Study of the relationship between leg strength and swimming speed using the flutter kick in the prone position

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A STUDY OF THE RELATIONSHIP BETWEEN LEG STRENGTH AND SWIMMING SPEED USING THE FLUTTER KICK IN THE PRONE POSITION

by

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B. S. Montana State University, 1961

Presented in partial fulfillment of the requirements for the degree of

Master of Science

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1962

Approved by:

Chairman, Board of Examiners

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TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. THE PROBLEM AND ITS SCOPE</td>
<td>1</td>
</tr>
<tr>
<td>The Problem</td>
<td>1</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td>1</td>
</tr>
<tr>
<td>Analysis of the Problem</td>
<td>1</td>
</tr>
<tr>
<td>Basic Assumptions</td>
<td>2</td>
</tr>
<tr>
<td>Definitions</td>
<td>3</td>
</tr>
<tr>
<td>Limitations of the Study</td>
<td>6</td>
</tr>
<tr>
<td>Need for the Study</td>
<td>7</td>
</tr>
<tr>
<td>Summary</td>
<td>7</td>
</tr>
<tr>
<td>II. REVIEW OF THE LITERATURE</td>
<td>8</td>
</tr>
<tr>
<td>Introduction</td>
<td>8</td>
</tr>
<tr>
<td>Range of Motion</td>
<td>9</td>
</tr>
<tr>
<td>Studies Related to Propulsion in Swimming</td>
<td>11</td>
</tr>
<tr>
<td>Analysis of the Flutter Kick</td>
<td>14</td>
</tr>
<tr>
<td>Instruments Used to Measure Muscular Strength</td>
<td>19</td>
</tr>
<tr>
<td>Cable-Tension Strength Tests</td>
<td>21</td>
</tr>
<tr>
<td>Summary</td>
<td>22</td>
</tr>
<tr>
<td>III. PROCEDURE OF THE STUDY</td>
<td>23</td>
</tr>
<tr>
<td>Selection of the Sample</td>
<td>23</td>
</tr>
<tr>
<td>Method of Measurement</td>
<td>23</td>
</tr>
<tr>
<td>The Kicking Test</td>
<td>26</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS (Continued)

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Used for Cable-Tension Strength Testing</td>
<td>28</td>
</tr>
<tr>
<td>Methods Used in Strength Testing</td>
<td>32</td>
</tr>
<tr>
<td>Description of the Strength Tests</td>
<td>34</td>
</tr>
<tr>
<td>Tabulating the Data</td>
<td>38</td>
</tr>
<tr>
<td>Types of Analysis</td>
<td>40</td>
</tr>
<tr>
<td>Summary</td>
<td>41</td>
</tr>
<tr>
<td>IV. ANALYSIS OF THE DATA</td>
<td>42</td>
</tr>
<tr>
<td>Introduction</td>
<td>42</td>
</tr>
<tr>
<td>Selecting the Sample</td>
<td>42</td>
</tr>
<tr>
<td>Kicking Test Results</td>
<td>43</td>
</tr>
<tr>
<td>Leg Strength Test Results</td>
<td>43</td>
</tr>
<tr>
<td>Correlations Between Speed and Strength</td>
<td>44</td>
</tr>
<tr>
<td>Comparisons Made in the Study</td>
<td>45</td>
</tr>
<tr>
<td>Summary</td>
<td>48</td>
</tr>
<tr>
<td>V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS</td>
<td>49</td>
</tr>
<tr>
<td>Summary</td>
<td>49</td>
</tr>
<tr>
<td>Conclusions</td>
<td>51</td>
</tr>
<tr>
<td>Recommendations</td>
<td>52</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>55</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>58</td>
</tr>
</tbody>
</table>
APPENDICES (Continued)

Appendix A. Directions for Administering the Ankle Plantar Flexion Range of Motion Test.... 58
Appendix B. Directions for the Flutter Kick Test .................................................. 62
Appendix C. Directions for the Leg Strength Tests .............................................. 67
Appendix D. The Data Card ................................................................. 74
Appendix E. The Cumulative Data Sheet ................. 75
## LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. The Mean Pounds and Range of Pounds for all Cable-Tension Strength Tests</td>
<td>44</td>
</tr>
<tr>
<td>II. The Mean Pounds of Strength for the Muscle Groups Performing the Hip and Knee Actions of the Upstroke of the Flutter Kick</td>
<td>47</td>
</tr>
<tr>
<td>III. The Mean Pounds of Strength for the Muscle Groups Performing the Hip and Knee Actions of the Downstroke of the Flutter Kick</td>
<td>48</td>
</tr>
</tbody>
</table>
CHAPTER I

THE PROBLEM AND ITS SCOPE

I. THE PROBLEM

Statement of the problem. The purpose of this study was to establish the degree of relationship between the muscular strength in selected movements of the lower extremities and the time needed to complete a twenty yard swimming test in which the subjects were permitted to use only the flutter kick in the prone position. The subjects used for this study were selected male undergraduate students participating in the required physical education program at Montana State University during the winter quarter, 1962.

Analysis of the problem. To obtain a semi-homogeneous group the subjects were selected on the basis of swimming ability and their ability to perform plantar flexion of the ankle joints. The subjects were participating in intermediate, senior life saving and water safety instructor's swimming courses.

The measurement of swimming speed using the flutter kick in the prone position was determined by swimming a distance of twenty yards on three different occasions, while holding on to a kick board. The times for each of the three trials were recorded.

A review of the literature determined which muscle groups...
were used in performing the flutter kick and how to test the strength of these muscle groups by using the cable tensiometer.

Statistical comparisons of swimming speed and the strength of the upkick, downkick and total movement strength was made to obtain the degree of relationship existing.

II. BASIC ASSUMPTIONS

This study proceeded under the assumption that the strength of the muscle groups used in performing the flutter kick is related to the time needed to swim a distance of twenty yards using the flutter kick in the prone position while holding on to a kick board. It was assumed that lack of plantar flexion of both ankles should eliminate those students whose swimming speed would be impaired because of hooked toes, producing a flutter kick that was performed improperly. ¹

It was also assumed that twenty yards was a logical distance for the swimming test because the swimming pool was twenty yards long. To swim a longer distance each subject would have had to make a turn and this skill was not a part of the study.

It was finally assumed that muscular strengths of specific movements could be found by making composite scores in pounds of the strength developed by the muscle groups tested.

III. DEFINITIONS

The following terms have been defined in relation to their use in the study:

1. **Flutter kick.** The alternate up-and-down vertical thrash of the legs which is used in performing the American Crawl swimming stroke.

   (a) **Upkick** (motion). The upward thrust of the legs during the flutter kick. This leg movement begins with hip extension, the knee is slightly flexed, and the final thrust from forcible plantar flexion of the ankles propels the swimmer forward.²

   (b) **Downkick** (motion). The downward thrust of the legs during the flutter kick. This leg movement begins with hip flexion, the knee is then completely extended and the ankles held in the position of plantar flexion.³

2. **Kick board.** A buoyant object which was held in the hands to maintain the head and trunk on the surface of the water, while performing the flutter kick.

3. **Range of motion.** The number of degrees of movement that occurs in a joint. Plantar flexion was the only range of motion joint measurement made in this study.

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³Ibid., p. 84.
4. **Plantar flexion.** A movement in the ankle joint resulting in a decrease in the angle between the sole or plantar surface of the foot and the posterior aspect of the leg. Normal range of motion for plantar flexion was forty-five degrees when the starting position was in the anatomical position.¹

5. **Hooking the toes.** A term used to label improper movement of the feet when performing the flutter kick. The swimmer drops the toes on the down kick, pointing them toward the bottom of the pool when performing the flutter kick.

6. **Hip flexion.** A movement occurring in the hip joint where the angle between the anterior aspect of the thigh and anterior aspect of the trunk becomes smaller.

7. **Hip extension.** A movement occurring in the hip joint where the angle between the posterior aspect of the thigh and posterior aspect of the trunk becomes smaller.

8. **Knee flexion.** A movement occurring in the knee joint where the angle between the posterior aspect of the thigh and posterior aspect of the leg becomes smaller.

9. **Knee extension.** A movement occurring in the knee joint where the angle between the anterior aspect of the thigh and the anterior aspect of the leg becomes smaller.

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10. **Tensiometer.** An instrument used to record the amount of tension the subject can apply to a cable appropriately placed for specific joint movements.\(^5\)

11. **Data card.** A card which was used to record the results of the range of motion test, kicking test and cable tension strength tests for each subject used in the study.

