activity occurred in the early part of the sit-up (scapulae clear of the floor)

(2) activity in the hip flexors (iliopsoas and rectus femoris) did not start until the scapulae were clear of the floor

(3) assisting the subject (holding the feet to the floor) made the sit-up easier (smaller amount of electrical activity)

(4) flexing the hips, which shortens the counter-balance resistance increased the general difficulty of the sit-up, but with the hip angle slight the increased activity in the iliopsoas was negligible

(5) the isometric contraction maintained with the shoulders just off the floor was more effective than the complete sequence

of the isotonic and eccentric contraction.

With the above evidence in mind, the investigator felt that a follow-up study was necessary to determine which sit-up would be most effective in an exercise program for developing strength in the abdominal wall. Therefore, the purpose of the present study was threefold:

(1) to determine the increase in the amount of strength developed in a selected graduated sit-up program of exercise as measured by the tensiometer

(2) to determine, if possible, which sit-up would be most effective in developing the strength of the abdominal musculature as measured by the tensiometer

(3) to compare the results of this study with the results of the electromyographic study involving different variations of sit-ups.

CHAPTER III

REVIEW OF LITERATURE

In order to get a more complete understanding of the study undertaken, the author felt that a brief review of literature was needed in the areas of the overload principle, abdominal musculature and sit-ups as well as in the area of strength testing.

Overload Principle

Physiologically speaking, the only way a muscle can increase in strength is by working against resistance. The general definition of the overload principle is a muscle must be worked beyond its normal capacity to increase in strength. Steinhaus (31:85) defines the overload principle more specifically. He says that the intensity of the work required of a muscle must be increased over and beyond that to which it is currently accustomed for no matter how much a muscle is used it will not grow larger or stronger until it is overloaded.

Hettinger (11:23), defining the overload principle, states that, "...an increase in muscle tension above that previously demanded of a muscle is the stimulus for an increase in muscle strength." He cited (11) that Roux and his student Lange, in 1905, formulated the first clear proposal of the overload principle when they postulated that a muscle would respond to growth only if it were required to perform intense work beyond the ordinary. Hettinger (11:19) also reported that Petow and Siebert were able to confirm that longer duration of effort was the least effective factor in increasing muscle strength as compared to greater work effort. Brouha (13:415) says, "strength of the muscles can be developed only by exercising them against gradually increasing weights and/or moving the body at increasing speed."

Physiologists and physical educators are in agreement with the proposal of the overload principle, but many investigations have been conducted and proposed to determine the most effective methods for increasing strength. Variables involved relate to amount of time, amount of weight, and type of contraction. (66, 28:42, 15:83)

Recently, concern has been directed toward the type of contraction most effective for increasing strength. The two types of muscular contraction are isotonic and isometric contractions. Isotonic contraction, which involves concentric and eccentric contraction, occurs when there is a change in length of the muscle during movement. Isometric contraction occurs when the muscle develops tension without changing length.

DeLorme's (8) organized system of progressive resistance exercises has been utilized for increasing muscle tone, muscle power and muscle efficiency. This system involves the principle of maximum resistance and repetition with the use of weights and pulleys which provides the resistance load. His technique has been used by physical therapists in therapeutic exercise programs and in other strength training programs. (12:27, 7:84) Wessel (28:106) has also advocated the use of progressive resistance exercises for girls and women. She believes if weight training is progressive, it can be easily adapted and adjusted to each girl's capacity and ability.

Flint (44) investigated the response of abdominal and back muscles to progressive resistance exercises and found a significant increase in abdominal and back muscle strength attained by the use of this technique. Capen (36) conducted a study of four programs of heavy resistance exercises for development of muscular strength. He used the manuometer to determine which four methods of weight training might be superior in the development of strength. The amount of strength gained from each of the four programs was found to be nearly equal.

Berger (35) studied the comparison between maximal loads and submaximal loads and found that "Training with submaximal loads of ninety per cent was just as effective for increasing strength as training with maximal loads." (35:637) He suggested further experiments to substantiate these findings because he felt most studies conducted always involved a resistance load that elicited maximum effort for a specific number of repetitions.

Hettinger (11:75) has postulated that "forty to fifty per cent of the current maximum strength of the muscle gives the muscle the maximum obtainable training effect." He suggests, for the purpose of increasing muscle strength, one isometric maximum muscle contraction for one or two seconds. Continued repetitions will not cause further growth.

Rarick and Larson (61) were interested in this theory and conducted an experiment by comparing the effectiveness of a single daily six-second contraction exercise bout using two-thirds maximum tension with an exercise program involving more frequent exercise bouts at eighty per cent maximum tension. The results supported the findings of Hettinger in that brief periods of isometric tension proved to be as effective for strength development as more frequently repeated bouts at higher levels of tension. Wolbers and Sills,(67) in determining the effect of static contractions upon high school boys, reported contractions of six seconds duration caused significant gains in strength.

On the other hand, Hellebrandt (28:28) has noted some studies which compared the effectiveness of isometric and isotonic exercises and commented that isotonic exercises were found to be superior in many respects. Darcus and Salter (41) compared the effects of isometric and isotonic exercise programs and found that both types of exercises contributed to the increase of strength development. However, Mathews and Kruse (58) conducted a program to determine the effects of isometric and isotonic training and results showed that more subjects increased significantly in strength with the application of isometric exercise than the isotonic training.

Many studies have been directed toward the determination of isotonic and isometric exercises most effective for increasing strength. Whether isometric or isotonic techniques are employed, the prime consideration continues to be the use of the overload principle for significant results.

Abdominal Musculature

The importance of strengthening the abdominal musculature has been stressed many times by several authors in the fields of physical education, medicine and physical therapy. Weak abdominal muscles can contribute to low back pain, visceral ptosis (sagging organs), and general debility. (24, 25, 29)

Since different parts of the abdominal musculature are involved in trunk movements and are used in vigorous activities such as gymnastics and swimming and many other activities, it is essential that this area of the body be developed to maintain good body function. Oberteuffer and Ulrich (21:111) state that "In the judgment of many people the key to the entire problem of muscular strength is in the abdominal wall."

Steinhaus (30:17) has reported that dysmenorrhea problems and disorders can be reduced if abdominal muscles are strengthened. Harris and Walters (48) conducted a study to determine the effects of prescribed abdominal exercises on dysmenorrhea. The subjects, who had moderate or severe pain, were tested for abdominal strength and endurance and then required to perform daily specified abdominal exercises for eight weeks. The investigators found an increase in abdominal strength and endurance significant at the one per cent level of confidence and a decrease in one or more factors indicative of the severity of dysmenorrhea.

Steinhaus (30:6) also mentioned, "weak abdominal muscles allow the pelvis to sag in front and the result is an exaggerated lumbar curve or sway back that may cause low back pains." Fox, (46) in her study of the relationship between abdominal strength and selected postural faults, found that there was no relationship between weakness of the abdominals and faulty pelvic tilt and sway back was probably not associated with the weakness of abdominal muscles. She suggested further study. One of the purposes in Flint's (44) study was to determine the effect of abdominal strength and back strength on lumbar posture. There was no significant relationship between lumbar lordosis and abdominal strength.

