A COMPARATIVE STUDY OF A HORIZONTAL AND A VERTICAL BODY POSITION AS A METHOD OF TRAINING COLLEGE WOMEN COMPETITIVE SWIMMERS TO PERFORM THE FLUTTER KICK

A DISSERTATION

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We hereby recommend that the dissertation prepared under our supervision by Luella Jean Lilly entitled A Comparative Study of a Horizontal and a Vertical Body Position as a Method of Training College Women Competitive Swimmers to Perform the Flutter Kick.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

ORIENTATION TO THE STUDY

Introduction

Swimming is one of the oldest forms of physical activity known to man. Evidences of the art of swimming prior to the year 1500 are plentiful but fragmented. Art reliefs and classical literature are two bases for speculations about the styles of swimming practiced by the ancients. Authorities on such works of art do not agree, however, on the type of kick used. Dunlap[1] implies that the position of the feet on the swimmers in the reliefs of Egypt and Assyria indicate the legs are separated in a vertical direction and their toes are turned downward as in the flutter kick. McVicar,[2] discussing the same works of art, states that since the legs appear to drag and do not represent any definite stroke or action, it would be suppositional to infer that the stroke portrayed is the modern crawl. Sanders[3] remarks that swimming was highly developed by the Greeks and Romans, but

[1]James E. Dunlap, "The Swimming Stroke of the Ancients," Art and Archaeology, XXVI (July-August, 1929), 27.

[2]J. W. McVicar, "A Brief History of the Development of Swimming," Research Quarterly, VII (March, 1936), 56.

[3]H. A. Sanders, "Swimming Among the Greeks," The Classical Journal, XX (June, 1925), 567.

the type of strokes used can only be speculated. He makes reference to a Greek vase which shows a woman with her feet "in an appropriate position" to perform the flutter kick. He further states that while literary references in classical literature are numerous, little attention is given to the style of swimming executed by the heroes. The American Red Cross confirms that:

> The alternate up-and down vertical thrash of the legs as exemplified in the 'human stroke' has been known apparently for thousands of years. Some primitive peoples in various sections of the world have used it in combination with the hand-over-hand stroke of the arms for unnumbered generations.[1]

The magnitude of the role of swimming to the ancients is indicated by Plato's[2] description of a dunce as one who "knew neither how to read nor how to swim; . . ."

In 1940 Greenwood[3] compiled a bibliography of approximately 10,000 titles classified under 608 subject areas in swimming. Some of the works cited date as far back as the early 1800's. Numerous books are available on the history of swimming, however, two are cited repeatedly as comprehensive and authoritative. Swimming, written by Ralph Thomas[4] in 1868

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[1]American Red Cross, Swimming and Diving (Philadelphia: Blakiston Company, 1938), p. 79.

[2]Plato, The Dialogues of Plato, Vol. II, translated by B. Jowett (New York: Random House, 1892), p. 464.

[3]Frances A. Greenwood, Bibliography of Swimming (New York: H. W. Wilson Company, 1940).

[4]Ralph Thomas, Swimming (2nd ed.; London: Sampson Low, Marston & Company, 1904).

(first edition) and 1904 (second edition), is referred to by Counsilman[1] as the "classic of the history of swimming" and by Cureton[2] as "the pillar of research and devotion." The second book often used as a history reference is Sinclair and Henry's,[3] Swimming, first published in 1885 (second edition, 1894).

Evolution of the Flutter Kick

Armbruster and Morehouse,[4] Cureton,[5] Kiphuth,[6] and Torney[7] relate similar accounts of the development of the swimming styles. Excerpting and combining portions of their works that relate specifically to the front crawl stroke, the following account is constructed as the evolution of the

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[1]James E. Counsilman, The Science of Swimming (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968), p. 201.

[2]Thomas Kirk Cureton, Jr., How to Teach Swimming and Diving (New York: Association Press, 1934), p. 86.

[3]A. Sinclair and W. Henry, Swimming (2nd ed.; London: Longmans, Green & Company, 1894).

[4]David A. Armbruster and Lawrence E. Morehouse, Swimming and Diving (2nd ed.; St. Louis: C. V. Mosby Company, 1950), Chapter I, "Introduction," pp. 1-11.

[5]Cureton, How to Teach, Chapter IV, "Historical Development of the Swimming Strokes," pp. 85-107.

[6]Robert J. H. Kiphuth, Swimming (New York: A. S. Barnes & Company, 1942), Chapter I, "History," pp. 1-22.

[7]John A. Torney, Swimming (New York: McGraw-Hill Book Company, Inc., 1950), Chapter I, "Highlights of Swimming History," pp. 3-11.

flutter kick. Events are stated to indicate the influence of the kick rather than the arm stroke.

The breaststroke and sidestroke were the most popular strokes used until the mid-1800's. Thus, the most common kicks were the frog and scissors kick. Gradually these kicks were modified until the modern flutter kick evolved. In 1863 a fast narrow kick known as "flutter sculling" emerged, followed in 1869 by the "steamer," a flat, straight-leg flutter. A wide scissor kick with a series of small flutters was used in 1883, and in 1894 the trudgen was introduced.

As swimming skills improved and speed increased, competitive swimming became more popular. The first English championships in swimming were held in 1871. The 100-yard event was won with the time of 1:15. From 1871 to 1894 during the "English-over-arm" era, times for the 100 improved 12.5 seconds from 1:15 to 1:02.5. From 1894 to 1901 during the Trudgen era, times improved to one minute flat. About this time in history, Richard Cavill introduced the four-beat flutter kick he had seen used by Alex Wickham of Colombo, Ceylon. This "Australian Crawl" enabled Cavill to lower the world record to :58.4. It was at this time that the term "flutter" became common terminology in discussions about swimming. Armbruster and Morehouse state, "The introduction of the flutter kick in 1902 established a new era in speed swimming."[1]

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[1]Armbruster and Morehouse, p. 4.

In 1903 the Americans modified the Australian crawl by changing the four-beat flutter kick to a six- (or sometimes eight-) beat kick. The kick was further modified by emphasizing the position of the feet as "pigeon-toed." Thus, the emergence of the "American Crawl." The primary difference between the crawl strokes was, and still is, the kick. In 1908 H. J. Handy used a "legless" crawl which may be compared to the current "drag" kick.

In 1913 "Duke" Kahanamoku lowered the world record to :54.6 while employing a "fast, vigorous leg kick." Much of the Duke's success is attributed to his leg kick, as is Johnny Weissmuller's. Weissmuller's kicking style was much deeper in the water than was previously used, thus allowing for greater traction and hydroplaning of his body. In 1927 Weissmuller reduced the time on the 100 to :51.0.

In 1932 the Japanese gained dominance in the swimming world. Again, one of the main differences in the stroke used by the Japanese was that of the kick. In the Japanese kick the knees remain in a slightly flexed position, and the two major beats of the six-beat kick were shortened to reduce the "parasitic drag" of the legs.