12. **Cumulative data sheet.** A sheet on which all scores achieved on the kicking test and cable tension strength tests were recorded. The scores were taken from the data cards of each subject.

13. **The product-moment (linear) coefficient of correlation.** Is that ratio which expresses the extent to which changes in one variable are accompanied by, or are dependent upon, changes in a second variable. This was the method used to calculate the coefficients of correlation in this study. Garrett's interpretations of the coefficients of correlation shall be used for the purposes of this study. An \(r\) from .00 to plus or minus .20 denotes indifference or negligible relationship; an \(r\) from plus or minus .20 to plus or minus .40 denotes low correlation; an \(r\) from plus or minus .40 to plus or minus .70 denotes substantial or marked relationship; and an \(r\) from

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plus or minus .70 to plus or minus 1.00 denotes high to very high relationship.

IV. LIMITATIONS OF THE STUDY

The sample used for this study was limited to forty male students taking intermediate, senior life saving, and water safety instructor's swimming courses for required physical education at Montana State University during winter quarter, 1962.

The study was limited to the use of those students whose range of motion of plantar flexion was normal or beyond the normal range. Normal range of motion for plantar flexion was forty-five degrees when the starting position was in the anatomical position.7

Variables not taken into consideration in this study were: age, height, weight, body type, buoyancy and the length of legs of the subjects. The weight of the subject's legs and gravitational pull were not considered in the leg strength tests.

Although the hip flexors, hip extensors, knee flexors, knee extensors and ankle plantar flexors are not the only muscle groups used in the performance of the flutter kick, the study was limited to the strength measurement of these five leg movements.

7Moore, loc. cit.
V. NEED FOR THE STUDY

With factual data indicating the degree of importance that the strength of five different muscle groups used in performing the flutter kick had in relation to the time needed to swim a distance of twenty yards using the flutter kick, methods used in teaching swimming could be improved.

The results of the study may help to determine whether there is more potential power for the upkick or downkick of the flutter kick.

To the knowledge of the author there has not been a similar statistical study of the flutter kick using speed and leg strength as variables.

SUMMARY

Chapter I introduced the problem and its scope. The second chapter presents a review of the literature related to the problem.
CHAPTER II

REVIEW OF RELATED LITERATURE

INTRODUCTION

This study was made to determine the relationship between the leg strength and speed of swimmers using the flutter kick in the prone position. A review of the literature revealed that strength is an extremely important factor for efficient swimming. It was stated by Armbruster, Allen and Harlan: \(^8\)

Recent analyses of the factors which make for success in athletic performance have shown that strength is extremely important.

The levers which are employed in sports, such as those of the arms and legs, are practically all of the types in which the muscle is attached quite near the end of the bone. The weight to be lifted is at the free end of the lever and far from the muscle which is to move the weight.

While this arrangement may be very convenient for movement of speed in which little resistance is encountered, it puts the muscle at a great disadvantage when moving against a resistance, an extraordinarily large force is required in the form of muscular contraction.

For peak performance in swimming, the muscles, which are the sources of power, must be strong.

Further support to the importance of strength for

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efficient swimming was given by Kiphuth: 9

It has been the writer's experience that a conditioning program before the season and conducted out of the water is extremely beneficial. A great deal can be done with free exercise and with pulley weights to strengthen the muscles necessary in efficient swimming.

From the literature available the author found a limited number of studies related to swimming speed and the flutter kick. The author could not find any available study comparing the leg strength of a swimmer to his using the flutter kick in the prone position.

RANGE OF MOTION

The effect hooked feet have on performing the crawl stroke is discussed by Cureton.

The hooked foot kick is executed by holding the foot in a hooked position. This means that the foot is flexed and is held in a position just opposite to that in which the toes are pointed. This position eliminates the upkick swirls and also changes the direction of the downkick swirls so that the swirls become directed downward against the bottom of the pool.

The hooked foot kick caused a loss of practically 100 percent in speed efficiency as compared with the normal kick. Armbruster, Allen and Harlan, 11 state that the effectiveness

11Armbruster, Allen, Harlan, op. cit., p. 85.
of the flutter kick was limited by the degree of extension of the ankles. If the ankle is stiff and the movement limited this lashing action is lost and the legs do not provide their share of the propelling force.

Scott\textsuperscript{12} in her analysis of motion in the articulations of the body, stated that the tibiofibulartalar articulations should perform from forty to forty-five degrees extension.

Meyers\textsuperscript{13} stated that one of the simplest tools used in evaluating range of motion is the goniometer. The most inclusive study of goniometry that he was able to find was that carried out by Moore.

Moore\textsuperscript{14} stated that normal range of motion of ankle extension is forty-five degrees when the foot begins the movement at zero degrees from the anatomical position forming a right angle to the leg.

The simple double armed goniometer is perhaps the most desirable instrument for general measurement of joint motion because it is universally applicable to all joints. If the instrument is made with two stationary arms instead of the usual one, it can be used without loss of precision in place-
The most difficult step in the technique of goniometry is localization of the axis about which the movement under study is occurring. The universal goniometer is in general a more dependable tool than devices designed to measure particular motions in specific joints.  

STUDIES RELATED TO PROPULSION IN SWIMMING

Karpovich presented a study to find the relative value of the arm and leg action in the crawl stroke and showed how this study could be utilized in practical coaching of swimming. He found the speed which swimmers were able to develop using arm alone, legs alone, and arms and legs together.

The subjects swam one length of the pool three times, using the arms alone, then the legs alone and finally the whole stroke. A rest of at least three minutes was given after each test. When the legs were used alone a water-polo ball was held in the hands, with the arms extended forward. A dead start was used to eliminate errors due to differences in the subjects' reaction time. The start was given in the following manner: "Get ready, one, two, go" with equal intervals of time between "one", "two", and "go".

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15 Ibid., pp. 256-257.
It was shown that the body length did not affect the test and that a sixty foot distance is better for this test than a seventy-five foot distance.

The contributory strength of the arms and legs to the power of the crawl stroke was found. Good swimmers derived seventy percent from their arms and thirty percent from their legs, while poor swimmers derived seventy-seven percent from the arms and only twenty-three percent from the legs.\textsuperscript{17}

In another study Karpovich evaluated resistance offered by the water in swimming. The method used in the procedure of this study was towing the swimmer through the water in a sixty foot pool by means of an electric motor. The tension on the towing rope and the speed of movement were recorded graphically by a resistograph. The swimmers were towed in the prone glide position and the back glide position. To maintain a uniform body position in the water, the feet of the subject were supported by means of a stick of balsa wood and the hands gripped a piece of balsa board attached to a towing cord.

The results of the study showed that by lifting the head so that the eyes were just above the water level no appreciable change in water resistance occurred. Every ordinary turning of the head for breathing increased the resistance. An

\addcontentsline{toc}{section}{Notes}

\textsuperscript{17} Peter V. Karpovich, "Analysis of the Propelling Force in the Crawl Stroke," \textit{The Research Quarterly}, May, 1935, pp. 49-57.
exaggerated lifting of head and body invariably increased the resistance. It was also found that the resistance was greater during an attempt to attain a greater speed than during the maintenance of that speed.  

An objective test for women measuring swimming power was developed for the side stroke and the front crawl by Fox. The swimmer being tested was allowed five strokes using the crawl stroke in one test and the side stroke in the other. The distance the swimmer covered in the five strokes was recorded to the nearest foot.

The value of a push-off from the side or bottom was eliminated by stretching a rope across the pool about one foot under the surface of the water. The swimmer would assume the proper starting position for either the crawl stroke or side stroke by resting her feet on the rope, which was fastened at one end and free at the other. An assistant pulled the free end of the rope taut while the swimmer held her starting position. The rope was weighted in the middle with a brick suspended from a chain which was tied to the rope so that when the free end was dropped the brick pulled the rope down. When the rope fell the swimmer lost her support and started from a dead start in the water.

To overcome the possible effect of height of the swimmer,

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the initial and final measurements were taken at the feet so that body length would not be an advantage.

**ANALYSIS OF THE FLUTTER KICK**

Summarization of the related literature presented discussions of the hip, knee, and ankle actions of the flutter kick. In the following discussion these actions will be considered in this same order.