There has been some agreement and some disagreement concerning weakness of abdominal musculature causing faulty posture and physiologic functions. Many authors have maintained that any relaxation and weakness of the abdominal muscles which permits sagging of the abdominal wall will result in and contribute to congestion and possible displacement of the internal organs. (22:275, 24:272, 25:347) Karpovich (14:300) disagrees and states:

> Mere sagging may not affect the function of the digestive organs, posture should be improved for aesthetic reasons only, and the physiological benefits obtained from correction of common deviations are mostly imaginary.

Though there are conflicting opinions relative to the harmful or beneficial effects of weakened and strengthened abdominal muscles, it appears to be a fact that sustaining muscle tonus and maintaining or increasing strength of the musculature of the body is important for the general well-being and fitness of the individual. (21:111)

Sit-Ups

Sit-ups, or variations of sit-ups,have been the primary exercise used to strengthen the abdominal musculature. From leading authorities have come varying opinions as to the most effective type of sit-up appropriate for strengthening this particular group of muscles. Some reasons for these varying types of sit-up exercises are justified by what is known about the actions of muscle groups and kinesiological analysis of motion.

Broer (3:320) lists eight different sit-up positions varying in degree of difficulty in relation to force of gravity, length of levers, and positions of the arms and legs. Other authors have postulated that the iliopsoas plays a conflicting role in the sit-up depending on the position of the subject's legs and type of assistance involved. (24:307, 33:463) The iliopsoas aids the abdominal muscles when it is put on stretch (legs straight) and when the feet are held down. In this way, the psoas is more effective, but at the same time this lessens the maximum work of the abdominal muscles. When the knees are flexed, and the feet are not held down, there is minimal activity in the iliopsoas muscle depending on degrees of flexion of the knees. (66, 68) Rasch and Burke (24:308) state that, in therapeutic exercise, stress is placed on the maximum development of the abdominal muscles and the iliopsoas development is minimized, "...since when the psoas contracts, it tends to pull on the lumbar vertebrae causing hyperextension."

The part of the sit-up which calls for maximum effort is the first part of the action. (68) When the trunk is first raised the rectus abdominis comes into action with no activity from the iliopsoas. As the sit-up continues into the upright position, the obliques come into action with significant activity starting in the iliopsoas. Broer (3:322) says "Effort to hold the body a few inches off the floor is probably as effective as, or maybe more so than the complete sit-up exercise." This was found to be true in an electromyographic study conducted by Crowe, et al. (68) The greatest activity occurred in the upper rectus abdominis followed about 0.2 to 0.3 seconds later by the lower rectus abdominis and internal oblique abdominals. Activity in the hip flexors (iliopsoas and rectus femoris) did not start until the scapulae were clear of the floor.

Strength Tests

Throughout the years, tests of strength, power and endurance have been used as basic procedures for evaluating the physical capacities of students in physical education programs. Strength tests are practical measures in determining progress of strength development in school and college programs, and there is evidence that reliable results can be obtained with a small amount of error involved. (17:55)

In order to evaluate and determine the most practical and feasible tests for the purpose of this study, the author has reviewed different studies involving various strength testing devices which are in wide use today. (43, 49, 52, 53, 57, 62) Special attention was given to the use of the tensiometer in measuring strength.

The dynamometer has been used for measuring static strength of certain muscle groups which have been impaired due to disease or injury. There have also been combinations of tests which involve dynamic strength items to measure general strength as a means of classifying students in physical activities. Wolbers and Sills (67) used the dynamometer to determine the effect of the static contractions upon strength of high school boys. With the use of this instrument, they found significant gains in strength. DeWitt (42) also used the dynamometer in a sit-up study. He measured in pounds, the power of the abdominal muscles to pull the trunk to a forward position.

Among the more recently developed instruments are the cable tensiometer, Newman myometer, strain gauge devices, and the Kelso-Hellebrandt ergograph. (37) All of these instruments have been used to assess the strength of various muscle groups.

In 1945, Clarke and Peterson (4) developed cable tension tests for testing the strength of individual muscle groups. The tensiometer, an instrument to measure the tension of aircraft control cable, was adapted for use in muscle testing to record the pounds force exerted upon a cable as a result of a given muscular action. They developed thirty-eight cable tension strength tests which involved most of the muscle groups. The initial purpose in developing this instrument was to test the strength of muscle groups involved in orthopedic disabilities.

In 1948, Clarke (38) used the cable tensiometer to determine the objectivity of measuring the strength of affected muscle groups in orthopedic disabilities. The evidence showed that, out of twenty-eight tests administered, twenty-two had high objectivity coefficients ranging from .92 and above. Six of the tests were below .90 but none of them was below .84. Clarke (38, 39) stated that improvements were definitely possible and more research would have to be done to study the effectiveness of different joint angles and strap positions for various tests.

In comparing four instruments, (cable tensiometer, Wakim-Porter strain gauge, spring scale and Newman myometer), Clarke (40) found that the cable tensiometer had the greatest precision for strength testing. The cable tensiometer was the most stable and generally useful and was free of most faults of the other three instruments. Objectivity coefficients ranged from .90-.95.

Clarke and associates (5:96) also devised a new test of muscular fatigue on cable tension tests. The Strength Decrement Index (SDI) designated the proportionate strength loss of individual muscle groups after exercise. Cable tension readings were taken on a particular group of muscles before and immediately after exercise. The investigators found that the SDI was significant in evaluating the amount of fatigue in exercised muscles, determining exercise routines for individuals in a convalescent state and returning to classes after illnesses, injuries and operations.

Other studies have been made to assess reliable strength measures by use of the tensiometer. In two studies, Kroll (55,56) used the tensiometer to measure strength. One study was conducted to determine the reliability of strength measures in test-retest situations. The purpose of his second study was the assessment of isometric strength.

Gardner (47) used the tensiometer in his research to determine the effect of cross transfer through the use of isometric exercises. Howell, et al (51), selected four tests by multiple correlation from eighteen cable tension tests to determine reliable effects of isometric exercise programs and a regular isotonic program. Rarick and Larson (61) used the tensiometer to test the effectiveness of a single daily six-second exercise bout using two thirds maximum tension with an exercise program involving more frequent exercise bouts at eighty per cent maximum tension.

Kennedy (54) substituted the tensiometer for the back and leg lift dynamometer when he used Roger's Physical Fitness Index Test (18:128). A lever was used to overcome the insufficient capacity of the tensiometer for the leg lift. Men were tested on both instruments on a test-retest pattern to determine if the two tests were in agreement. By obtaining the mean and standard deviations from the subjects, the two instruments were compared. The correlation between the dynamometer and the tensiometer indicated an r .92 and an r.95 for back and leg lifts, respectively.