Numerous kicks have been introduced since 1940. In addition to the standard four-beat, six-beat, and eight-beat kicks, terms such as drag,[1] feather,[2] two-beat straight,[3,4] two-beat crossover,[5] and the hip-knee-ankle[6] kick are found in current literature. The distinctions between some of these kicks are very slight and may express minor variations by a particular author. As Weissmuller so appropriately states,

> This [leg kick] is probably the most elusive subject connected with the crawl stroke, and it has given rise to endless arguments. . . .There are almost as many different styles of American-crawl leg beats as there are swimmers.[7]

Three nations, Australia, America and Japan, have contributed significantly to the evolution and standardization of the flutter kick. The Australian kick usually consists of two or four beats, while the American has six or eight beats. Collins explains the difference between the

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[1] David A. Armbruster, Robert H. Allen and Bruce Harlan, Swimming and Diving (3rd ed.; St. Louis: C. V. Mosby Company, 1950), p. 109.

[2] William Robinson Thrall, "A Performance Analysis of the Propulsive Force of the Flutter Kick" (unpublished Ph. D. dissertation, State University of Iowa, 1960), p. 21.

[3] Martin Cobbett and J. Racster, Swimming (London: George Bell & Sons, 1891), p. 37.

[4] John Tallman, "The Modern Two Beat Crawl," Swimming World, VII (May, 1966), 4, 47.

[5] James E. Counsilman, "The Crossover Kick in the Crawl," Junior Swimmer, I (November, 1960), 6-7.

[6] Alonzo Snyder, "Hip-Knee-Ankle Foot-Propelling Drive Kick," Beach and Pool, XI (August, 1937), 7-8, 25, 27.

[7] Johnny Weissmuller, Swimming the American Crawl, collab. with Clarence A. Bush (Boston: Houghton, Mifflin Company, 1930), pp. 39-40.

American and Japanese flutter kicks more graphically. In the American crawl,

> The thrash is so loose that the legs appear to be trailing rather than driving, working independently rather than maintaining rhythm with the arms, floating to the surface rather than being muscularly impelled thither. Actually, the rhythm aimed at is the ordinary 6-beat, though the extreme looseness of the movement removes all appearance of emphasis from it. Actually, again, of the upward and downward thrashes, the former receives more muscular effort than the latter, the whole leg being lifted on the hip-joint as a hinge.[1]

In the Japanese crawl,

> The leg is kept pliant throughout, and appears never to straighten completely even on the downward movement. On the upward movement there is less straightening still, and one of the most characteristic features of this drive is the permanently-bent appearance of the leg.[2]

Theories of Force

One of the major points of debate regarding the flutter kick is the application of force. Three theories, the upbeat, downbeat, and the squeeze, are presented as an explanation of the forward movement achieved by the leg drive. Collins[3] states that the "normal" or American flutter emphasizes the upbeat, while the Japanese kick concentrates

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[1]Gilbert Collins, The Newest Swimming (London: Windmill Press for William Heinemann, Ltd., 1937), p. 8.

[2]Ibid., p. 22.

[3]Ibid., p. 56.

on the downbeat. Barrows,[1] Daviess,[2] Harris,[3] and Robinson[4] advocate emphasizing the upbeat, while Armbruster and Morehouse,[5] Smith,[6] and Carlile[7] stress the downbeat. Smith elaborates on the downbeat:

> . . . swimmers must force their legs down through the water in order to achieve a full stroke upward. Also, the upstroke in the streamline is achieved with less conscious effort than the downward swing, which is made against water resistance. Hence, coaches find it necessary to stress the downward swing for efficient kicking.[8]

Carlile qualifies his statement about the downbeat by saying:

> Personally I think it is better to concentrate on the flick downwards of the feet, rather than the up-beat. . . .The best type of leg kick will vary with individuals. It may be that equal stress should be placed on both up and down beats.[9]

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[1]Duane Barrows, "Basic Components of the Freestyle," Scholastic Coach, XXXV (December, 1965), 37.

[2]Grace Bruner Daviess, Swimming. Its Teaching, Management, and Program Organization (Philadelphia: Lea & Febiger, 1932), p. 51.

[3]Marjorie M. Harris, Basic Swimming Analyzed (Boston: Allyn and Bacon, Inc., 1969), pp. 93, 99.

[4]Tom Robinson, "How Swimmers Use Their Legs," The Athletic Journal, XIII (January, 1933), 8-9.

[5]Armbruster and Morehouse, p. 4.

[6]Ann Avery Smith, Skillful Swimming (Ann Arbor, Michigan: J. W. Edwards, Publisher, Incorporated, 1954), p. 21.

[7]Forbes Carlile, Forbes Carlile on Swimming (London: Pelham Books, Ltd., 1963), p. 27.

[8]A. Smith, Ibid., p. 21.

[9]Carlile, p. 27.

Armbruster, Allen and Billingsley,[1] and Bartels[2] state that the upbeat and downbeat are equally important. Kiphuth[3] summarizes the differences of opinion about emphasizing the upbeat or downbeat by stating:

> Although the greatest part of the propulsion in the crawl comes from the arms, the most interesting development in the modern crawl has resulted from advances in the efficiency of the leg drive. It is difficult to say which part of the legs' action contributes most to the propulsion, the down-beat or the up-beat, and until this is determined scientifically it will remain a moot question.

Armbruster and Morehouse,[4] Sheffield and Sheffield,[5] and Ulen and Larcom[6] make reference to the third theory of propulsion which indicates that the forward movement of the body is the result of water being squeezed from between the legs. Since the forward propulsion is obtained when the legs come together, there is an equal emphasis on the first half of the downstroke and upstroke when the legs are coming

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[1]David A. Armbruster, Robert H. Allen, and Hobert Sherwood Billingsley," Swimming and Diving (5th ed.; St. Louis: C. V. Mosby Company, 1950), p. 71.

[2]Robert Bartels, Swimming Fundamentals (Columbus, Ohio: Charles E. Merrill Publishing Company, 1969), p. 20.

[3]Kiphuth, pp. 73, 75.

[4]Armbruster and Morehouse, p. 4.

[5]Lyba Sheffield and Nita Sheffield, Swimming Simplified (Rev. & Enlarged ed.; New York: A. S. Barnes & Company, 1927), p. 98.

[6]Harold S. Ulen and Guy Larcom, Jr., The Complete Swimmer (New York: Macmillan Company, 1949), p. 63.

towards each other. The recovery phase of the kick occurs during the second half of the downstroke and upstroke after the legs have passed each other.

Analogous Forms of the Flutter Kick

Walking, bicycling and the tail action of a fish are three analogous forms of the action of the legs while performing the flutter kick which are found frequently in swimming literature. Handley[1] and Harris[2] make reference to the action of the legs in the flutter kick as being similar to that of walking. The American Red Cross[3] and Armbruster and Morehouse[4] compare the flutter kick to the action of riding a bicycle. By far the oldest and most common analogy of the flutter kick is to that of the action of a fish's tail. Classic studies, cited by Cureton,[5] which analyze the movements of the fish are those of Borelli, Pettigrew and Wallace-Dunlop. Borelli represents force in terms of a rectangle; Pettigrew describes force in terms of a double or figure-eight curve; and Wallace-Dunlop depicts forward propulsion in relationship to crossing an axis.

[1]L. de B. Handley, Swimming for Women (New York: American Sports Publishing Company, 1931), p. 33.

[2]Harris, pp. 96-99.

[3]American Red Cross, p. 84.

[4]Armbruster and Morehouse, p. 69.