**Hip action.** Armbruster, Allen and Harlan stated that the flutter kick leg action originates at the hip joint and is transmitted through the thigh to the knee joint. At the beginning of the upward leg movement the hip is flexed and is then extended to a slightly flexed position. The downward beat starts with the hip in this slightly flexed position. Wells stated that the lower extremity is completely extended at the beginning of the upstroke. The hip extends during the upstroke but stops before reaching a position of complete extension. She also stated that the hamstrings, adductor magnus and gluteus maximus contract strongly to perform the movement and that no rotation of the thigh occurs. The downstroke begins with the hip in a slightly flexed position

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and becomes moderately flexed. The muscles that perform the movement are the iliopsoas, tensor fasciae latae, pectineus, sartorius, and gracilis. Slight adduction may occur.

Brown\(^{22}\) stated that the upstroke begins from a flexed position and is then extended to a slightly flexed position. The downstroke begins with the hip joint in the slightly flexed position and is then flexed.

**Knee action.** In discussing the knee action of the flutter kick, Armbruster, Allen, and Harlan\(^{23}\) indicate that the knee is extended at the beginning of the upward leg movement and at the end of this movement the knee is slightly flexed. During the downstroke the knee moves from a slightly flexed to the extended position.

Wells\(^{24}\) stated that the leg flexes at the knee joint during the upstroke through an arc of about forty-five degrees. The hamstrings, satorius, gracilis, politeus, and gastrocnemius flex the knee. The action of the gastrocnemius is limited because the muscle is put on slack owing to the ankle extension. At the beginning of the downstroke the knee extends and remains extended until the stroke is completed. Knee extension is


\(^{23}\)Armbruster, Allen, Harlan, *loc. cit.*

\(^{24}\)Wells, *loc. cit.*
performed by the quadriceps femoris.

Scott\textsuperscript{25} indicated that the knee bends a little at the start of the downward leg action and is then extended quickly. The leg is then lifted forcibly with the knee straight.

Broer\textsuperscript{26} states that on the down beat of the crawl kick the knee bends slightly, putting the top of the foot into position to apply force more directly backward.

Bowen and Stone\textsuperscript{27} state that on the start of the downward movement the knee is bent about fifteen degrees. The bend in the knee allows the top surface of the foot to face the rear.

Brown\textsuperscript{28} stated that the knee was extended at the beginning of the upstroke and was slightly flexed at the end of the movement. On the downstroke the knee began from a slightly flexed position, was dropped, and then extended completely.

**Ankle action.** In the discussion of the ankle action of the flutter kick, Armbruster, Allen and Harlan\textsuperscript{29} state that at the beginning of the upward leg movement the ankle is extended and at the end of the upward beat the ankle is still


\textsuperscript{28}Brown, loc. cit.

\textsuperscript{29}Armbruster, Allen, Harlan, op. cit., pp. 84-85.
extended. They state that if the ankles are stiff, limiting the degree of movement of ankle extension, the effectiveness of the kick will be limited.

Wells\textsuperscript{30} states that the foot is in a position of plantar flexion during the upstroke but that it is not complete until the very end of the movement when the sole of the foot exerts maximum pressure against the water. On the downstroke the ankle and tarsal joints remain in a position of complete plantar flexion. The action of the plantar flexors is even stronger in the upstroke than in the downstroke because they are working directly against the pressure of the water. The muscles which contract are the gastrocnemius, soleus, peroneus longus, peroneus brevis, tibialis posterior, flexor digitorum longus, and flexor hallucis longus.

Broer\textsuperscript{31} states that on the downbeat of the crawl kick, backward force can be produced by the top of the hyperextended foot as the leg moves down. During the upbeat the sole of the foot applies backward force as it moves from a flexed to an extended position.

Scott\textsuperscript{32} indicates that at the start of the downstroke the ankles are hyperextended and then flex when the knee is extended. On the upstroke the ankle is extended quickly.

\textsuperscript{30}Wells, loc. cit.
\textsuperscript{31}Broer, loc. cit.
\textsuperscript{32}Scott, loc. cit.
Bowen and Stone\textsuperscript{33} stated that the ankle is extended as much as the structure of the joint permits at the start of the downward movement of the leg and when the bottom of the stroke is reached the ankle is dorsiflexed. On the upward stroke the ankle is extended with all the snap or power at the swimmer's disposal.

According to Armbruster, Allen and Harlan\textsuperscript{34} the upward leg action of the crawl stroke is as effective in propelling the swimmer forward as the downward action. The slight knee flexion and powerful ankle extension as the leg completes its upward sweep contribute to the fishtail action which sends large amounts of water backward from the sole of the foot. This fishtail action is inhibited on the downward kick by the inability of the knee to bend forward. The small amount of propelling surface presented by the instep as compared with that of the sole of the foot is also a restricting factor in the downward beat.

Bowen and Stone\textsuperscript{35} indicate there is power developed in both directions of the flutter kick, not equal as in the back and forth motion of the fish's tail, but a little more on the upward kick than on the downward kick.

\textsuperscript{33}Bowen, Stone, \textit{loc. cit.}
\textsuperscript{34}Armbruster, Allen, Harlan, \textit{op. cit.}, pp. 86.
\textsuperscript{35}Bowen, Stone, \textit{op. cit.}, p. 362.
INSTRUMENTS USED TO MEASURE MUSCULAR STRENGTH

A comparison of instruments used in measuring muscle strength was made by Clarke. The cable tensiometer, Wakin-Porter gauge, spring scale, and Newman myometer were the four instruments compared in his study. The evaluation of the instruments was based upon the degree of agreement of the results obtained by different testers, as indicated by objectivity correlations, by the comparison of the mean pounds recorded by the instruments for the same strength tests, and by the amount of correlation between the results recorded by the instruments on the same test.

The results of the experiments showed that the tensiometer was more consistent as its precision was consistently higher than the other instruments and was also found to have a definite advantage in strong pulls. The objectivity coefficients for the tests obtained with the tensiometer varied between .90 and .95.

The Wakin-Porter strain gauge obtained satisfactory objectivity, but the results were inconsistent.

The spring scale was inferior to both the tensiometer and strain gauge because the amount of movement of the testing unit when tension was applied allowed the specified joint angle

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and the angle of pull to change. When applying tension to the spring scale with a calibrator, a large amount of movement of the spring scale's testing unit permitted motion beyond the limit of the calibrator so the scale could only be calibrated to sixty pounds.

The Newman myometer was limited to strength efforts not exceeding sixty pounds and had an extremely low objectivity coefficient. It was not possible to calibrate the myometer with the calibrator used for the other recording instruments as the calibrator was designed for a pull rather than the push technique of the myometer.

Hunsicker and Donnelly\(^\text{37}\) described and illustrated devices which have been used to measure human strength during the past two hundred and fifty years. The dynamometer, especially the spring steel type, has been the major instrument utilized for strength testing. The spring steel, mercurial, and pneumatic dynamometers and the cable tensiometer are designed to measure single maximum effort. The ergograph and the electrical strain gauge dynamometers were developed with the idea of securing a series of muscular efforts or for making a total record of the force from the initial movement through the drop-off.

A study of recent advances in measurement and understanding

of volitional muscular strength, by Clark in 1956, indicates that the amount of strength which can be applied by the same muscles when the body parts are in different positions can fluctuate. A mean increase of twenty-four percent in knee extension strength was found when the subjects sat at the end of the table leaning backward and grasping the side of the table rather than assuming the same position but sitting upright with the arms folded. A one hundred and nine percent increase in the mean for ankle plantar flexion was obtained when the subject was in the supine position with the knee and hip of the leg being tested held straight and the ankle in ninety degrees dorsal flexion as contrasted to sitting at the end of the table with the legs hanging free.

CABLE TENSION STRENGTH TESTS

Descriptions of the proper bodily positions and methods of strength testing using the cable tensiometer were given by Clarke. Information concerning the starting position, attachments of the pulling assembly, precautions, and objectivity coefficients were given for each strength test. The illustrations and descriptions of strength tests involved movements of the finger, thumb, wrist, forearm, elbow, shoulder,

neck, trunk, hip, knee and ankle joints.

The test for hip flexion has an objectivity coefficient of 0.90; hip extension, 0.94; knee extension, 0.94; knee flexion, 0.97; and ankle plantar flexion, 0.93.\(^3^9\)

**SUMMARY**

Chapter II presented the literature related to this study. Information concerning the methods of measuring and testing range of motion, swimming, and strength as well as a thorough analysis of the flutter kick used in the crawl stroke was taken from the literature available.

Chapter III presents the procedures used in this study.

\(^3^9\)H. Harrison Clarke, *Cable-Tension Strength Tests* (Springfield: Stuart E. Murphy, 1953), pp. 11-31.
CHAPTER III

PROCEDURES OF THE STUDY

SELECTION OF THE SAMPLE

The subjects used for the study were freshmen and sophomore male students participating in intermediate, senior life saving, and water safety instructor's swimming courses for required physical education credit.