In his evaluation of selected studies dealing with strength testing, Hunsicker (52) stated, "It can be safely assumed that the instruments available for testing human strength are sufficiently valid and reliable for meeting the needs of the profession."

Electromyography

When a muscle contracts it is accompanied by an electrical current so that any presence of electrical activity in a muscle denotes activity. The electrical charge that is produced is called an action current. Thus, the rate of contraction in a muscle can be determined by measuring the action current. (26:80) The measurement of action current also reveals whether a muscle is in a state of contraction or at rest, whether a motion is free or resisted, and whether a movement is forceful, slight, rapid, or slow. (29:48)

Recording the electrical current is done by the use of an electromyograph and one of the most important aspects of electromyographic research is the evaluation and interpretation of these recordings. Basmajian (2:38) has stated that the most abused part of electromyography is in the interpretation of electromyograms. O'Connell (60) and Basmajian (2:38) give accurate accounts and helpful information in their discussions on the interpretation of electromyograms.

Since the introduction of the EMG there have been great advances in kinesiology, physical therapy, and medicine. With the use of this instrument, many accepted theories and postulations have been proven to be in error and new theories have been brought forth. (6:26, 24:29) This type of measurement has also been beneficial in determining the amount of activity in a paralyzed or injured muscle. (27:162)

Electromyography has been useful in assessing the relationships of various muscles to specific movements and skill patterns. (50, 64, 65) Basmajian (2:55) has noted that in some of O'Connell's unpublished EMG studies at Boston University, she was able to assess the actual experience and skill of subjects performing the headstand by the amount of undesired activity present in muscles that was not directly related to the exercise.

Studies have also been done in relation to specific muscle groups involved in selected exercises. (2, 63, 66, 68) The purposes of these studies were to determine if these muscles which are called on for a selected exercise actually do the work and to what degree one muscle group contributes to a specific movement.

Since the late 1940's, a number of papers have been published which involved the actions of specific abdominal muscles in selected exercises, posture and breathing. In 1950, Floyd and Silver (2:61) studied the abdominal musculature using an electrode grid which recorded activity from different parts of the rectus abdominis and external and internal obliques. They reported that there was a difference between the left and right sides of the abdominal muscles and, with a head raising exercise (similar to the curl sit-up), the rectus abdominis showed a greater amount of electrical activity as compared to the minimal amount of activity recorded in the obliques.

Sheffield (63) was concerned with the relationship of the activity of the abdominal muscles during locomotion and other movements. In his study he used needle electrodes in preference to surface electrodes because of the lesser amount of artifact. He reported that none of the subjects showed any electrical activity in the upper and lower rectus abdominis, and the medial and lateral abdominal muscles, while standing or walking at sixty steps per minute. When the subjects lowered and raised trunks with the knee flexed at 45° and sat up into an upright position there was maximal activity in all four muscles simultaneously. His most striking finding, in which there was no activity in the muscles during walking, contradicted the assumption that walking activities are effective in the strengthening the abdominal musculature.

Walters and Partridge (66) studied the effect of various positions and commonly used exercises for strengthening the abdominal musculature. Paired electrodes were placed on the upper and lower rectus abdominis, the anterior, middle and posterior fibers of the external oblique, the middle fibers of the internal oblique, and the rectus femoris. They found when the action of the hip flexors was minimized, the exercise became more difficult. They also found that when the knees were flexed at a 65° angle in a hook lying position, greater activity occurred in the abdominal muscles. When the knees were flexed at a 90° angle, there was less activity in the abdominal muscles and more activity in the hip flexors.

An unpublished electromyographic study on sit-ups by Crowe, et al, (68) revealed that greatest activity occurred in the upper rectus abdominis followed about 0.2 to 0.3 seconds later by the lower rectus abdominis and internal oblique abdominals. Activity in the hip flexors (iliopsoas and rectus femoris) did not start until the scapulae were clear of the floor. Surprisingly, the electromyograms showed a marked increase in iliopsoas activity when the sit-up was performed with the knees flexed at 50^{o} as compared to the 110^{o} flexion. Flexing the hips, which shortens the counter balance resistance, increases the general difficulty of the sit-up, but when the hip angle is slight, the increased activity in the iliopsoas is negligible. (see appendix)

Summary

Much research has been conducted in the area of abdominal strength. Measures of abdominal strength have been evaluated by use of electromyographs, tensiometers, dynamometers and general physical fitness batteries. Diverse opinions have been formulated relating to the effectiveness of dynamic and static tension. Theories have been postulated regarding the use of various sit-up positions for assurance of maximum efficiency and work output of the abdominal muscles.

Regardless of the divided opinions or methods used, the evidence is strong that maintainance and attainment of increased strength is recognized as having a desirable effect on human performance. Whether using strength testing devices or subjective tests, continued research is needed for more evaluation of the cause and effect relationship in the development of strength.

CHAPTER IV

PROCEDURE

The purpose of this study was threefold:

(1) to determine the increase in the amount of strength developed in a selected graduated sit-up program of exercise as measured by the tensiometer

(2) to determine, if possible, which sit-up was most effective in developing the strength of the abdominal musculature as measured by the tensiometer

(3) to compare the results of this study with the results of a previous electromyographic study involving different variations of sit-ups.

Selection of Subjects

Subjects selected for the experimental group were female students from the University of North Carolina at Greensboro who were enrolled in a Recreational Sports class taught by the author during the first semester of 1963-64. Fifteen students were selected from a class of thirty-one. The subjects were chosen on the basis of their interest in class and their willingness to participate in the study during their free time. Four additional subjects were later added to the experimental group upon their request.

All nineteen subjects in the experimental group took varied physical activities for the second semester. Activities including bowling, basic activities, golf, modern dance, and tennis. Since these activities, especially modern dance, could possibly affect abdominal strength to some extent, a control group was formed. The subjects selected for the control group were ten nurses enrolled in a Recreational Sports class during the second semester of 1963-64. Their activities included basketball, billiards, and table tennis. The control group was asked not to participate in any activities which would have direct effect upon the abdominal musculature.

Selection of Measuring Instruments

Cable tensiometer. The aircraft tensiometer, manufactured by the Pacific Scientific Company, Los Angeles, California, was used to measure abdominal strength. This instrument was selected because of its value as a reliable and valid measure for strength testing. Clarke (5:73) obtained objectivity coefficients of .90 and above when the tests were administered by experienced testers. The tensiometer had a special calibration for an "up-pull" with a capacity of testing 3-5 to 100 pounds and a maximum pointer to facilitate reading the subjects's score.

An adjustable trunk strap (army surplus belt), was fastened securely around the subject's back, just under the arm pits by an interlocking clasp. A one-sixteenth inch flexible cable attached to a welded link chain was fastened to the interlocking clasp on the back of the trunk strap. A sturdy hook was secured to a two by four stringer below the slit in the testing table. The cable and link chain were dropped through the slit in the table and attached to the hook. The appropriate chain link was selected so that the cable would be taut. The tensiometer was attached to the cable by opening the trigger of the tensiometer and passing the cable part of the pulling assembly between the two sections and the riser. The trigger was closed and the investigator held the tensiometer steady while testing.