[5]Thomas Kirk Cureton, Jr., "Mechanics and Kinesiology of Swimming--The Crawl Flutter Kick," Research Quarterly, I (December, 1930), p. 91, citing Borelli, De Motu Animalium, Rome, 1680; p. 91, citing J. B. Pettigrew, Animal Locomotion (New York: Appleton, 1891); and p. 93, citing R. H. Wallace-Dunlop, Plate Swimming (London: Routledge and Sons, 1876).

Definitions and Descriptions of the Flutter Kick

Most swimming texts give a definition and/or description of the flutter kick. The following are selected references. Thrall states:

> The normal kick is defined as a flutter kick of approximately twelve inches in width as measured from the top of the instep of one foot to the back of the heel of the other at the instant of maximum spread. It is a kick of six beats for each armstroke cycle. This is the kick normally used by the subjects when they are competing in swimming events.[1]
>
> The action of the lower extremity should originate at the hip joint and be transmitted through the thigh to the knee joint and in a whiplike motion the leg should press backward and with specific emphasis upon the backward and downward lash of the instep. The ankle joint should be flexible to permit a large range of extension. In both the upward and the downward beat the initial movement is at the hip joint. The width of the flutter-kick stride should not be more than twelve inches. The kick should be close to the surface so that the legs may be raised in the water to reduce the resistance that must be overcome with the arm stroke.[2]

Kiphuth and Burke define the flutter kick precisely as:

> The leg drive of the swimmer combines all the essentials of propulsion. The leg action has a whiplash and yet a smooth, undulating motion which is vital to the flow of power. The whip comes from the powerful extensors and flexors of the hip joint, with a following deep knee action ending with a lash at the ankle and foot joints.[3]

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[1]Thrall, p. 21.

[2]Ibid., p. 58.

[3]Robert J. H. Kiphuth and Harry M. Burke, Basic Swimming (New Haven: Yale University Press, 1950), p. 85.

Cureton outlines the action of the legs as:

> The legs move up and down in a rapid oscillating movement with the ankles separating about twelve to fourteen inches. The legs alternately kick the water upward and downward. The water forced downward by the down-kick of the legs reacts to support them. The up-kick acts to sink them. The ideal kick is well balanced, with the legs not coming too far out of the water. The legs usually remain at the surface because, as a rule, the force on the down-kick is directed more nearly vertically downward and acts more to support the legs than the up-kick action tends to sink them. The up-kick swirls are very important for propulsion. The regulation of this balance is largely a matter of ankle action. For best results with beginners, the ankles should be loose and the action a fairly straight leg-action from the hip. The knees bend somewhat but this action should be minimized.[1]

One of the major problems in comparing the various definitions and descriptions is to find a common base of measurement. An example of this problem is illustrated by measurements listed to describe the width of the kick. Harris[2] states that the downswing should be fifteen to twenty inches "below the surface of the water." Bush[3] reports the feet "separate" fifteen inches. Carlile[4] relates that the width of the kick should be eighteen inches "from the heel of one foot to the toes of the other."

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[1]Cureton, How To Teach, pp. 213-14.

[2]Harris, p. 93.

[3]Clarence A. Bush, "An Analysis of the Swimming of Borg and Weissmuller," The Athletic Journal, VI (March, 1926), 20.

[4]Carlile, p. 151.

Rajki[1] declares that the feet are sixteen to twenty-four inches "from each other at maximum separation." Comparison of the different statements is difficult when a common point of reference is not used. "Width" and "depth" of kick are stated as specific criteria by some authors and used interchangeably by others. Basically, "width of kick" refers to the distance between the feet at the point of maximum separation, while "depth of kick" refers to the feet in relationship to the surface of the water.

Common Kicking Faults

The majority of books on swimming instruction make reference to common faults that may occur while performing various swimming skills. Common faults are of interest because they point to essential aspects for the execution of the skill. Armbruster, Allen and Billingsley report:

> Common faults in the sprint crawl leg action are as follows: (a) kicking with the legs too near the surface, (b) spreading the legs laterally so that the heels are beyond hip width, (c) kicking away from the vertical plane, especially during inhalation, (d) holding the ankles in a rigid extended position, (e) holding the feet inward during the upward stroke, and (f) holding the knees in a rigidly extended position.[2]

Rather than listing common errors, Harris[3] gives a detailed analysis of the consequences of the error. Fixed

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[1]Bela Rajki, The Technique of Competitive Swimming, trans. by Lasglo Gondor (Budapest, Hungary: University Printing House, 1956), p. 42.

[2]Armbruster, Allen and Billingsley, p. 71.

[3]Harris, pp. 99-101.

or extended knees and ankles result in a laborious effort to keep the legs in motion. Continuous flexion of the knees produces ineffective movement and unnecessary fatigue because of the loss of the summation of forces. Kicking too shallowly reduces the resistive surface to such a nominal size that the legs simply "shake" and do not push against the water. Kicking too deeply is tiring and disrupts rhythm, thus reducing the kinesthetic awareness for the skill. Inconsistency of rhythm and range of movement of the legs contributes to an irregular and unpredictable stroke which in turn makes breathing and coordination of the arm stroke with the leg movement more difficult.

Ankle Flexibility and Toe-in

Ankle flexibility is directly related to flutter kicking efficiency and is generally attributed a major role for the success or failure of a flutter kick. The concept generally held is that the ankle should be as relaxed as possible to allow the foot to toe-in and thus create a larger surface area of resistance to the water.

Bartels,[1] Counsilman,[2] and Daviess[3] agree that if the ankle is relaxed, the desired amount of toe-in will occur automatically and, therefore, a conscious effort should not

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[1]Bartels, p. 20.

[2]Counsilman, Science of Swimming, p. 36.

[3]Daviess, p. 51.

be made to assume a "pigeon-toed" position of the feet. Armbruster, Allen and Billingsley[1] point out that if the ankle is too fully extended or too fully pigeon-toed throughout the kick, the gastrocnemius and the muscles of the plantar regions of the feet will soon fatigue.

Reichart and Brauns[2] describe the movement of the flutter kick as weaving or undulating. The ankles are so relaxed they are "floppy." Colwin[3] indicates that the feet are pigeon-toed because of a slight inward rotation of the legs from the hips, not the knees or ankles.

Energy Output; Arms-Legs Relationship

There is some question as to the amount of energy used while kicking as compared to either the amount used while pulling or while executing the whole stroke. The ratio of propulsion gained from the legs as compared to the arms is also a point of debate, although several authors make statements in this regard. Bush[4] and Weissmuller[5] remark that energy used while kicking creates a greater strain on the

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[1]Armbruster, Allen and Billingsley, p. 109.

[2]Natalie Reichart and Jeanette Brauns, The Swimming Workbook. A Manual for Students (New York: A. S. Barnes & Company, 1937), p. 36.

[3]Cecil M. Colwin, "Crawl Leg Action," in Teaching Beginners to Swim, Beach and Pool (New York: Hoffman-Harris, Inc., 1949), p. 24.

[4]Bush, p. 22.

[5]Weissmuller, p. 49.

heart than that used by the arms. Also, if too much energy is used by the legs, there is not a sufficient amount remaining for the arms. Counsilman[1] expresses a similar opinion when he states that the heart can only supply a certain amount of blood to the muscles during a long race and if the legs are kicked <u>too hard</u> the muscles in the arms are deprived of the blood that is needed for them to perform proficiently over an extended period of time. Faulkner[2] reports that the energy cost of "legs only" is two to four times greater than the energy cost of "arms only" or of the whole stroke when propulsive force is kept constant.