Because the forward progress of a swimmer using the flutter kick may be hindered by the "hooking" of his toes on the downstroke of the kick, the students who did not have forty-five degrees or more plantar flexion in the ankle joints were eliminated from the study. In chapter two, it was stated that forty-five degrees of movement from the anatomical position is the normal range for plantar flexion.

METHOD OF MEASUREMENT

For the purposes of this study the exact number of degrees of motion of plantar flexion was not required information. The author was concerned only with the student's ability to plantar flex the normal range of motion of forty-five degrees or more.

To measure the subject's range of motion of plantar flexion accurately and rapidly a block of wood cut to an angle of forty-five degrees was used. For this study a rectangular
piece of three quarter inch five ply board measuring one foot wide and two feet long was cut to a forty-five degree angle at one end.

To take the test the subject sat on a flat surface with his legs extended forward and the posterior aspect of the heel, calf and thigh resting on the supporting surface. The subject leaned back, supporting the weight of his trunk with his hands and kept his elbows extended. One foot was measured at a time. The subject held the foot that was to be measured at a right angle to the supporting surface until he was told to plantar flex the foot as hard as he could. When the subject moved his foot into plantar flexion, he was not permitted to bend the knee, lift the hip, turn the foot inward or outward or curl the toes of the extremity being tested.

To prevent the subject from bending the knee or lifting the hip an assistant tester placed his hands on the subject's leg above and below the knee and applied just enough pressure to prevent the knee from bending and the hip from lifting off the supporting surface. The assistant tester was cautioned against applying too much pressure against the subject's extremity as this would hinder the action of the gastrocnemius, and possibly prevent a few degrees of movement of the ankle joint needed to pass the test.

When the subject reached his maximum range of motion, the tester held the board with the lower edge on the supporting surface and the forty-five degree angle under the sole of the subject's foot. The board was in straight alignment with leg
cutting through the median plain of the extremity. If the subject's ankle was extended to an angle of exactly forty-five degrees, the edge of the board would simultaneously contact the heel and ball of the foot in line with the second toe. The subject did not curl his toes or he would prevent the edge of the board from making contact with the ball of the foot.

If the subject's ankle was extended to an angle greater than forty-five degrees the ball of the foot would contact the edge of the board before the heel. However, if the subject's ankle was extended to an angle of less than forty-five degrees the heel would contact the edge of the board but not the ball of the foot.

The results of the test were recorded on the subject's data card. If he passed the test for both ankles he received check marks in the squares beside "left ankle" and "right ankle". If he failed the test for one or both ankles he received an "X" in the squares provided, and the subject was then rejected from the study.

A list of test directions for the testees, assistant tester, and tester was inserted in Appendix A. An illustration of the data card was included in Appendix D.
THE KICKING TEST

The kicking test was given in a twenty yard swimming pool located in the Men's Gymnasium on the Montana State University campus. Each subject swam the distance of twenty yards using the flutter kick in the prone position while holding a plastic foam kick board in his hands.

To perform the test uniformly each subject was required to grip the kick board in the same manner. The kick boards measured twenty-two inches in length and were marked with two strips of tape eleven inches down the sides of the board. The subjects held the kick board with both hands and gripped the sides at the place where the tape was attached. The metacarpal-phalangeal joint of the second finger crossed over the edge of the kick board at the top of the tape. The tester explained to the subjects that they would obtain best results by holding the kick board flat on the surface or with a slight upward tilt of the front end of the board. If the forward end of the kick board was tilted up too high or down into the water it would hinder rather than help maintain the subject's prone position. The subjects held the kick board in front at arm's length with the elbows locked until the kick board made contact with the other end of the pool.

Each subject swam with his face in the water while exhaling and lifted his head out of the water facing straight ahead when inhaling.
The kicking test was given to one subject at a time and each subject was given three trials at the test. As there was not enough time for all the subjects to complete three trials in one class period, one trial was given on the first day and two trials the next day with a rest of ten to fifteen minutes between each trial on the second day.

To begin the test the subject entered the water at the shallow end of the pool, adjusted himself to the water, gripped the kick board properly and assumed the starting position which was prone lying on the surface of the water. The soles of the feet were held flat against the side of the pool, the knees and hips extended, the kick board extended forward with the elbows locked and the head up looking straight ahead waiting for the command to start.

An assistant supported the subject in the starting position. He gave the subject support at the knees so that the soles of the subject's feet were flat against the wall and his body lay in the prone position.

The commands given to start were as follows: "Swimmer up", at which time the subject assumed the starting position, "Get set", to alert the subject for the start, and finally the blast from the whistle which came after a pause of about one to two seconds following the command "Get set".

When the whistle blew the assistant quickly released his support and the subject pushed off the wall by using the thrust of the ankles and began kicking. The subject was not permitted to bend his knees or hips to get additional thrust.
off the wall.

The tester started the stop watch with the reaction of the subject after the whistle had been blown and not simultaneously with the whistle. This was done to eliminate the variance of reaction times of the different subjects. The subject was instructed to cover the twenty yard distance as quickly as possible and, when the kick board made contact with the opposite end of the pool, the watch was stopped and the subject's time was recorded on the data card.

A list of kicking test directions for the testees, assistant tester and tester was included in Appendix B.

EQUIPMENT USED FOR CABLE-TENSION STRENGTH TESTING

The equipment used for the cable tension strength tests was the same as that prescribed by Clarke.\textsuperscript{40}

The Testing table. The testing table used for this study was six and one half feet long, two feet nine inches wide and two feet six inches high. A slit twenty inches long and seven inches wide was cut lengthwise in the center of the table beginning ten inches from one end. This end of the table was called the lower end of the table and the opposite end, the upper end. This was done to simplify explanation of the subject's position while on the testing table.

\textsuperscript{40} H. Harrison Clarke, \textit{Cable-Tension Strength Tests} (Springfield: Stuart E. Murphy, 1953), p. 7.
Pulling assemblies. The pulling assembly used in cable-tension strength testing includes a strap, cable and chain. For strength measurements required in this study, it was found that the twelve inch length of one-sixteenth inch cable and the strap constructed of webb belting two feet six inches long and two inches wide prescribed by Clarke were too long.

During practice testing it was found that the cable and strap suggested by Clarke were so long that when the chain was attached to the proper hook for a test, the subject could not hold his extremity in the proper joint position for the test because he would have to take slack out of the cable and strap.

For the testee to maintain the proper position for the strength tests the length of the cable and strap had to be shortened. The cable was shortened to seven and one-quarter inches measured from the end of one loop in the cable to the end of the other loop. The length of the cable where the tensiometer was to be attached measured four and three-quarter inches. The strap was shortened to thirteen and one-half inches in length when measured on a flat surface from the end of the strap to the inner edge of the D-ring.

The seven and one-quarter inch cable was attached to the thirteen and one-half inch strap by a hook making a total length of twenty-two and one-half inches. A chain was attached to the cable through the loop in the cable opposite the end which was attached to the strap. The free end of the
chain was attached to the hooks on either the testing table or the wall, depending on the strength test being administered.

**Hooks.** Open-eye hooks, on the wall and testing table, were used to attach the pulling assembly to a firm base. They were large enough to withstand the pounds of tension applied by all of the subjects used in the study without bending or pulling free.

**Bracing equipment.** In the knee extension test Clarke states that the subject's starting position is sitting in the backward leaning position with the arms extended to the rear and the hands grasping the sides of the table.\(^4^1\)

When practicing the administration of this test, it was noted that a subject could exert a greater force if he leaned back rather than sit in an upright position. The farther he leaned back from the vertical, the greater the strength of the contraction.

To unify the backward leaning angle for all subjects an adjustable backrest ten inches high and twelve inches wide was set at a fifteen degree angle from the vertical. The backrest was clamped to the table to prevent it from sliding out of position. This blocking technique is similar

\(^{41}\)Clarke, *op. cit.*, p. 29.
to that used by Logan and Lockhart.\textsuperscript{42}

The blocking technique illustrated by Clarke\textsuperscript{43} for the ankle plantar test was done by an assistant tester who assumed a position at the head of the subject between the end of the testing table and the wall. The assistant tester placed his forearms on the testing table and his hands on the subject's shoulders to prevent the subject from sliding out of position. To brace himself, the assistant leaned back against the wall.