The subject was placed in a supine position on the testing table, hips in 180^{o} extension and adduction with the knees fully extended and the arms folded on the chest. The subject was instructed to pull with as strong an effort as possible against the cable. For motivation, the investigator continually shouted "pull" so that the subject would use as much abdominal strength as possible. An assistant held the hips and legs in a stable position by pressing down on the anterior superior spines and lower part of the legs of the subject (see Appendix). A reading of the tension exerted was recorded and converted into pounds according to the calibration chart which can be found in the Appendix.

Goniometer (19). This instrument was used to measure knee flexion at 110^{o}, which is the largest angle that a subject can attain and still maintain full plantar contact with the floor (68). It consisted of a 360^{o} protractor with a stationary arm projecting from the right side of the protractor and a movable arm hinged at the center. The center of the goniometer was placed at the center of joint motion and both arms were placed parallel to the leg and thigh (19:293).

Preliminary tests

Five graduate students were tested for abdominal strength on the cable tensiometer for the purpose of testing the objectivity of the investigator and her assistant in administering the tests. During the first week in February the subjects were given a test-retest on Wednesday and Friday of the same week. All tests were carried out in exactly the same manner. The Spearman Rank-Order Correlation method (32:301) was used to correlate the best trials on the first and second administrations of the tests. The correlation showed a reliability coefficient of .77. If more subjects were involved in the preliminary tests, a higher correlation could have possibly been obtained.

Initial Tests and Training Period

During the last Recreational Sports class of the first semester, the investigator explained briefly to the selected subjects the purpose and length of the experimental study. The subjects were told that they would be contacted at the beginning of the second semester by telephone to set a date for a meeting for more details. They were asked to turn in second semester schedules to the investigator as soon as possible so that times could be arranged for testing on the tensiometer and also for the five-week training period.

A second meeting was held at the end of the first week in February and the nineteen subjects were told in detail, the purpose, scope, and length of the study. All subjects were told that they would perform under the investigator's supervision at all times. They were divided into three exercise groups: Group A consisted of four subjects, Group B consisted of five subjects and Group C consisted of six subjects. The exercises, which were curl sit-ups with three variations, were selected because of the results of the electromyographic study found in the Appendix.

Group A performed an isotonic contraction with assistance, with the knees flexed at 110°. Each subject was instructed to curl the trunk into a full sit-up position and then return to a supine position. An assistant held her partner's ankles holding the feet firmly to the floor.

Group B performed an isotonic contraction, with the knees flexed at 110°, but without assistance. Each subject was instructed to curl the trunk into a full sit-up position and then return to a supine position.

Group C performed an isometric contraction, unassisted, with the knees flexed at 110°. Each subject was instructed to raise the trunk only enough to bring the scapulae off the floor. This position was held for six seconds. See appendix for a full description of the exercises.

A master schedule was arranged for the initial test on the tensiometer and for the five-week training period, which encompassed five days a week for five weeks exclusive of weekends. Meetings for the initial test ranged from 10 a.m. to 6 p.m. All nineteen subjects were tested on the same day by the investigator and an assistant. Scheduled meeting times for the five-week training period ranged from 9 a.m. to 3 p.m. every day. Four girls, who were unable to come during the day for various reasons, were tested at different times every evening. The subjects met with the investigator every day and were told that if they missed one day of training they would have to be dropped from the study.

On the day after the initial testing, the subjects were given a tolerance level test by performing as many sit-ups as possible. The number of sit-ups performed in Group A ranged from 18 to 30. The number of sit-ups performed in Group B ranged from 22 to 58. The number of sit-ups performed in Group C ranged from 8 to 24. (See Table I) The following day, which was the start of the training period, the subjects were told to start at their level of tolerance and to go beyond this level until they felt that they were unable to continue. The overload principle was thus used, and each day thereafter the subjects performed beyond the number of sit-ups done the preceding day.

On the same day as the tolerance level test, the control group was given the initial test on the tensiometer. The same instructions for exerting tension on the cable were given to this group. The subjects were told that they would be tested again in five weeks.

After thirteen days of training, the investigator tested sixteen subjects on the tensiometer. This had not been originally planned, but many subjects after two weeks of exercise, had already performed 200 sit-ups. The investigator was interested in knowning if there was any significant increase in strength at this point of the training period. Three subjects were dropped

TABLE I

NUMBER OF SIT-UPS PERFORMED

FOR TOLERANCE LEVEL TEST

Group A	Group B	Group C
18	22	8
25	30	9
28	32	9
30	35	11
	58	13
		24

from the study at this time because they had failed to keep appointments.

Seven graduate students were asked to participate in the study. The students were classified as Group D and were given an initial test on the tensiometer. Group D performed the isometric contraction in the same manner as Group C, with one difference; the overload principle was not used. Only one six-second contraction was required each day for seventeen days. Hettinger, et al (11:75, 61, 67) have postulated that only one-six-second contraction utilizing two-thirds maximum strength, and not increased repetitions of six-second contractions, is sufficient for increasing strength. The investigator was interested in comparing Group C (overload) with Group D (no overload). Six of the graduate students were enrolled in a golf class and all seven students participated in various physical activities.

Final Tests

On Thursday, March 19th, the day after training ended, the final test was administered to fifteen subjects. One other subject had been dropped from the study because of sickness. The investigator selected the time for the final test which took place at seven o'clock in the evening. Morehouse (28:22) has maintained that "the time of day for exercise is unimportant as far as strength is concerned". The investigator and subjects decided that maximum results could be obtained a few hours after the last meal. The test was carried out in the same manner as the initial test and by the same investigator and assistant. The investigator continually shouted "pull" to obtain maximum strength results.

The final test was administered to the control group on the same day as the experimental group. This was the only available day that the whole group could be together, and therefore, they were tested during their physical education class period at 4 p.m. The final test was given to the graduate students on March 20th. Due to teaching load and class time, these subjects were tested at various times during the day.

After all final tests were administered, the investigator found that three of the subjects in the experimental group had pulled over one hundred pounds. Since the cable tensiometer was only calibrated for one hundred pounds, correction scores were unavailable. A letter was sent to the manufacturing company for a chart of correction scores over one hundred pounds. The investigator received an answer and was told that the tensiometer would have to be sent back to be calibrated to two hundred pounds. Because of a time factor involved, this could not be done. Dr. Anna J. Reardon, Head of the Physics Department at the University of North Carolina at Greensboro, suggested that the tensiometer be re-calibrated to 120 pounds. Weights were obtained from The Curry School in Greensboro, North Carolina, and the tensiometer was taken to the Greensboro-High Point Aircraft Service in Greensboro, North Carolina, for calibration. Five-pound weights were added to the cable tensiometer consecutively with each reading and a scale was devised to obtain the poundage for each reading. The complete calibration chart and reading scale can be found in the Appendix.