After studying five styles of front crawl swimming, Sanders[3] concluded that the American crawl requires more energy than the other four styles because of the continuous movement of the legs. Ulen and Larcom[4] contend that the legs provide twenty-five per cent of the propulsive force for the front crawl. The majority of authors mentioning the relationship of the legs to the total stroke make generalized

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[1]Counsilman, <u>Science of Swimming</u>, p. 28.

[2]John A. Faulkner, ed., <u>What Research Tells The Coach About Swimming</u> (Washington, D. C.: American Association for Health, Physical Education and Recreation, 1967), p. 23.

[3]Charles L. Sanders, "A Photographic Analysis of Five Methods of Freestyle Swimming" (unpublished Master's thesis, North Carolina College at Durham, 1968), p. 45.

[4]Ulen and Larcom, p. 68.

statements. For example, Carlile[1] remarks that many coaches declare the leg kick plays a relatively minor part in the crawl stroke. He further exclaims ". . ., it has been wrongly stated that 'Carlile does not believe in kicking the legs.' Actually I am certain that an efficient leg action can help a swimmer greatly. . ."[2] Weissmuller[3] comments that the arms provide from seventy-five to ninety per cent of the propulsion in the crawl stroke. Other research related to the determination of the proportion of force obtained from the arm stroke in relationship to the leg kick is presented in Chapter II.

The importance of the cadence and type of kick used may vary with the length of the race or with the individual. Carlile[4] comments that the irregularity of the leg kick is characteristic of champions--each develops his own style. Collins[5] contends that the type of kick used should depend upon the shape of the swimmer's legs. Short, stocky legs demand a different type kick from that which is effective with long, thin legs. Handley[6] agrees and implies that the speed

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[1]Carlile, p. 125.

[2]*Ibid*., p. 181.

[3]Weissmuller, p. 23.

[4]Carlile, p. 27.

[5]G. Collins, p. 56.

[6]L. deB. Handley, *Swimming and Watermanship* (New York: Macmillan Company, 1925), p. 29.

of the kick depends upon the build of the swimmer. Counsilman[1] makes the generalization that the swimmer should experiment with different kicks and adopt the method that allows him to swim the fastest. Ulen and Larcom[2] acknowledge that, "Most swimmers sooner or later fall into a kick which is best suited to their size, weight, and strength." Mackenzie and Spears[3] urge that the legs be allowed to work in natural rhythm with the arms to promote total body balance and to avoid power loss.

Daviess' work summarizes many of the points mentioned previously.

> The motion is a thrashing one, up and down, with the <u>up</u> rather than <u>down</u>, or more exactly, the force applied bringing the legs together, which forces water from between them, and so pushes the body ahead. The motion starts in the <u>hip-joints</u>, the <u>knees</u> being only slightly bent, not enough for motion in themselves but sufficiently for relaxation. The <u>ankles</u> must always be relaxed, allowing the water to move the foot. Thus on the down motion the toes will be pointed, and as the leg pushes up, the water will flex the foot. This foot motion, especially if the toes are turned in, gives an extra propelling power. The legs should not be separated farther than from 8 to 12 inches, the <u>width</u> being determined by the build of the person and the speed desired. The wider the separation, the slower is the stroke. A slight swimmer can afford to take a wider separation than a heavier swimmer, because of cutting through the water with less resistance. The drive of each leg is called a "<u>beat</u>," and the number of beats

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[1] Counsilman, <u>Science of Swimming</u>, p. 29.

[2] Ulen and Larcom, p. 67.

[3] M. M. Mackenzie and Betty Spears, <u>Beginning Swimming</u> (Belmont, California: Wadsworth Publishing Company, Inc., 1963), p. 46.

> to a complete arm cycle determines the type of crawl one is swimming, as '6-beat,' '8-beat,' '12-beat,' . . . .The number of 'beats' is largely determined by the desire and capability of the swimmer, along with the speed she wishes to obtain. The short fast thrash, '8- and 12-beats,' give greater speed for short distances, while the wider slower thrash is used for longer dashes and distance swimming. The feet should be just below the surface in the flutter kick, but in greater speed, they may cut the surface slightly.[1]

Functions of the Flutter Kick

In the early history of the flutter kick, its primary function was thought to be that of propulsion. The aforementioned statements seem to indicate that forward propulsion produced by the kick may be nominal. However, the flutter kick serves other functions in addition to propulsion in the execution of the front crawl. It helps to reduce racing times when efficiently applied, although, Counsilman[2] states that if the swimmer moves faster than five feet per second, the kick is useless as a propelling force. Scharf and King,[3] Juba,[4] and Rajki[5] mention that the value of the kick lies in the force it produces to assist the swimmer into and out of turns. A common expression in swimming is "Drive in and out of the

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[1]Daviess, pp. 51-52.

[2]Counsilman, Science of Swimming, p. 27.

[3]Raphael J. Scharf and William H. King, "Time and Motion Analysis of Competitive Freestyle Swimming Turns," Research Quarterly, XXV (March, 1964), 37-44.

[4]Bill (W. J.) Juba, Instructions to Young Swimmers (London: Museum Press Limited, 1956), p. 39.

[5]Rajki, p. 47.

turn." The drive is partially supplied by the legs. The same type of assistance is offered by the kick when surfacing from the racing dive. Tallman[1] declares the value of the continuous flutter action for a strong finish. Karpovich[2] states that the kick helps maintain momentum if there is a weak phase of the arm pull recovery.

Counsilman reports the value of the kick as:

> The kick raises the legs, fixes the body, and acts a great deal as a gyroscope might in that it stabilizes the swimmer's body and gives him a firmer base from which to work. He actually creates less resistance because he has less lateral movement and is in a more streamlined position. The propulsive phase of the kick may altogether counteract its own resistive phase; so that a swimmer, although not receiving any additional propulsion from his legs, has less to pull with his arms.[3]

Weissmuller[4] states that the chief value of the flutter kick is to maintain body position--"shoulders high and back arched--hydroplaning." In addition to the hydroplaning effect, the legs also provide stability and balance to help eliminate the side to side roll that is often produced by the armstroke. Batterman[5] declares that in addition to

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[1]Tallman, p. 47.

[2]Peter V. Karpovich, "Swimming Speed Analyzed," Scientific American, CXLII (March, 1930), 225.

[3]James E. Counsilman, "Theory of the Flutter Kick," Beach and Pool, XXIV (June, 1949), 124.

[4]Weissmuller, p. 20.

[5]Charles Batterman, "Mechanics of the Crawl Arm Stroke," Scholastic Coach, XXXIII (October, 1963), 46.

supplying some propulsive power, the flutter kick counterbalances the arm-stroke and, in the longer races, prevents the legs from sinking. Juba agrees that,

> Once again it is essential that you first concentrate on working up a strong flexible leg drive. Besides gaining more propulsion, constant leg work is a vital factor in governing the balance in this stroke, disturbing the body position in the water as little as possible. In other words, this means maintaining a streamlined attitude for speed, grace and ease of movement through the water.[1]

If the legs are allowed to drop below a horizontal plane, resistance to forward progress is increased.