It was found to be a difficult task in Clarke's technique for the assistant tester to prevent the table from moving and, at the same time, prevent the subject from sliding down the table. There was always the possibility that the assistant tester, by applying some pressure to the subject's shoulders, helped to increase the tension on the cable. To alleviate this problem the end of the table was placed in contact with the wall and a mechanical blocking method devised.

Two pieces of two-by-four lumber were cut to a length of twenty inches and one of the ends was covered with padding. The two pieces of two-by-four were placed in contact with the wall in line with the shoulders of the subject. The subject's head lay between the two blocks of wood and the padded ends


\textsuperscript{43}Clarke, \textit{op. cit.}, p. 31.
of the blocks were in contact with his shoulders. The assistant held the blocks in place to prevent them from slipping out of position.

The table could not move because it was pressed against the wall, and by using the blocking method the testee could not slide on the table top because of the two pieces of two-by-four.

**Angle measurements.** Angle measurements of the knee joints were required for the proper administration of the knee extension and knee flexion tests. For the knee extension test the starting angle between the posterior aspect of the thigh and the posterior aspect of the leg was one hundred and fifteen degrees. A piece of one-quarter inch ply-board cut to the one hundred and fifteen degree angle was used to ascertain the correct starting position. When testing knee flexion the same joint angle was increased to one hundred and sixty-five degrees. A second piece of one-quarter inch ply-board was cut to one hundred and sixty-five degrees to measure the starting angle for the knee flexion test.

**METHODS USED IN STRENGTH TESTING**

The muscle groups used in performing the flutter kick were divided into those involved in the downstroke, and those used in the upstroke. A complete analysis of the flutter kick was made in chapter two on pages fourteen to nineteen, and on the basis of this information the following muscle groups were
selected. The major muscle groups used in the upstroke of the flutter kick were the hip extensors, knee flexors and ankle plantar flexors. The major muscle groups used in the downstroke were the hip flexors and knee extensors.

Because bracing equipment was required to test ankle plantar flexor and knee extensor strength, these tests were given either first or last. If the first test given a subject was knee extension, the last test he took was ankle plantar flexion. If the first test was ankle plantar flexion, the last test for that subject was knee extension and the next subject began with knee extension. This procedure eliminated unnecessary removal of, or change of equipment.

Following the test of either knee extension or ankle plantar flexion of a subject, tests of knee flexion, hip extension and hip flexion were given. By taking the test items in this order the testing ran smoothly and rapidly.

It was emphasized to each subject that he put forth maximum effort on all tests or the results of the test would be unreliable. When the tester was sure the subject knew exactly what he was to do, the subject was given one attempt at the test to reach his maximum strength, and then proceeded with the next test. Each subject applied force gradually, working up to his maximum power slowly without jerking into the action.

Strengths related to the five major muscle groups were measured for each leg making a total of ten measurements for
each subject. The amount of time required to complete all of the test items for one subject was between twelve and fifteen minutes. A schedule of afternoon appointment hours was made up for five days, beginning Monday and ending Friday of the week following the administration of the kicking test.

Directions of the cable-tension strength tests for the testees, assistant tester and tester are given in Appendix C.

DESCRIPTION OF THE STRENGTH TESTS

Knee extension. The subject sat at the upper end of the table with the backs of the knees in contact with a sponge pad placed over the edge of the table. The back rest was altered to fit snugly against the posterior aspects of the sacrum and pelvis of the subject. The subject grasped the sides of the table by placing his hands in line with the back rest, keeping the elbows fully extended.

The strap was placed around the leg being tested midway between the lateral condyle of the femur and the lateral malleolus. The knee was flexed so that an angle of one hundred and fifteen degrees was measured, and the chain was attached to a hook located on a piece of vertical frame attached to the under part of the table.

The assistant tester placed his hands on the subject's shoulders applying a downward pressure to prevent the subject's buttocks from lifting off the table.
The tester attached the tensiometer to the cable and told the subject when to begin. The subject attempted to straighten his leg, applying as much force as possible without lifting the hips or gaining extra leverage by pressing against the backrest. After the subject had reached his maximum contraction his score was recorded from the tensiometer and the same test was then applied to the other leg.

**Knee flexion.** The subject was placed in the prone position at the lower end of the table with his head resting on folded arms. The knee of the leg being tested was flexed to the angle of one hundred and sixty-five degrees. The knees were placed on a sponge pad placed about four inches in from the end of the table. The leg being tested was placed a little to the side of the slit in the table top so that the thigh of that leg would not be placed over the slit in the table top.

A point halfway between the lateral aspect of the lateral condyle of the femur and the lateral malleolus was located and the strap was placed around the leg at this position. The chain was attached to the hook below the lower end of the table using the link that held the subject's knee at one hundred and sixty-five degrees flexion.

The assistant tester placed his hands on the subject's shoulders to apply a downward pressure to prevent the shoulders from lifting off the table.
When performing the test the subject strained against the pulling assembly without lifting the thigh off the table. When maximum effort had been reached the reading from the tensiometer was recorded and the same test was given to his other leg.

**Hip extension.** The subject was placed in the prone position with the thigh of the leg being tested over the slit in the table top. The hip was extended and adducted to one hundred and eighty degrees and the knee was fully extended. The subject lay with his arms and hands at his sides.

The center of the strap was placed around the thigh one-third of the distance above the knee between the knee and hip. The pulling assembly was then attached to the hook below the thigh through the slit in the table.

The assistant tester placed his hands on the subject's low back area and pressed downward to prevent the pelvis from lifting off the table. The subject lifted the extremity off the table by lifting from the hip. After the subject had reached his maximum power his score was recorded and the same test was administered to his other leg.

**Hip flexion.** The subject was placed in the supine position with the thigh of the leg which was to be tested over the slit in the table. The hip and knee of the leg being tested were fully extended and adducted to one hundred and eighty degrees. His free leg was flexed with the plantar
surface of the foot resting comfortably on the table and arms folded on his chest.

The center of the strap was placed around the thigh one-third of the distance above the knee between the knee and hip. The pulling assembly was placed through the slit in the table top and attached to a hook on the base of the table. The assistant tester placed his hands on the subject's shoulders and applied pressure to prevent them from lifting off the table. The subject lifted the entire leg off the table by lifting from the hip and could not gain extra force by pressing the heel of the leg being tested on the table top.

After the subject completed the test his maximum score was recorded and his other leg was given the same test.

Ankle plantar flexion. The subject was placed in the supine position with his head at the upper end of the table. The hips were extended and adducted to one hundred and eighty degrees and the knees were completely extended. The arms were folded on the chest, and the ankle of the leg being tested was held in the anatomical position, which was a ninety degree angle between the dorsum of the foot and the anterior aspect of the leg, midway between an inverted and everted position. The foot was to the side of the slit in the table top.

The end of the table was placed in contact with the wall and the strap was placed around the ball of the foot and adjusted to prevent the little toe from being pinched. The
pulling assembly was attached to a wall hook behind the subject's head so that the pulling assembly passed over the shoulder of the side being tested in line with the subject's foot. The blocking device described on page thirty-one was placed between the subject and the wall.

The assistant tester held the blocking device to prevent it from slipping or moving. When the subject plantar flexed the foot, he was not permitted to invert or evert, toe-in or toe-out the foot, raise the hips or lift the leg. While the subject performed the test, the tester held the tensiometer in one hand and placed the other hand on the subject's thigh just above the knee to prevent the leg from lifting off the table.

After the test was completed and the score had been recorded the same procedure was followed in testing the strength of his other foot.

**TABULATING THE DATA**

The data from the data cards, which are illustrated in Appendix D, were placed on a cumulative data sheet which contained the required data for every subject. The subjects were placed in rank order according to their best times achieved on the kicking test. From this rank order each subject was listed by a number rather than by name. The following data was then given for each subject:

1. Kicking test results.
   (a) Best time for the kicking test
(b) **Average** time for the kicking test

2. Leg strength test results (left leg and right leg)

   (a) **Downstroke**
   
   (1) Strength in pounds for hip flexors
   (2) Strength in pounds for knee extensors

   (b) **Upstroke**
   
   (1) Strength in pounds for hip extensors
   (2) Strength in pounds for knee flexors
   (3) Strength in pounds for ankle plantar flexors

From the results each subject achieved on the individual muscle group strength tests, the scores were combined to give strength totals for the following:

(1) Downstroke of the right leg
(2) Downstroke of the left leg
(3) Total downstroke
(4) Upstroke of the right leg
(5) Upstroke of the left leg
(6) Total upstroke
(7) Total strength of the right leg
(8) Total strength of the left leg
(9) Total strength of plantar flexion
(10) Total leg strength

The scores in pounds achieved by all the subjects for the individual muscle group strength tests, and each strength total listed above were totalled to give a composite strength
of the whole sample for each item.