Statistical procedures were employed to determine the means and standard deviations of initial and final tests in each group. Fisher's test of significance was calculated between the means of the initial and final tests to determine any significant improvement within each group. Analysis of variance was employed to determine if three of the experimental groups were from a common population. The analysis of covariance was used to determine if any sit-up exercise resulted in a significant improvement of abdominal strength. With the analysis of covariance, comparisons between groups were determined.

After all statistical procedures were employed, a subjective comparison was made between the results of the electromyographic study and the results found in this study.

CHAPTER V

ANALYSIS AND INTERPRETATION OF DATA

The purpose of this study was threefold:

(1) to determine the increase in the amount of strength developed in a selected graduated sit-up program of exercise as measured by the tensiometer

(2) to determine, if possible, which sit-up was most effective in developing the strength of the abdominal musculature as measured by the tensiometer

(3) to compare the results of this study with the results of a previous electromyographical study involving different variations of sit-ups.

The selected subjects were divided into five groups: four exercise groups, and one control group. Group A performed an assisted isotonic contraction, group B performed a non-assisted isotonic contraction, and Groups C and D performed isometric contractions. Groups A, B, and C used the overload principle, and Group D performed one single six-second contraction daily. All groups were given an initial and final test on the tensiometer to measure abdominal strength. Groups A, B, and C were given a five-week training period and Group D was given a three-week training period between the initial test and the final test on the tensiometer.

Statistical Analysis

The first statistical treatment was to determine the means and standard deviations of the initial and pre-final abdominal strength tests and of the initial and final abdominal strength tests for all groups. The mean increase between the initial and pre-final abdominal strength tests ranged from three to twenty pounds. The standard deviations also increased. The mean differences between the initial and final abdominal strength tests ranged from 1.3 to thirty-one pounds. The standard deviations scores showed a similar increase in all groups.

The mean increase for the control group was 1.3. The standard deviation score increased considerably in the control group. This was probably due to the variations of scores around the mean. The means and standard deviations may be found in Tables II and III.

TABLE II

MEANS AND STANDARD DEVIATIONS FOR

INITIAL AND PRE-FINAL ABDOMINAL STRENGTH TESTS

Sit-up Exercise	Initial Test			Pre-Final Test		
	N	M	S.D.	N	M	S.D.
Isotonic-assisted (Group A)	4	46	9.15	4	66	9.38
Isotonic-unassisted (Group B)	5	68	14.50	5	71.8	20.2
Isometric-overload (Group C)	6	49.5	9.20	6	52.2	11.2

TABLE III

MEANS AND STANDARD DEVIATIONS FOR

INITIAL AND FINAL ABDOMINAL STRENGTH TESTS

Sit-up Exercise	Initial Test			Final Test		
	N	M	S. D.	N	M	S. D.
Isotonic-assisted (Group A)	4	46	10.5	4	81	19.9
Isotonic-unassisted (Group B)	5	68	14.5	5	89.2	18.2
Isometric-overload (Group C)	6	49.5	9.20	6	64	17.2
Isometric-non-overload (Group D)	7	51	16.6	7	65.1	22.3
Control Group	10	60.4	5.19	10	61.7	18.2

Tests of Significance

Fisher's "t" tests of significance for correlated means (32:319) were used to compute the significance of difference between means of initial and pre-final test scores within each group. The five per cent level of confidence or below was accepted for statistical significance. The results of the "t" tests for the initial and pre-final tests may be found in Table IV.

The investigator was interested in knowing if there was any significant increase of strength development after two weeks of training. Group A (isotonic assisted) showed a significant improvement at the 5 per cent level of confidence. Groups B and C were not significantly different. Since only group A showed a significant difference, it seemed that two weeks training

TABLE IV

SIGNIFICANCE OF DIFFERENCE BETWEEN THE MEANS

FOR INITIAL AND PRE-FINAL ABDOMINAL STRENGTH TESTS

Sit-up exercise	"t"
Isotonic - assisted (Group A)	3.11**
Isotonic - non-assisted (Group B)	.4828
Isometric - overload (Group C)	.5521

* - indicates significance at the 1% level of confidence
**- indicates significance at the 5% level of confidence

was not a sufficient amount of time to develop strength of the abdominal muscles. The investigator felt that this result was possibly due to the lower mean in group A as compared to the other four groups. Therefore, group A had a lower strength index and a greater potential for increasing strength in a shorter time span.

The analysis of variance supports the above explanation. Since the F was significant at the 1 per cent level of confidence, it was assumed that the groups were not from a common population. Further analysis was undertaken employing Fisher's "t" test to determine where the differences between groups lay. The results showed that the mean of group B was significantly higher than Group A and C. The mean difference between Group A and Group C was not significantly different. Since the mean in Group A was considerably lower the investigator thought that learning took place within two weeks. The results of analysis of variance and tests of significance can be found in Tables V and VI.

The "t" values computed between the initial and final abdominal strength tests were all significant in the four experimental groups. In Groups A, B, and C, changes were significant at the 5 per cent level of confidence which seemed to indicate that five weeks of training were sufficient to increase the strength of the abdominal muscles. Improvement in Group D was also significant at the 5 per cent level of confidence but only had seventeen days of training.

The control group showed no significant difference and thus seemed to indicate that the omission of the experimental measures (training period) was the factor responsible for no increase in abdominal strength. The "t" values for the initial and final tests may be found in Table VII.

Analysis of Covariance

The data from the four experimental groups and the control group were statistically treated by analysis of covariance (9:333). This statistical treatment was employed for two reasons. First, the investigator wished to determine if any experimental measure or sit-up exercise resulted in an improvement of abdominal strength when compared to the other three sit-up exercises. Secondly, differences in initial performance were taken into account because the five groups were not matched prior to experimental conditions. Through analysis

TABLE V

SUMMARY OF ANALYSIS OF VARIANCE

OF THREE TREATMENT GROUPS

Source of Variation	Sum of Squares	df	Mean Square	F
Between Groups	1350	2	675	4.56*
Within Groups	1779	12	148	
Total	3129	14		

* - indicates significance of difference at 1% level of confidence
** - indicates significance of difference at 5% level of confidence

TABLE VI

SIGNIFICANCE OF DIFFERENCES BETWEEN THE MEANS

OF INITIAL ABDOMINAL STRENGTH TESTS

Sit-up exercise	"t"
Isotonic-assisted (Group A)	
Isotonic non-assisted (Group B)	2.68**
Isometric (Group C)	.443
Isotonic-non-assisted (Group B)	
Isometric (Group C)	2.50 **

* - indicates significance of difference at 1% level of confidence
** - indicates significance of difference at 5% level of confidence

TABLE VII

SIGNIFICANCE OF DIFFERENCE BETWEEN THE MEANS

FOR INITIAL AND FINAL ABDOMINAL STRENGTH TESTS

Sit-up exercise	"t"
Isotonic-assisted (Group A)	2.75**
Isotonic-non-assisted (Group B)	2.63**
Isometric-overload (Group C)	2.06**
Isometric-non-overload (Group D)	2.28**
Control Group	.2006

* - indicates significance at the 1% level of confidence
**- indicates significance at the 5% level of confidence

of covariance the means of the experimental variable were adjusted by regressing the scores in terms of initial performance.