The functions of the kick may be summarized as follows: 1) to assist the swimmer in turning, starting and finishing; 2) to increase stability and eliminate side to side roll about the longitudinal axis, and lateral sway or thrust about the anterior-posterior transverse axis; 3) to elevate the feet so that the body assumes a streamlined or hydroplaned position in the water; and 4) to serve as a gyroscope to provide balance and stability.

Additional statements have been offered which stress the importance of the flutter kick. Armbruster and Morehouse[2] state that the flutter kick was responsible for a new era in speed swimming, while Kiphuth[3] declares the flutter kick was

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[1]Juba, Young Swimmers, p. 30.

[2]Armbruster and Morehouse, p. 4.

[3]Kiphuth, p. 73.

the key to the development of the crawl. Cureton[1] relates that the flutter kick, in the form of "steamboating," is one of the first skills taught to beginning swimmers and may be used as a method to eliminate the fear of putting the face in the water. He also confirms that in 1922 at least ten different front crawl strokes existed and that they were distinguished mainly by the kick.[2] Counsilman[3] implies that the lack of ability to kick efficiently serves as a motivator to improve the mechanics of a stroke. Corsan[4] and Juba[5] express the aesthetic value of the kick as it adds speed, grace, beauty and ease of movement to the crawl stroke. Aesthetic values are judged in form swimming.

Leg Conditioning--"Legs Only" Practice

Research indicates that the kick tends to provide very little propulsive force. Yet in spite of this fact coaches continue to emphasize the conditioning of the legs and ankles in land and water drills. Counsilman[6] justified this fact as follows:

> From the fact that the kick is used as a stabilizer and neutralizer, and does not act as a

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[1] Cureton, How to Teach, p. 212.

[2] Cureton, "Mechanics and Kinesiology," p. 89.

[3] Counsilman, Science of Swimming, p. 341.

[4] George H. Corsan, Sr., The Diving and Swimming Book (New York: A. S. Barnes & Company, 1929), p. 35.

[5] Juba, Young Swimmers, p. 30.

[6] Counsilman, Science of Swimming, p. 30.

> propulsive force in the crawl stroke, it does not follow that less emphasis should be placed on conditioning the legs in workout. The movements of the legs are very important and, at times, quite vigorous. If they are not conditioned properly, they will fatigue and become less effective in their stabilizing role, thereby allowing hips and legs to drop too low and to move about laterally, creating unwanted resistance. . . .
> I believe that a person should have an efficient kick and that the legs should be conditioned. I also recommend that the swimmer kick while swimming; however, I do not believe that the primary function of the kick is propulsive.

The authors of an English coaching handbook[1] indicate that even the finest crawl swimmers in the world cannot do too much leg practice. Harris[2] concurs in the belief that a larger portion of the training period than is currently practiced should be devoted to the legs. Juba and Madders agree that it is essential to practice kicking ". . . until they [the legs] drive continuously without any apparent effort. It is an absolute waste of time considering anything else until this is accomplished."[3]

Numerous coaches agree that the "legs only" method is the most effective way to practice the flutter kick. "Legs only" implies that the arms are not used in any manner, and that the legs are used as the sole means of propulsion. It is interesting to note that even with the relatively small

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[1]English Schools' Swimming Association, Swimming and Diving (Great Britain: William Heinemann, Ltd., 1963), p. 25.

[2]Harris, p. 150.

[3]Bill (W. J.) Juba and Max Madders, "The Front Crawl," in Swimming and Diving, English Schools' Swimming Association (Great Britain: William Heinemann, Ltd., 1963), p. 23.

proportion of propulsive force from the legs as compared to the arms, most coaches include nearly an equal amount of "legs only" and "arms only" practice regardless of the time in the season. Rajki[1] and Heffner,[2] who divide the training season into four and five phases respectively, suggest the same amount of work for "arms only" and "legs only" in each phase, although the amount does vary from one phase to another. The trend for equal amounts of arm and leg work appears to also be evident regardless of the distance for which the swimmer is training. Counsilman[3] states that "legs only" practice is of value because in addition to conditioning the legs, it adds variety to the training program and allows more flexibility in the workouts.

In addition to water practice, land drills and exercises, including weight training and running, are acceptable methods of conditioning the legs for swimming. The swimming belt or "rubber band" technique in which the swimmer is harnessed to the edge of the pool, is also a standard routine.

Five traditional methods of "legs only" practice are generally recognized: (1) holding onto the edge of the pool, (2) using a kickboard, (3) gliding prone with both arms overhead, (4) gliding prone with one arm at the side and one

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[1]Rajki, Chapter XI, "One Year Training Plan of a Competitive Swimmer," pp. 56-80.

[2]Fred Heffner, "Training for Swimmers," The Athletic Journal, XXXVIII (February, 1958), 46.

[3]Counsilman, Science of Swimming, p. 341.

overhead, and (5) gliding prone with both arms at the side. Kicking while holding onto a kickboard to practice the flutter kick is perhaps the most common method. Scholey[1] and Armbruster, Allen and Harlan[2] and Counsilman[3] indicate, however, that using a kickboard to practice the flutter kick may be detrimental to the swimmer. The swimmer's body does not always assume a natural swimming position and the kick is often too deep when the kickboard is used. If bad habits may be learned from practicing in a recommended manner, then a new method of training to perform the flutter kick seems feasible.

Statement of the Problem

The proposed investigation entailed the study of eleven college women who were members of the Texas Woman's University competitive swimming team during the spring semester of the academic year 1970-1971 and eleven college women who had swum, at some time, on a competitive team but who were not participating at the time of the investigation. The investigator proposed to determine whether training in a horizontal body position or in a vertical body position resulted in a significant difference in the ability to perform

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[1]Ray Scholey, "Front Crawl," in Swimming as Taught By Experts, ed. by Bill (W. J.) Juba (New York: Arco Publishing Company, 1961), p. 26.

[2]Armbruster, Allen and Billingsley, p. 83.

[3]Counsilman, Science of Swimming, p. 33.

the flutter kick in relationship to kicking speed, velocity of the legs and ankle flexibility as measured by selected instruments.

Speed was determined by the stopwatch method while velocity of the legs and ankle flexibility were calculated from a frame analysis of motion picture film. A 70 H. R. Bell and Howell sixteen millimeter camera was used with Tri-X film. Pictures were taken at a shutter speed of 1/288 second and at the rate of thirty-two frames per second.

The control group trained in a traditional horizontal position. The subjects practiced for fifteen minutes, five days a week for five weeks. Both groups performed the same interval training workout at the same time, with body position being the only variable. On the basis of the findings, the investigator drew conclusions concerning the relationship of body position during training and the ability to perform the flutter kick.

Definitions and/or Explanations of Terms

For the purpose of clarification the following definitions and/or explanations of terms have been established for use in the study:

Beat: The investigator accepts Alley's definition of beat:

> A kicking beat is defined as the movement of the leg and foot from maximum depth

> in the water to minimum depth in the water, or from minimum depth to maximum depth.[1]

Competitive Swimmer: For the purpose of this study the investigator defines a competitive swimmer as a member of the women's swimming team at the Texas Woman's University during the 1970-71 competitive season.