An illustration of the cumulative data sheet is located in Appendix E.

TYPES OF ANALYSIS

Group means were found for the times of the kicking test, the muscle group strength tests, and for the seven items listed above.

Coefficients of correlation were found between the following: total leg strength composite score and kicking speed; composite strength of the upstroke for both legs and kicking speed; composite strength of the downstroke for both legs and kicking speed; and the scores for ankle plantar flexor strength and kicking speed.

By using the mean pounds of each strength total, comparisons were made between the total strength of the right leg and the total strength of the left leg, and the total strength of the plantar flexors of the right leg and the total strength of the plantar flexors of the left leg, by using the critical ratio technique to determine the level of significance. A comparison between the upbeat and downbeat of the flutter kick was made by comparing the means of the muscle strength of knee extensors and hip flexors on the downstroke of the flutter kick with the muscle strength of the knee flexors and hip extensors used in the upstroke.
Chapter III presented the procedure of the study. Discussion covered the methods of measuring and testing the subjects, recording, compiling and analyzing the data. Chapter IV will present the findings of the study.
CHAPTER IV

ANALYSIS OF THE DATA

INTRODUCTION

This chapter presents the findings of the study to determine the relationship between strength of selected muscle groups used in the flutter kick as measured by the cable tensiometer, and the time needed to swim a twenty yard distance using the flutter kick in the prone position while gripping a kick board in the hands. Forty male students participating in swimming classes for required physical education credit were used as subjects for the study. In the selection of the sample from the swimming classes the students were given a test to determine whether or not they had normal ankle plantar flexion range of motion. If both of the subjects ankles could perform adequate range of motion for ankle plantar flexion he was selected as a subject for the study otherwise he was rejected. The results of the tests administered in this study are presented in the order in which they were given.

SELECTING THE SAMPLE

A total of forty-three students were participating in the three swimming classes used for this study. Three of the students were rejected from the study because they failed
to pass the test measuring the normal range of motion of ankle plantar flexion. Two of the three rejected students failed the test of adequate flexion for both ankles and the other student failed to meet the standard for one of his ankles.

KICKING TEST RESULTS

Each subject was given three trials on the kicking test with at least a ten minute rest period between each trial and not more than two trials in one day. The best time and average time were recorded on the cumulative data sheet a copy of which is located in Appendix E.

The range and mean for the best time were 14.6 to 22.9 and 18.34 respectively. The range for the average time was 14.8 to 23.2 and the mean was 19.15.

LEG STRENGTH TEST RESULTS

The testing device used to measure leg strength was the cable tensiometer. The muscle groups tested were those which supply the power in performing the flutter kick. The test was composed of five items each for the left and right legs: hip flexion, hip extension, knee flexion, knee extension and ankle plantar flexion.
TABLE I

THE MEAN POUNDS AND RANGE OF POUNDS FOR ALL CABLE TENSION STRENGTH TESTS

<table>
<thead>
<tr>
<th>Muscle Group Tested</th>
<th>Mean Pounds</th>
<th>Range of Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip Flexion of the Right Leg</td>
<td>152.5</td>
<td>73 - 200</td>
</tr>
<tr>
<td>Hip Flexion of the Left Leg</td>
<td>151.2</td>
<td>73 - 205</td>
</tr>
<tr>
<td>Hip Extension of the Right Leg</td>
<td>126.6</td>
<td>60 - 205</td>
</tr>
<tr>
<td>Hip Extension of the Left Leg</td>
<td>122.4</td>
<td>46 - 180</td>
</tr>
<tr>
<td>Knee Flexion of the Right Leg</td>
<td>126.9</td>
<td>73 - 192</td>
</tr>
<tr>
<td>Knee Flexion of the Left Leg</td>
<td>128.6</td>
<td>73 - 196</td>
</tr>
<tr>
<td>Knee Extension of the Right Leg</td>
<td>257.5</td>
<td>105 - 280</td>
</tr>
<tr>
<td>Knee Extension of the Left Leg</td>
<td>239.2</td>
<td>160 - 334</td>
</tr>
<tr>
<td>Ankle Plantar Flexion, Right Leg</td>
<td>239.2</td>
<td>136 - 360</td>
</tr>
<tr>
<td>Ankle Plantar Flexion, Left Leg</td>
<td>254.1</td>
<td>140 - 374</td>
</tr>
</tbody>
</table>

CORRELATIONS BETWEEN SPEED AND STRENGTH

Coefficients of correlation were computed between the best time the subjects achieved on their kicking test and their totals of various leg strength combinations which include total leg strength, upstroke strength, downstroke strength and ankle plantar flexion strength.
The coefficient of correlation between the best time achieved on the kicking test and the total leg strength was .24. The coefficient of correlation between the best time achieved on the kicking test and upstroke strength was .24. A coefficient of correlation of .24 was also found between the best time achieved on the kicking test and downstroke strength. The final coefficient of correlation, between the best time achieved on the kicking test and total ankle plantar flexor strength, was .12.

COMPARISONS MADE IN THE STUDY

The first comparison was made between the mean pounds of the total left leg strength and the mean pounds of the total right leg strength by finding the critical ratio. The mean pounds of strength for the left leg was 909 pounds and the mean pounds of strength for the right leg was 902.6 pounds. The standard deviation of left leg strength was 147.05 and the standard deviation for right leg strength was 149. The standard error of the difference between the means was 33.03 and the critical ratio was .19, hence there was no significant difference in the total leg strength of the right and left legs.

A second comparison was made between the mean pounds of plantar flexor strength of the left ankle and the mean pounds of plantar flexor strength of the right leg by finding the critical ratio. The mean of the left ankle plantar flexors
was 254.1 pounds and the standard deviation was 62.86. The mean of the right ankle plantar flexors was 239.2 pounds and the standard deviation was 62.92. The standard error of the difference between the means was 14.06 and the critical ratio was found to be 1.06, also indicated no significant difference between the strength of the plantar flexors of the right and left legs.

The final comparison was made between the upstroke and downstroke of the flutter kick by comparing the means of the following group totals: hip flexors and knee extensors in the downstroke with hip extensors and knee flexors on the upstroke. The strength of the ankle plantar flexors was not considered in the comparison because the ankles remain in the plantar flexed position during the upstroke and downstroke of the flutter kick and also during the downstroke ankle plantar flexion is assisted by the resistance of the water whereas in the upstroke the ankles must plantar flex forcibly.

By comparing the mean pounds of the muscle groups it was found that the strength of the hip flexors of the right leg was 25.9 pounds greater than the hip extensors of the right leg. The hip flexors of the left leg produced 28.8 pounds more strength than the hip extensors of the left leg. The strength of the knee extensors of the right leg was 130.6 pounds greater than the knee flexors of the right leg, and the knee extensors of the left leg produced 124.4 more pounds of power than the knee flexors of the left leg.
By totalling the mean pounds of strength for the muscle groups performing the downstroke and totalling the mean pounds of strength for the muscle groups performing the upstroke, it was found that the downstroke had 814 pounds compared to 504.5 pounds for the upstroke for a difference of 309.5 pounds.

TABLE II

THE MEAN POUNDS OF STRENGTH FOR THE MUSCLE GROUPS PERFORMING THE HIP AND KNEE ACTIONS OF THE UPSTROKE OF THE FLUTTER KICK

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Mean Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip Extensors of the Left Leg</td>
<td>122.4</td>
</tr>
<tr>
<td>Hip Extensors of the Right Leg</td>
<td>126.6</td>
</tr>
<tr>
<td>Knee Flexors of the Left Leg</td>
<td>128.6</td>
</tr>
<tr>
<td>Knee Flexors of the Right Leg</td>
<td>126.9</td>
</tr>
<tr>
<td>Total Strength available for upstroke</td>
<td>504.5</td>
</tr>
</tbody>
</table>
TABLE III

THE MEAN POUNDS OF STRENGTH FOR THE MUSCLE GROUPS PERFORMING
THE HIP AND KNEE ACTIONS OF THE DOWNSTROKE OF THE
FLUTTER KICK

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Mean Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip Flexors of the Left Leg</td>
<td>151.2</td>
</tr>
<tr>
<td>Hip Flexors of the Right Leg</td>
<td>152.5</td>
</tr>
<tr>
<td>Knee Extensors of the Left Leg</td>
<td>252.8</td>
</tr>
<tr>
<td>Knee Extensors of the Right Leg</td>
<td>257.5</td>
</tr>
<tr>
<td>Total Strength available for Downstroke</td>
<td>814.0</td>
</tr>
</tbody>
</table>

SUMMARY

Chapter IV has presented a statistical analysis of the data gathered in this study.