The analysis of covariance in Tables VIIIthrough XI showed an F of 2.19, which was not significant. It was therefore unnecessary to continue with tests of significance. In interpreting the insignificant F, a consultation was held with Dr. William Ray, statistician in the Psychology Department at the University of North Carolina at Greensboro. It was concluded that even though there was no significant difference between the control and experimental groups, the experiment variables were equally effective in strengthening the abdominal muscles within groups.

TABLE VIII

ANALYSIS OF VARIANCE OF SCORES

OF FIVE GROUPS OF SUBJECTS

ON PRELIMINARY TRIAL: X

Source of Variation	Sum of Squares	df	Mean Square	F
Between Groups	1748	4	437.	3.38*
Within Groups	3493	27	129.37	
Total	5241	31		

* - indicates significance at 1% level of confidence
** - indicates significance at 5% level of confidence

TABLE IX

ANALYSIS OF VARIANCE OF SCORES OF

FIVE GROUPS OF SUBJECTS TESTED UNDER

DIFFERENT EXPERIMENTAL CONDITIONS: Y

Source of Variation	Sum of Squares	df	Mean Square	F
Between Groups	3414	4	853.50	2.31
Within Groups	9966	27	369.11	
Total	13380	31		

* - indicates significance at the 1% level of confidence
** - indicates significance at the 5% level of confidence

TABLE X

SUMS OF SQUARES AND CROSS PRODUCTS FOR

FIVE GROUPS OF SUBJECTS ON

PRELIMINARY TRIAL (X)

AND UNDER EXPERIMENTAL CONDITIONS (Y)

Source of Variation	df	Sx^2	Sxy	Sy^2
Between Groups	4	1748	763	3404
Within Groups	27	3493	1670	9966
Total	31	5241	2433	13380

TABLE XI

ANALYSIS OF COVARIANCE OF PERFORMANCE

OF FIVE GROUPS OF SUBJECTS

Source of Variation	Sums of Squares of Groups of Estimate	df	Mean Square	F
Total	12250.55	30		
Within Groups	9167.55	26	352.60	2.19
Adjusted Means	3083	4	770.75	

* - indicates significance at the 1% level of confidence
** - indicates significance at the 5% level of confidence

This indicated that no one treatment effect was better than the other one. No exercise was superior to the other in influencing a greater increase in strength of the abdominal muscles. Though there was no significance of difference between groups, there was a significant improvement within each group exclusive of the control group.

Comparison of Results of Electromyographic Study

Three of the sit-ups used in this study were taken from the electromyographic study for various reasons. The investigator was interested in determining the difference between a complete isotonic contraction and an isometric contraction following a training period. In the electromyographic study the report was made that the greatest activity occurred in the early part of the sit-up and activity in the iliopsoas and rectus femoris did not start until the scapulae were clear of the floor. Also, a lower degree of activity was recorded during the eccentric (lengthening) contraction of the sit-up. In the assisted isotonic contraction, the subject found that it was easier to perform, but there was less activity recorded from the abdominal muscles and more activity recorded from the iliopsoas and the rectus femoris.

All sit-ups in the present study were performed with the knees flexed at 110°. In the electromyographic study the recordings showed greater activity in the abdominal muscles and negligible or slight activity in the iliopsoas when the knees were flexed at 110^o compared to 50^o flexion. Since the sit-up is specifically an exercise to increase the abdominal musculature, it would be an advantage to decrease the activity in the hip flexors as much as possible.

In the conclusion of the electromyographic study, the authors state the following:

> ...if the objective is to strengthen abdominal muscles, the isometric contraction maintained with the shoulders just off the floor should be more effective than the complete sit-up sequence of isotonic and eccentric contraction. (68)

In the present study, the author found through analysis of covariance no significant difference between the groups. This indicated that no exercise was superior to the other. The isotonic and isometric exercises were equally effective in increasing the strength of the abdominal muscles. This seems to support the view of some investigators mentioned in the review of literature, that increasing strength is effective with both isotonic and isometric contractions, as long as the overload principle is used. Yet, Group D, performed a single daily six-second contraction with only seventeen days of exercise and was just as significant as the other three groups. This would tend to support, to some extent, the above quote relating to the effectiveness of holding the scapulae off the floor.

Also interesting is the fact that when one is assisted, the iliopsoas is more active. Yet, again, in the present study, no one exercise was better than the other. This would indicate that abdominal strength can be increased just as much with the use of the iliopsoas as without it.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this study was threefold:

(1) to determine the increase in the amount of strength developed in a selected graduated sit-up program of exercise as measured by the tensiometer

(2) to determine, if possible, which sit-up was most effective in developing the strength of the abdominal musculature as measured by the tensiometer

(3) to compare the results of this study with the results of a previous electromyographic study involving different variations of sit-ups.

Thirty-two students were selected from two classes that the author had taught at the University of North Carolina at Greensboro. The subjects were divided into five groups; one control group and four experimental groups. Each experimental group performed a different variation of a sit-up. Group A performed an isotonic contraction assisted; Group B performed an isotonic contraction unassisted; Groups C and D performed isometric contractions unassisted. All groups used the overload principle except group D who performed a single six-second contraction daily.

The raw data were treated statistically to determine any differences between initial and final tests within groups and to determine any differences between initial and final tests between groups. Statistics were employed to ascertain the most effective exercise for increasing abdominal strength. The following results were obtained:

1. There was a significant difference between the means of the initial and final tests within all four experimental groups.

2. There was no significant difference between the means of the initial and final tests of the control group.

3. There was no significant improvement between groups.

4. Results of the present study conflicted with the results of the electromyographic study relating to the assistance of the exercise and isometric contractions.

The findings of the present study resulted in the following conclusions:

1. Both isotonic and isometric contractions were effective in increasing the abdominal musculature as long as the overload principle was used. This supported other findings.

2. One six-second contraction performed daily was just as effective as performing isometric contractions using the overload principle. This supported other findings.

3. No one exercise was superior to the other for increasing the strength of the abdominal musculature.

4. Five weeks training was a sufficient time to increase the strength of the abdominal muscles.

The comparison of results between the present study and the previous electromyographic study are as follows:

1. In the present study, Group A (isotonic-assisted) had significantly improved in strength after two weeks of training and after five weeks of training. The findings of the electromyographic study indicated that assisting the subject made the sit-up easier but there was an increase of iliopsoas activity. It would seem to be an advantage to decrease iliopsoas activity so that maximal use of the abdominal muscles can be obtained. Yet, the above result indicated that abdominal strength can be increased just as much with the action of the iliopsoas as without it.