Dead Start: For the purpose of this study the investigator defines a dead start as the position of the swimmer's body prior to the start of the speed test. The swimmer is in the water in a prone floating position, feet plantar flexed with the toes touching the edge of the pool. The arms are fully extended and the hands hold a playground ball measuring seven inches in diameter. An assistant holds the swimmer's ankles to keep the toes in contact with the edge of the pool until the signal "go" at which time the ankles are released.

Downswing: The investigator accepts Harris' definition of downswing:

> The downward swing of the leg is initiated at the hip joint by muscular contractions strong enough to overcome water resistance and the bouyancy of the leg. Knee flexion increases slightly following the transitional movement. The ankle joint remains passively extended until the leg nears the end of the downswing. The knee and ankle joints then extend quickly to push water down and backward with the front (anterior) surface of the lower leg and instep of the foot. The

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[1]Louis E. Alley, "An Analysis of Water Resistance and Propulsion in Swimming the Crawl Stroke," Research Quarterly, XXIII (October, 1952), 254.

> transition of direction occurs as the hip extensors reverse the leg swing and the knee and ankle joints flex slightly.[1]

Ex-competitive Swimmer: For the purpose of this study the investigator defines an ex-competitive swimmer as any college woman who had previously participated in a race which had an official starter or who had trained as a member of any swimming team.

Flutter Kick: The investigator accepts Harris' definition of flutter kick:

> The flutter kick is characterized by a continuous, alternating and undulating action of the legs in a vertical plane. The objective of the kick is to push the water up and backward or down and backward with alternate leg swings. Action of each leg is initiated at the hip joint. Sequential joint action in the knee and ankle projects the power, as it builds to a forceful release in the whipping action of the feet.
>
> Maximum power is gained on the upswing (power phase) of each leg; minimal power is generated on the downswing (recovery phase) of each leg.[2]

Horizontal Body Position: For the purpose of this study the investigator defines the horizontal body position as the traditional prone glide position with the arms extended overhead. The left hand holds onto the gutter of the pool, the right wrist is hyperextended and the right hand is supinated and placed against the

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[1]Harris, p. 93.

[2]*Ibid*., pp. 92-93.

wall directly under the left hand approximately twelve inches below the surface of the water.

Upswing: The investigator accepts Harris' definition of upswing:

> As the leg swings upward through the power phase, it exposes the back (posterior) surface and the sole of the foot on an angle sufficient to direct force away from the direction in which the body is to move. The knee is slightly flexed at the very beginning of the swing. The ankle flexes as the foot reacts to the weight and pressure of the water. The foot assumes a pigeon-toed (inverted) position that exposes a greater surface area to apply force. As the leg continues its upward swing, it gains momentum from rapid extension of the knee and ankle. The action carries the foot toward the surface for the final whip-like impetus. The heel breaks the surface and creates a bubbling action of the water as the momentum of the swing diminishes. The leg action is reversed as the leg muscles momentarily relax. The weight of the leg provides momentum for the transition of the leg to the downswing.[1]

Vertical Body Position: For the purpose of this study the investigator defines the vertical body position as maintaining an upright position in the water, arms medially rotated and fully extended, and palms in contact with the lateral sides of the thighs.

Purpose of the Study

The purpose of the study was to determine if there was a significant difference in the flutter kicking speed, the velocity of the legs, and the ankle flexibility of college women competitive or ex-competitive swimmers as a result of

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[1]Ibid., p. 93.

changing from a horizontal to a vertical position for practice as measured by selected tests.

Specific sub-hypotheses to be tested were:

1. There is no significant difference in the speed of performing the flutter kick as a result of changing from a horizontal to a vertical position for practice as measured by the stop watch method.
2. There is no significant difference in the velocity of the legs as a result of practicing the flutter kick in a vertical position as measured by a frame analysis of motion picture films.
3. There is no significant difference in ankle flexibility as a result of practicing the flutter kick in a vertical position as measured by a frame analysis of motion picture films.

Limitations of the Study

This investigation was subject to the following limitations:

1. The eleven college women competitive swimmers during the spring semester of the academic year 1970-1971 and the eleven former competitive swimmers who attended the Texas Woman's University.
2. The competitive group composed of four free-stylers, three backstrokers, one butterflier, and three breaststrokers.

3. The degree to which the swimmers were representative of the population from which they were drawn.
4. The cooperation of the subjects to follow training instructions and work at maximum effort.
5. The objectivity, reliability and validity of the selected instruments for the measurement of speed, velocity and flexibility.
6. The treatment period of fiteen minutes, five days a week for five weeks.
7. The practice period conducted during recreational swimming time.
8. The variables of body size, length of legs, body surface area, body density, vertical balance, center of gravity, size and shape of feet, and bouyancy of the swimmers.
9. The variables of pool depth and slope, backwash, type of gutters, room temperature, water temperature, and water circulation system of the training site.

Summary

Chapter I has presented an introduction to the investigation. A history of the development of the flutter kick was constructed from secondary sources which were in agreement. Information was presented regarding the theoretical bases for propulsion from the kick, analogous forms of the movement of the legs, definitions and descriptions of the flutter kick and common kicking faults. A brief discussion was also presented regarding some of the topics of debate regarding the flutter kick--the contribution of ankle flexibility to the propulsive force of the kick, the energy requirement for the use of the legs, the amount of propulsion contributed by the kick to the total stroke, the various functions of the kick in the front crawl stroke, the amount of leg work recommended in workouts, and the various methods of training to perform the flutter kick.

Since the flutter kick has been shown to be a valuable component of the crawl stroke, and since at least one of the popular methods of training to perform the flutter kick is questioned in the literature, a different method of training appears to be not only feasible, but desirable. As the vertical body position is a possible method of training to perform the flutter kick, the remainder of the study was approached with the assumption that there is no significant difference in the flutter kicking speed, velocity of the legs, or ankle flexibility of college women competitive or ex-competitive swimmers as a result of changing from a horizontal to a vertical position for practice.

CHAPTER II

SURVEY OF RELATED LITERATURE

The studies presented in this chapter are organized into five sections according to topic area, and then chronologically within subject area: analysis of the flutter kick; water resistance and propulsion; flexibility; exercise, weight training, and leg strength; and training--overload principle and interval training. Each of the studies has some relevance to the background information and procedures for the experiment. Studies have been restricted to the area of swimming as much as possible, and more specifically to the flutter kick. When more than one aspect of swimming was examined in a study, only results and conclusions related to the flutter kick have been reported.

While the literature describing swimming skills was prolific, research studies in the area were limited until 1930. As skills continued to improve, the emphasis of competitive swimming came to the front. While Swegan and Thompson[1] state that there is so much research being done in the area of competitive swimming it is difficult to keep up with current

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[1]Donald B. Swegan and Hugh L. Thompson, "Experimental Research in Swimming," Scholastic Coach, XXVIII (August, 1959), 22.

findings, Mohr[1] remarks that there is still a great need for additional research in many areas of aquatics, including mechanical analyses of the strokes and principles for teaching swimming skills. In 1964 Spangler[2] compiled and analyzed the research that had been completed since 1930 on the topic of competitive swimming.

Analysis of the Flutter Kick

The classic study of the flutter kick was conducted in 1930 by Cureton.[3] This work is presented in more detail than the remainder of the studies because of its magnitude and its role in the procedures of the studies which used it as a precedence.