Chapter V will include a summary of the study, and state conclusions and recommendations that can be made.
CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The purpose of this study was to determine the degree of relationship between the strength of selected lower extremity movements and the time needed to complete a twenty yard kicking test. The subjects used in the study were male freshmen and sophomore students participating in intermediate, senior life saving, and water safety instructor's swimming classes for required physical education credit during the winter quarter of 1962.

A semi-homogeneous sample was selected from the three swimming classes by requiring each student to take a test which measured his ability to plantar flex both of their ankles to what had been established as normal range of motion. To measure the propulsion speed in water, derived from the flutter kick, the subjects swam a twenty yard distance in the prone position while holding on to a kick board. This test was repeated three times, and the time for each trial was recorded.

A review of the literature indicated that the flutter kick is performed as an upstroke and downstroke of the legs. The downstroke begins as hip flexion, continues with knee extension and finishes with the drive of the hyperextended foot. The upstroke begins with hip extension and continues...
with the knee flexing slightly and the foot remaining in the hyperextended position. From this analysis tests to measure the strength of the muscle groups that perform the flutter kick were selected. The muscle groups selected were hip flexors, and knee extensors for the downstroke; and hip extensors, knee flexors and ankle plantar flexors for the upstroke of the flutter kick.

The techniques described by H. Harrison Clarke for the use of the cable-tension method of strength testing were used with the exceptions that a back rest was used in the knee extension test and a different blocking device for the ankle plantar flexion test was employed by the author. These adaptations were described in chapter three.

In analyzing the data, coefficients of correlation were found between the best times achieved on the kicking test and the various leg strength combinations, which included total leg strength, total upstroke strength, total downstroke strength and total ankle plantar flexor strength.

The coefficient of correlation between kicking speed and total leg strength was .24. The coefficients of correlation between kicking speed and total upstroke strength, and kicking speed and total downstroke strength were both .24. The coefficient of correlation between kicking speed and

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44H. Harrison Clarke, *Cable-tension Strength Tests* (Springfield: Stuart E. Murphy, 1953), pp. 11-37.
and strength of the ankle plantar flexors was .12.

In analyzing the data further, the critical ratio between the mean pounds of the total strength of the right leg, and the mean total strength of the left leg was found to be .19. A second comparison between the mean pounds of plantar flexor strength of the left ankle and the mean pounds of plantar flexor strength of the right leg revealed a critical ratio of 1.06.

The upstroke and downstroke of the flutter kick were compared by showing the relationship between the mean pounds of hip flexor and knee extensor strength on the downstroke with the mean pounds of hip extensor and knee flexor strength on the upstroke. The muscle groups that performed the downstroke for both legs had higher mean strengths than the muscle groups that performed the upstroke for both legs. The total downstroke strength in mean pounds was 814, compared to 504.5 for the upstroke, giving a difference of 309.5 pounds.

CONCLUSIONS

1. The coefficients of correlation made in this study reveal that there was negligible relationship between the best times achieved on the kicking test and total ankle plantar flexor strength. A low or slight relationship was found between the best times achieved on the kicking test when compared with total leg strength, total upstroke strength and total downstroke strength. A discussion
concerning the interpretations of the coefficients of correlation is located in chapter one under definitions.

2. The findings of the study also indicated that there was no significant difference between the total leg strength of the left leg and the right leg.

3. There was no significant difference between the mean pounds of the left ankle plantar flexors and the mean pounds of the right ankle plantar flexors. However, the critical ratio found for this comparison was much larger than the critical ratio found for the comparison made between the mean pounds of the total left strength and the mean pounds of the total right leg strength.

4. When comparing the total strength of the hip and knee actions of the upstroke of the flutter kick with the total strength of the hip and knee actions of the downstroke of the flutter kick, the downstroke muscle groups were found to be stronger.

RECOMMENDATIONS

1. It is recommended that this type of statistical study be carried out with a much larger sample than forty men.

2. Future study should include a classification of subjects as to body size. There is a possibility that body size may be related to buoyancy and could effect the speed of propulsion through the water. Likewise, speed of
movement in water could be materially affected by water resistance on a larger, heavier body.

3. It is recommended that a similar study should classify the subjects according to their swimming skill and experience. Some of the subjects used in this study had just completed a beginning swimmer's course and were continuing with intermediate swimming, while others had been qualified life guards with several years of swimming experience.
BIBLIOGRAPHY
BIBLIOGRAPHY

A. BOOKS


PERIODICALS


APPENDIX A

DIRECTIONS FOR ADMINISTERING THE ANKLE PLANTAR FLEXION RANGE OF MOTION TEST

Directions to the testee.

1. Place yourself in the sitting position with the knees straight, legs flat on the supporting surface, and resting on the hands with the elbows locked.

2. When performing the test do not attempt to lift the knees off the supporting surface.

3. To perform the movement properly, point the toes as far as you can, straight ahead. Do not curl the toes or let them turn in or turn out, and do not turn the sole of the foot in or out.

4. All of the movement must occur in the ankle joint.

5. While performing the test hold the foot in the extended position as forcibly as you can until the tester tells you to relax. If the extension of the foot is not held forcibly during the test an accurate measurement cannot be made.

Directions to the assistant tester.

1. If you are standing to the left side of the subject place your hands on the leg that is to be tested, by placing the left hand on the thigh just above the knee and place the right hand on the leg just...
below the knee.

2. If you are standing to the right side of the subject, reverse the placement of the hands as stated above.

3. When the subject begins to plantar flex the foot, apply a slow steady pressure on the hands with the elbows straight and the shoulders above the hands.

4. Apply only enough pressure to prevent the knee from bending.

5. Continue holding the knee down until the tester instructs the subject to relax.

Directions to the tester.

1. Be sure the subject and assistant tester are in proper position before you give the command to extend the foot.

2. When the command to extend is given to the subject watch for the following:
   (a) See that the foot is extended straight forward and correct any toeing in or toeing out, inversion or eversion.
   (b) Watch the knee to see that it does not lift off the supporting surface. If it does, tell your assistant to apply more pressure.
   (c) Do not allow the subject to curl his toes.
3. When the leg and foot are in the proper position slide the block of wood with the side cut at a forty-five degree angle under the sole of the foot.

4. The block should be in line with the second toe or median plane of the extremity.

5. As you slide the block forward and under the sole of the foot watch to see how the flat surface of the edge of the block contacts the sole of the foot.
   (a) If the edge of the board strikes the heel of the foot and the ball of the foot simultaneously the subject's foot is extended to exactly forty-five degrees.
   (b) If the edge of the board strikes the heel of the foot before it strikes the ball of the foot, the subject's foot is extended less than forty-five degrees.
   (c) If the edge of the board strikes the ball of the foot before it strikes the heel of the foot, the subject's foot is extended greater than forty-five degrees.

6. To record the data on the data card place a check mark in the square beside the ankle tested if the subject could extend his ankle forty-five degrees or more. Place an "X" in the square provided, if
the subject could not extend the ankle forty-five degrees.

7. Try to test each subject as rapidly and accurately as possible after he has extended the foot. If the subject has to forcibly extend the foot over a long period he may cramp or slightly relax the muscles performing the movement.
DIRECTIONS FOR THE FLUTTER KICK TEST

Directions for the testee.

1. Proper use of the kick board.
   (a) Grip the kick board by placing the hands on the spot marked by the adhesive tape. The joint at the knuckle of the second finger should cross over the edge of the kick board at the top of the tape. The position and method of this grip must not be changed by any subject during the entire test on any one of the three trials taken.
   (b) While kicking hold the kick board flat on the surface or with a slight upward tilt. If the nose of the kick board is tilted up out of the water or down into the water, the water resistance against the flat surface of the board will slow you down.

2. The starting position in the water.
   (a) Extend the arms out in front of you with the elbows locked and grip the kick board properly.
   (b) Level off on the surface of the water in the prone or face lying position with the feet flat against the wall of the pool, and the heels just at the surface of the water. The assistant
tester will help you into this position.

3. The start

(a) To start the swimmer the instructor shall say the following:

(1) "Swimmer up" - at which time the subject assumes the starting position.