2. In the present study, no exercise was superior to the other. The findings of the electromyographic study indicated that under all circumstances activity appeared first in the upper rectus abdominis followed about 0.2 to 0.3 seconds later by the lower rectus and internal oblique abdominals. Activity in the hip flexors did not start until the scapulae were clear of the floor. As the trunk approached the erect sitting posture, there was a marked decrease in muscular activity.

It would seem to be an advantage to use the isometric contraction with the scapulae just clear of the floor instead of completing the isotonic contraction. Yet, the present study indicated that isotonic and isometric contractions increased the strength of the abdominal muscles with no one exercise superior to the other.

CHAPTER VII

CRITIQUE AND SUGGESTIONS FOR FURTHER STUDY

Whenever an investigation is undertaken to assess human performance, many unexpected variables are involved. In the present study, some factors could not be avoided, but other factors were overlooked which could have been avoided.

The time of day, examination periods, menstrual periods, and lack of sleep seemed to be causative factors in this study. If students were motivated more during initial tests, training periods and final tests, there may have been an indication of one exercise superior to another. The physical education graduate students, who participated in the study, may have possibly affected the results to some extent because of high motivational and strength factors.

The number of subjects affected this study to a large extent. The total group was fairly large, but when they were divided, the groups were small. Added to this factor were dropouts which reduced the size of the groups.

Because of these problems that arose, the investigator suggests the following for further study:

1. For a more accurate measurement of individual differences, larger groups should be used in this type of study. The investigator thinks that there should be at least fifteen in a group.

2. Groups should be matched in initial ability, if at all possible, and there should be equal numbers in each group.

Because of conflicting results between the electromyographic study and the present study the author suggests the following:

1. Continued studies should be made to determine the effectiveness of isometric versus isotonic contractions.

2. More research should be undertaken with the use of the electromyograph and the use of the tensiometer in relation to gravity factors, eccentric and concentric contractions,and the assisting of subjects during a sit-up exercise.

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APPENDIX

AN ELECTROMYOGRAPHIC STUDY OF THE ABDOMINAL MUSCLES AND CERTAIN HIP FLEXORS DURING SELECTED SIT-UPS

Part I

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Sit-ups, or variations of sit-ups, are used in nearly all physical fitness tests and are included in practically all exercise routines for developing strength in the muscles of the abdominal wall. The attached bibliography lists eighteen sources which describe fifty-two variations of sit-ups used for either or both of these purposes. Eliminating the duplications, our group has compiled a list from these sources comprising a number of different forms of the sit-up varying in degrees of difficulty. It is our ultimate purpose to examine these electromyographically to determine, if possible, which variations would be most useful in developing and/or testing the strength of the abdominal musculature. Determination will be based on the fact that the amount of electrical activity recorded from a contracting muscle is directly related to the number of motor units contracting in that muscle. This paper will report on results from a limited part of the total study.

Pairs of 8 mm. surface electrodes were placed over the abdominal muscle of the right side as follows: upper rectus abdominis, lower rectus abdominis, the antero-lateral aspect of the external oblique and the internal oblique. Electrodes on the latter were placed below the anterior superior iliac spine where only an aponeurotic tendon separates the internal oblique from the skin.

To record from the iliopsoas a pair of electrodes was placed just below the inguinal ligament and just lateral to the femoral artery where only areolar subcutaneous tissue lies between the muscle and the skin. Some anatomists question the ability to record from this muscle with surface electrodes because of its relative inaccessibility. According to the Warm Springs (Georgia) Foundation test for "trace to poor grade" muscle action the iliopsoas may be palpated in this area during hip and knee flexion (with the hip laterally rotated) between 90^{o} and full hip flexion. Control electromyograms from our electrodes showed increasing electrical activity during this movement. We feel confident that the activity originated in the iliopsoas because the sartorius, which lies adjacent to this region, cannot be contributing to any great extent to the electromyogram because of the fact that it is being moved further and further away from the recording electrodes as the lateral rotation and hip flexion increase.

Electrodes were also placed on the rectus femoris and on the erector spinae muscles of the lumbar region.

This report is confined to the study of the two simplest sit-ups; (A), the "curl" and (B), "straight back"; both performed from the supine position with the arms at the sides, and hands resting on the thighs.

In the "curl" (A), the subject tucks her chin and flexes the vertebral column as she sits up. The elbows are kept extended and the hands slide toward the feet along the lower extremities as the trunk is raised. In the "straight back" (B), the subject maintains the normal alignment of the vertebral column as she sits up.

Each of these sit-ups is performed with three variations as follows:

1. with the entire length of the lower extremities in contact with the floor (i.e., legs straight)

2. with the knees flexed 110^{o} (This is the largest angle that a subject can attain and still maintain full plantar contact with the floor.)

3. with the knees flexed 50^{o} (This angle brings the heels within approximately eight to ten inches from the hips.)

Both the "curl" (A) and the "straight back" (B) series were performed unassisted, and then repeated while the feet were held firmly in contact with the floor by a partner, i.e., assisted.

Four of the subjects also performed an additional "curl" series, both assisted and unassisted, in which the trunk was raised only enough to bring the scapulae off the floor. This position was then held for several seconds before returning to the starting position.

In every subject the electromyograms recorded during sit-ups performed with the flexed vertebral column ("curl") showed less activity than the corresponding variation performed with the back held straight. This is not surprising as the "curl" shortens the moment arm of the lever involved (i.e., the trunk), thus requiring less effort to move it.

Assisting the subject by holding the feet to the floor also makes the sit-up easier to perform as shown by a smaller amount of electrical activity recorded from the abdominal muscles. On the other hand, the activity in the rectus femoris and iliopsoas increases when subject is assisted. As far as the former is concerned, anchoring the feet, and therefore the tibia (whatever the angle at the knee) gives the rectus femoris a fixed attachment so that its contraction can only produce movement at the proximal attachment, thereby rotating the pelvis on the head of the femur and thus flexing the trunk at the hip. In regard to the iliopsoas muscles, we must remember that a relatively small fraction lies below the inguinal ligament. Many of the muscle fibers, particularly those of the psoas major arising from the lumbar vertebrae, may attach to the tendon before the muscle passes over the ilio-pubic ramus. Under these circumstances contractile activity of these fibers would not be registered by the electromyograph, and this would account for the "slight-to-moderate activity which we record from this muscle as the subject sits up.

The sequence of muscle action is interesting. Under all circumstances activity appears first in the upper rectus abdominis, followed about 0.2 to 0.3 second later by the lower rectus and internal oblique abdominals. Activity in the hip flexors (iliopsoas and rectus femoris) does not start until the scapulae are clear of the floor. As the trunk approaches the erect sitting posture there is a marked decrease in muscular activity, which in many instances disappears entirely during the "hold." As the subject returns to the supine position, the eccentric (lengthening) contraction registers a lower degree of activity than the isotonic (shortening) contraction during the sit-up. This is in agreement with A. V. Hill (Science, March 25, 1960) who points out that less energy is consumed (i.e., fewer muscle fibers contracting) when a muscle is performing negative work.