Cureton investigated four major problems of the flutter kick: the source of power (fishtail theory; squeeze; up and down emphasis; and ankle, knee and hip action), the maximum propulsive force developed, the regulations for maximum efficiency (ankle and foot position, knee action, width of kick, and rate of kick), and the kinesiology of the crawl flutter kick. Each study was a separate investigation and involved different procedures.

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[1]Dorothy R. Mohr, "Needed Aquatics Research," Journal of Health, Physical Education, and Recreation, XXVIII (May, 1957), p. 23.

[2]James R. Spangler, "A Compilation and Analysis of Completed Research in Competitive Swimming and Diving in the United States from 1930 to 1963" (unpublished Master's thesis, University of Illinois, 1964), pp. 1-303.

[3]Cureton, "Mechanics and Kinesiology," pp. 87-121.

<u>Source of Power</u>.--The factors for propulsion of the flutter kick are commonly made analogous with the action of a fishtail. Undulation and flexibility seem to be the main points stressed. The investigator obtained films and made tracings of the projected images to analyze the movements in the kick. To examine the "squeeze action" or "wedge" theory, three methods of kicking were designed to eliminate the wedge effect: kicking with one leg, with both legs simultaneously, and with the legs spread apart. Five subjects kicked two trials using each style of kick. Efficiency of the kick was calculated on a percentage basis in comparison to the normal kick. The one-leg kick was 62.3 per cent as efficient, the simultaneous kick was 62.5 per cent as efficient, and the spread leg kick was 82.5 per cent as efficient as the orthodox kick. Cureton attributed the loss in efficiency to the disturbance of balance and poorer control rather than to the absence of the wedge effect.

To determine whether the upswing or the downswing movement of the legs was more propulsive in the flutter kick, the investigator employed a four faceted approach: power impulses from the feet were felt tactually, group observations were utilized, "peculiar" kicks which eliminated the upswing swirls were studied, and a motion picture study of normal kicks was analyzed cinematographically. Two experimenters were assigned to "feel" the swirls around each leg as seven subjects kicked while holding onto the gutter of the pool.

Angles of the upswing ranged from forty to sixty (average of fifty) degrees and from fifteen to forty (average of 26.4) degrees for the downswing.

Experimenters observed that the downswirls were reduced when the legs and feet were raised seventy-five to ninety degrees out of the water ("flapping kick"), and both swirls were effective when the heels just broke the surface of the water. A graphic analysis of the upswirls and downswirls was constructed. The hypotenuses of the two triangles greatly favored the upswing action. The upswing was computed to account for 63.0 per cent of the total effective power for forward propulsion and the downswing was analyzed as responsible for 37.0 per cent. Fourteen experienced observers then viewed one highly effective kicker and came to the conclusion that the upswing phase was seemingly as powerful as the downswing.

Five subjects performed three "peculiar kicks" (simultaneous kick, flapping kick, and hooked-foot kick). The loss of speed for the simultaneous kick was 51.9 per cent, and losses of 39.3 per cent and nearly 100 per cent were found with the flapping kick and the hooked-foot kick respectively. The average loss of speed for the three kicks was 63.7 per cent which compared favorably with the 63.0 per cent obtained by the tactual analysis of the swirl angles.

The motion picture analysis of the subjects indicated that the upswing phase of the kick is capable of powerful propulsion since the sole of the foot is in a better mechanical position to exert force than is the instep. The observation group concurred with the findings. The investigator summarized this point by stating that the upswing is an effective component of propulsion.

Immobilization tests were administered to determine the amount of force the hip, knee, and ankle joint contribute to the total kick. The contribution of the ankle, knee and hip joints to the total speed varied greatly with the ability of the swimmer. The highly skilled swimmer obtained more than fifty per cent of the propulsive force from the hip joint, while the lesser skilled procured more than half from the knee joint. The amount of force received from the ankle was similar for both groups being in the range of twenty-five and thirty per cent respectively. Theoretical estimation of the contributions of the various joints did not correspond to the experimental evidence as some of the eight subjects scores more than 100 per cent which was attributed to slippage and to the lack of total immobilization of the joints.

<u>Propulsive Force</u>.--The investigator designed a kick-meter which utilized a lever arm to indicate readings on a scale in terms of pounds. Crawl kicks in the prone and supine position were found to yield approximately the same propulsive force.

Width of kick (eighteen inches), horizontal force (12.73 pounds), beats in sixty feet (seventy), and angle of swirls (up, fifty degrees; down, twenty-six degrees) were used to calculate the amount of work done. Further calculations indicated that 48.4 per cent of the total work done in the flutter kick was useless for propulsion. The kick appeared to serve a purpose, however, in keeping the legs at a position where less resistance occurred.

Maximum Efficiency.--The main power for the kick was found to emanate from the hip, although the ankle regulates this force. The ankles should be relaxed, however, there is a fraction of a second when the ankle changes directions which adds a powerful "flick" to the kick. The foot, at this point, meets the swirl it has just created and which is moving in the opposite direction. Since interception of this swirl increases the propulsive force, the kick is more effective at high speeds when such interception is possible.

Five subjects were tested for ankle flexibility and speed. The two variables were found to be directly proportional to each other, although Cureton states, contrary to other writers, "The propelling surface is not changed by toeing-in."[1]

Knee bend of forty-five to ninety degrees was found very fatiguing. For the five subjects tested, approximately fifteen degrees knee flexion was found to be most conducive to maximum propulsion. A "kick-tie" was used to measure and control the distance the feet separated while kicking.

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[1] Ibid., p. 114.

Measurements were made at four inches, eight inches, fourteen inches, and twenty-four inches. These tests yielded results which led the investigator to conclude that the best width for a kick depends upon the physique of the swimmer and that width decreases in direction proportion to the increase in rate.

Kinesiology.--Performance of the flutter kick involves muscles of the legs, abdomen and lower back regions. The "kicking muscle" of the quadriceps group is the rectus femoris. The harder the kicking effort, the more the abdominals come into action. Land exercises may help swimmers increase kicking speed by increasing muscle strength and power.

A summary of Cureton's findings may be stated as: The upswing of the flutter kick provides more propulsion than does the downswing as a result of the position of the sole of the foot. Approximately half of the work performed by the legs appears to be useless for propulsion but apparently does serve the purpose of keeping the legs in a position where less resistance occurs. The hip joint contributes to the propulsion force of the kick for the excellent swimmer, while the knee and ankle respectively provide force for the poor swimmer. The ankle plays an important role in the performance of the flutter kick as it is the final joint for the summation of forces. The most effective width for the kick depends upon the physique of the swimmer. The flutter kick used muscles of the legs, abdomen and lower back, the main "kicking muscle" being the rectus femoris.