(2) "Get set" - by this time the subject should be ready to go and waiting for the whistle.

(3) The blast from the whistle will come after a pause of about one to two seconds after the command "Get set". As soon as the whistle is blown, snap the ankles thrusting away from the wall and begin kicking. Take a breath and put the face in the water.

(4) Do not bend the knees and hips to spring from the wall just use the snap of the ankles.

4. Swimming the twenty yard distance.

(a) To breathe lift the head up out of the water, look straight ahead, inhale, and put the face back in the water. While the face is in the water blow out as you would while swimming the crawl stroke.

(b) Kick as hard and as fast as you can to get
to the other end of the pool.

(c) Keep kicking until the nose of the kick board makes contact with the other end of the pool, and keep the arms straight during the entire swim.

(d) Hold the proper grip on the kick board until after you have made contact with the other end of the pool.

5. You will be given three trials at this test, once the first day and twice the next time you come to class.

Directions for the assistant tester.

1. Supporting the subject.
   (a) Get in the water and stand to either side of the subject and help him maintain the proper prone position by giving him a support with both hands at the knees.
   (b) If the soles of the subject's feet are not in contact with the wall of the pool, pull him back until they do make contact.

2. Check the subject's position to see that he is completely extended into the prone position.

3. Check to see that the arms are straight and that the subject is holding the kick board with the proper grip.

4. Check to see that his heels are at the surface.
5. When gripping the legs don't squeeze, just give support. Apply just enough pressure to hold him in the prone position with the soles of the feet pressed against the wall.

6. When the whistle blows, immediately pull the hands away from the subject's knee so you will not obstruct his kick.

Directions for the tester:

1. Describe the proper use and grip of the kick board to the subjects and assistant tester.

2. Explain the proper starting position, commands given to start, how to breathe while swimming, position while swimming, and the finish to the subjects.

3. When the subject assumes the starting position, note the following:
   (a) Check the body position.
   (b) Check to see that the feet are flat against the wall.
   (c) Check the grip on the kick board.

4. Commands given to start the swimmer.
   (a) "Swimmer up". Give the subject time to get into position and the assistant time to apply the proper support.
   (b) "Get set". After the subject is in the proper position give this command to alert
him for the whistle.

(c) Blow the whistle. Following a one to two second hesitation after the command "get set", give a short, loud blast from the whistle.

5. Starting and stopping the stop watch.

(a) Don't start the watch until the subject makes his reaction, by starting his thrust from the wall.

(b) Stop the clock as soon as the end of the kick board makes contact with the edge of the pool at the deep end.

6. Record the times for each subject on their data card in the space provided.
APPENDIX C

DIRECTIONS FOR THE LEG STRENGTH TESTS

Hip flexion strength test.

1. Directions to the subject
   (a) Assume the supine position with your feet at the lower end of the table.
   (b) Flex the hip and knee of the free leg comfortably with the sole of the foot resting on the table.
   (c) Fold the arms on the chest.
   (d) Extend and adduct the hip and knee of the leg being tested to one hundred and eighty degrees.
   (e) While performing the test do not lift the shoulders off the table.

2. Directions to the tester.
   (a) Place the strap around the thigh one third of the distance above the knee between the knee and hip.
   (b) Attach the chain to the hook beneath the subject through the slit in the table top.

3. Directions to the assistant tester.
   (a) Place the hands on the subject's shoulders and press downward to prevent the shoulders and chest from lifting off the table.
Hip extension strength test.

1. Directions to the testee
   (a) Assume the prone position with the feet at the lower end of the table.
   (b) Extend and adduct the hips to one hundred and eighty degrees.
   (c) Fully extend the knees.
   (d) Extend the arms along the sides of the body.
   (e) While performing the test do not lift the hips off the table.

2. Directions for the tester.
   (a) Place the strap around the thigh, one third of the distance above the knee between the knee and hip joints.
   (b) Attach the chain of the pulling assembly to the hook beneath the subject through the slit in the table.

3. Directions to the assistant tester.
   (a) Place the hands on the hips of the subject just above the buttocks.
   (b) Apply a downward pressure to prevent the subject's hips from lifting off the table.

Knee flexion strength test.

1. Directions to the subject.
   (a) Assume the prone lying position with the feet at the lower end of the table.
(b) The knee caps should be about four inches in from the edge of the table.
(c) Rest your head on folded arms.
(d) The free leg should be extended and adducted to one hundred and eighty degrees.
(e) The knee of the leg being tested should be flexed to one hundred and sixty-five degrees.
(f) While performing the test do not arch the back to lift the chest off the table.

2. Directions to the tester.
   (a) Place the strap midway between the knee and ankle joints.
   (b) Attach the chain of the pulling assembly to the hook in the frame below the edge of the lower end of the table so that the knee joint will maintain an angle of one hundred and sixty-five degrees when the subject performs the test.

3. Directions for the assistant tester.
   (a) Place the hands over the shoulder blades.
   (b) Apply a downward pressure to prevent the chest from lifting off the table.

Knee extension strength test.

1. Directions to the testee.
   (a) Sit at the upper end of the table in the backward-leaning position with the arms extended
and hands grasping the sides of the table.

(b) Lean back until you come in contact with the back rest.

(c) The edge of the table top should fit behind the knee of the free leg as it hangs over the end of table in a relaxed position.

(d) The knee of the leg being tested should be flexed so that the angle between the back of the leg and the back of the thigh is one hundred and fifteen degrees.

(e) While performing the test do not lift the buttocks off the table and do not lean against the back rest to gain added leverage.

(f) Keep the elbows locked during the entire test.

2. Directions to the tester.

(a) Place the strap around the leg midway between the knee and ankle joints.

(b) Attach the chain of the pulling assembly to the hook on the vertical frame below the upper upper end of the table so that the knee joint will maintain an angle of one hundred and fifteen degrees when the subject performs the test.

3. Directions to the assistant tester.

(a) Place the hands on the top of the subject's shoulders.

(b) Apply a downward pressure to prevent the
subject from lifting the buttocks off the table.

(c) Watch the elbows and see that they remain in the extended position.

Ankle plantar flexion strength test.

1. Directions to the testee.
   (a) Assume the supine lying position with the head at the upper end of the table.
   (b) Extend and adduct the hips and knees to one hundred and eighty degrees.
   (c) Fold the arms on the chest.
   (d) While performing the test do not allow the foot to invert or evert, toe-in or toe-out, and do not allow the leg on the side being tested or the hips to raise off the table.

2. Directions to the tester.
   (a) Slide the table up against the wall so that the upper end of the table will be in contact with the wall.
   (b) Place the two pieces of two-by-four between the subjects shoulders and the wall, with the padded ends of the two-by-fours in contact with the shoulders and the opposite ends in contact with the wall.
   (c) Place the strap around the ball of the foot.
   (d) Attach the chain to the hook on the wall be-
hind the subject's head.

(e) The cable should run in a line from the dorsum of the foot up the middle of the leg, over the hip, directly over the shoulder on the same side as the leg being tested, to the hook on the wall.

(f) While the subject is performing the test apply pressure to the leg just above the knee with your free hand to prevent the leg from lifting off the table.

3. Directions to the assistant tester.

(a) Hold the two pieces of two-by-four in place to prevent them from slipping off the subject's shoulders.

General instructions to the tester.

1. Use a piece of wood cut to the proper angle to measure the number of degrees of knee bend for the knee flexion and knee extension strength tests.

2. Mounting the pulling assembly.

(a) Mount the pulling assembly by placing the strap around the subject's body part and attaching the chain to the proper hook.

(b) Adjust the chain to a link that will keep the cable taut and the subject's extremity at the proper joint angle.
3. Instruct the subjects to pull on the cable and make as strong an effort as they can by building up to their maximum contraction slowly and not jerking into the action.

4. Record each reading from the tensiometer on to the data card. There are two squares beside each muscle group that was tested. Record the reading from the tensiometer in the square to the left. Convert the readings from the tensiometer into pounds by using the calibration chart and record the number of pounds on the data card in the square to the right. When readings are between those shown on the chart you must interpolate to determine the pounds force.
APPENDIX D

THE DATA CARD

Name ____________________________

1. Range of Motion of Ankle Joints Using Plantar Flexion Only
   Right Ankle ____________________
   Left Ankle _____________________

2. Twenty Yard Swim - Legs Only
   a. _____ seconds
   b. _____ seconds
   c. _____ seconds

3. Strengths of Muscle Groups Used in Performing the Flutter Kick.
   a. Downstroke
   b. Upstroke

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