With the evidence in mind that the greatest activity occurs in the early part of the sit-up, the last four of the subjects tested were asked to curl the thorax until the scapulae were just off the floor and then to hold this position for 2-3 seconds. The resulting electromyograms recorded intense activity in all the abdominal muscles when performed with straight legs or with slight hip flexion (knees flexed 110°). Surprisingly, with greater hip flexion (knees flexed 50°) the maximum level of activity was less than that during the isotonic movements.

It has often been postulated that flexing the hips (and knees) while sitting up puts the iliopsoas "on slack" so that the actual hip flexion is performed by the auxiliary hip flexors (such as the rectus femoris, sartorius, tensor fascia lata and possibly some of the adductor muscles), thus obviating any tendency toward lordosis due to the pull of the psoas on the lumbar spine. Our electromyograms show a marked increase in iliopsoas activity when the sit-up is performed with the greater degree of hip flexion (i.e., knees flexed 50^{o}). Furthermore, in subjects who, when unassisted, were unable to raise the trunk completely from this position the iliopsoas recorded maximum activity as long as the effort was maintained. With assistance these subjects were able to perform successfully from this position and activity in iliopsoas, although not maximal, was still greater than that recorded in the other sit-ups. The increase in both instances may be due to the fact that the iliopsoas is not only attempting to raise the trunk by pulling at its proximal attachment, but also to maintain the required hip flexion by pulling at the distal attachment.

These findings suggest that the aforementioned postulate needs further study in regard to activity in auxiliary hip flexors. It would also be wise to study the activity in the hamstrings (which flex the knee while extending the hip), and in the gluteus maximus (which may be stabilizing the hip joint).

Summary:

1. Assistance (i.e., holding the subject's feet to the floor) decreases the amount of effort necessary, either to sit up or to just raise the scapulae from the floor.

2. The straight back sit-up requires more effort than the curl.

3. Flexing the hips, which shortens the counter-balance resistance, increases the general difficulty of the sit-up: although when the hip angle is slight, the increased activity in the iliopsoas is negligible.

Conclusions:

At this point in our study it seems that, if the objective is to strengthen abdominal muscles, the isometric contraction maintained with the shoulders just off the floor should be more effective than the complete sit-up sequence of isotonic and eccentric contraction.

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DESCRIPTION OF EXERCISES

Curl Sit-up - Isotonic Contraction with Assistance

Subject is in a supine position with the knees flexed 110°. The subject tucks her chin and flexes the vertebral column as she sits up. The elbows are kept extended and the hands slide toward the feet along the lower extremities as the trunk is raised. The subject's feet are held firmly in contact with the floor by a partner. Subject performs as many sit-ups as possible. Each day the overload principle is used. (Subject performs beyond the number of sit-ups performed preceding day).

Curl Sit-up - Isotonic Contraction without Assistance

Subject is in a supine position with the knees flexed 110°. The subject tucks her chin and flexes the vertebral column as she sits up. The elbows are kept extended and the hands slide toward the feet along the lower extremities as the trunk is raised. Subject performs as many sit-ups as possible without assistance. Each day the overload principle is used. (Subject performs beyond the number of sit-ups performed preceding day).

Curl Sit-up - Isometric Contraction (six seconds)

Subject is in a supine position with the knees flexed 110°. The subject tucks her chin and raises the trunk only enough to bring the scapulae off the floor. This position is held for six seconds. Subject returns to starting position. Subjects perform as many six-second contractions as possible. Each day the overload principle is used. (Subject performs beyond the number of isometric contractions performed preceding day).

Curl Sit-up - Isometric Contraction (six seconds)

Subject is in a supine position with the knees flexed 110°. The subject tucks her chin and raises the trunk only enough to bring the scapulae off the floor. This position is held for six seconds. Subject returns to starting position. Only one six-second contraction is performed each day. The overload principle is not used.

SAMPLE SCORE CARD

Name ___S. M.___ Dorm ___Cotton___

Type of Contraction ___Isometric (overload)___

Tensiometer

Initial Test ___67___

Second Test ___60___

Final Test ___70___

Tolerance level test ___24___

Number of training days ___25___

Number of sit ups performed each day

1.	16	10.	175	19.	280
2.	25	11.	200	20.	283
3.	27	12.	215	21.	285
4.	68	13.	225	22.	288
5.	54	14.	250	23.	291
6.	73	15.	265	24.	294
7.	100	16.	268	25.	301
8.	102	17.	271		
9.	105	18.	274		

Figure 1. Abdominal Strength Test

TABLE XII

CALIBRATION CHART FOR CABLE TENSIOMETER

Instrument Reading	Tension Pounds	Instrument Reading	Tension Pounds
2	5	36	57
3	6	37	58
4	7	38	60
5	8	39	61
6	10	40	62
7	12	41	64
8	15	42	65
9	16	43	67
10	17	44	70
11	18	45	72
12	20	46	75
13	21	47	77
14	22	48	78
15	23	49	80
16	25	50	82
17	26	51	83
18	27	52	85
19	28	53	88
20	30	54	90
21	32	55	92
22	33	56	93
23	35	57	95
24	36	58	97
25	37	59	100
26	39	60	101
27	40	61	102
28	41	62	104
29	43	63	105
30	45	64	106
31	47	65	108
32	48	66	110
33	50	67	112
34	52	68	115
35	55	69	117
		70	120

TABLE XIII

TENSIOMETER READINGS FOR EXPERIMENTAL GROUP

	Name	ABDOMINAL STRENGTH Initial	Second	Final
1.	C. R.	45	39	47
2.	H. F.	43	52	70
3.	M. F.	60	70	85
5.	E. T.	47	70	57
6.	M. J.	42	52	77
7.	L. J.	82	60	85
8.	L. M.	45	52	70
9.	L. C.	65	72	112
10.	A. W.	70	70	75
11.	P. S.	78	105	104
12.	N. M.	52	45	62
13.	S. M.	67	60	70
14.	J. W.	43	47	43
15.	N. K.	35	72	105
16.	L. A.	47	70	90
17.	P. C.	67		100
18.	E. C.	60		90
19.	Y. S.	52		67
20.	M. S.	65		52
21.	A. F.	18		40
22.	R. T.	47		60
23.	B. Z.	47		47

TABLE XIV

TENSIOMETER READINGS FOR CONTROL GROUP

Name	ABDOMINAL STRENGTH	
	Initial	Final
1. B. R.	60	80
2. V. P.	65	36
3. P. M.	61	58
4. N. L.	58	95
5. J. S.	62	67
6. L. L.	60	35
7. C. S.	70	61
8. P. L.	57	60
9. D. S.	61	55
10. S. R.	50	70

TENSIOMETER READING SCALE