Van Atta[1] compiled information about the techniques and variations for seven swimming styles. The materials were presented in outline form with notations attached to those statements from different sources which were in conflict with each other. Regarding the analysis of the leg kick, information for sprint, distance, and general kicking were separated. An example of the conflicts listed was in reference to the position of the feet in relation to the surface of the water. Three sources recommended respectively that "the feet are slightly lower than the head," "the feet are close to the surface," and "the feet are submerged far enough to keep them from breaking water." Various reports analyzing the sprint kick during the propulsion phase were: "break the surface of the water with the heels," "keep the legs close to the surface," and "keep the legs well below the surface." The legs move in the sagittal plane, but there is a difference of opinion regarding the position of the lower leg and ankle, e.g., "keep the tips of the toes directed medialward," "keep the ankle extended so that it is aligned with the lower leg," and "keep the ankles loose." Van Atta found that the correct width of the kick as recommended by the various authors, varied from six to twenty-two inches. No conclusion was drawn from the study other than there is a wide variety of

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[1]William Davidson Van Atta, "Techniques of Performing Basic Swimming Strokes" (unpublished Ph. D. dissertation, State University of Iowa, 1964), pp. 1-239.

opinion regarding the mechanics and the techniques for the execution of the various strokes and their components.

Mosterd and Jongbloed[1] analyzed the four racing strokes of nineteen women and eleven men in training for the Olympic Games. The subjects were strapped into a swimming belt or harness which was attached to a dynamometer. Results were recorded on a kymograph for four tests (twenty second sprint swim, one minute swim, twenty second arm sprint, and twenty second leg sprint). Each test recorded four different signals: time in seconds, moment of expiration, arm movement and leg movement. Swimmers were ranked in order of the force exerted during the one minute swim. The rank order appeared similar to the order in which they finished the 100-meter race. The graph analysis of the front crawl revealed that the subject made six legstrokes for each two armstrokes. The authors concluded that the graphs provided an acceptable method of studying the strokes.

Osborn[2] used a film analysis to determine the application of force while swimming the front crawl. One female speed swimmer and one female endurance swimmer were selected as subjects from an advanced swimming class at the University of California at Los Angeles. Film was projected on a large

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[1]W. L. Mosterd and J. Jongbloed, "An Analysis of the Stroke of Highly Trained Swimmers," Arbeitsphysiologie, XX (June, 1964), 288-93.

[2]Lola Lee Osborn, "A Method of Analysis of Swimming Strokes with Relation to the Application of Force" (unpublished Master's thesis, University of California at Los Angeles, 1941), pp. 1-86.

sheet of drawing paper and analyzed frame by frame. Reference points were marked on the paper and then measured with a micrometer calibrated to tenths of millimeters. Reliability was established by checking the measurements of the arm cycle three times for each subject. After analyzing the drawings, speed and acceleration curves were constructed. In summary, speed and endurance swimmers apply force at different points in the arm cycle and develop a curve characteristic of their own style of swimming.

Collins[1] conducted a comprehensive analysis of the breaststroke, sidestroke, and prone flutter kick. The subjects were twelve male members of the varsity swimming team and thirteen members of the synchronized swimming club at the University of Iowa. The primary procedures used in the collection of data were the frame analysis of motion pictures and tests of speed and power. Subjects performed two twenty-five yard trials on each kick and were photographed from overhead and underwater. The subjects were marked for the filming by a series of quarter-size dots and six-inch strips of tape. Measurements were calculated for the width of the flutter kick; the angular and linear width of the side stroke kick; and abduction, rotation, and flexion of the hip and knee flexion for the breaststroke kick. Reliability coefficients were .966 for the flutter kick, .984 for the breaststroke, and .874 for the sidestroke.

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[1]Patricia A. Collins, "A Film Analysis of Selected Swimming Stroke Kicks" (unpublished Ph. D. dissertation, University of Iowa, 1968), pp. 1-176.

The subjects were separated by sex and placed into either Group I (faster and more powerful; six women and five men) or Group II (slower and less powerful; six women and six men). A sequential list of joint actions was developed from a film analysis of the three fastest male and three fastest female subjects. The only significant mean difference between Group I and Group II for the women's flutter kick was in speed. The rank order correlation of joint action with speed revealed that ankle extension and ankle range were significant factors at the .05 level of significance.

The investigator made the following conclusions regarding the flutter kick: (1) On the downswing the knee flexes slightly, then extends, and the hip flexes as the ankle extends. On the upswing the knee reaches maximum extension shortly after the upward movement begins and then flexes throughout the remainder of the kick. (2) Faster swimmers have significantly less knee flexion than slower swimmers. (3) Ankle extension and range of the ankle in women correlate positively and significantly with speed.

Water Resistance and Propulsion

Numerous studies have been conducted to determine the components of water resistance and factors related to propulsion. The first studies concerning water resistance and propulsion were investigations of the maritime problems of drag, aerodynamics and hydrodynamics. The majority of literature reviewed lists a series of early studies and gives a brief statement of the finding. While the content is the same, there is some disagreement as to the dates reported in the various works. The classic studies of water resistance and propulsion include the work of: William Froude (1872, 1874*), F. T. Bowles (1883), M. Saint-Venant (1888), R. Dubois Reymond (1905) who conducted the first study of human water resistance, F. W. Lancaster (1908), W. F. Durand (1909), F. Houssay (1912), G. Liljestrand and N. Stenstrom (1912, 1919*), B. C. Laws (1914), and Jules Amar (1920) who applied the first water resistance formula to swimmers.

Bunn lists eight factors resulting in a loss of force in swimming: waves, eddies, cavitation (loss of suction), skin friction, force used at an unproductive angle, starting and stopping (overcoming inertia), internal resistance (tenseness), and physical features of the swimmer.[1] To eliminate the loss of force he suggests maintaining a constant force, eliminating up and down movements (which create waves), eliminating body rotation, and eliminating movements causing eddies or swirls.[2] He did not, however, suggest the means of accomplishing these points.

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*A conflict of dates was found. The date used most often is underlines.

[1]John W. Bunn, Scientific Principles of Coaching (New York: Prentice-Hall, Inc., 1955), p. 81.

[2]Ibid., p. 177.

Scott[1] points to the following resistances in swimming: resistance to movement through the water which increases with the width of spread, skin friction, and the tendency for the water to be pushed ahead of the swimmer; resistance of the water to allow an object to pass; and resistance to the action of the eddies in forming low pressure areas or suction. Wells[2] states that swimming is a unique activity in that its supporting media is also its resistance.

Tews[3] studied the relationship of the resistance of velocity and the propulsive force to swimming velocity of arms alone, legs alone, and the whole crawl stroke. Twenty subjects were towed for twenty-two feet to gain a constant velocity and then tested for the remaining twenty-eight feet of a fifty-foot pool. Resistance measurements were taken at the velocity of four feet per second. Recordings were made on a kymograph. In addition to the towing tests, each subject performed three trials each for speed of arms alone, legs alone, and the whole crawl stroke.

Multiple correlations calculated in terms of velocity in relationship to propulsive force and resistance at a

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[1]M. Gladys Scott, Analysis of Human Motion (2nd ed.; New York: Appleton-Century-Crofts, 1963), p. 296.

[2]Katharine Wells, Kinesiology (3rd ed.; Philadelphia: W. R. Saunders Company, 1960), p. 375.

[3]Richard William J. Tews, "The Relationship of Propulsive Force and External Resistance to Speed in Swimming" (unpublished Master's thesis, State University of Iowa, 1941), pp. 1-25.

constant velocity were: .7635 for arms alone, .6705 for legs alone, and .7701 for the whole stroke. Three types of resistance were determined: friction drag of the water on the body surface, pressure drag of the water, and wave resistance. Tews concluded that body resistance was not an important factor limiting speed of swimming for the group tested and that the biggest factor regulating speed in swimming was the propulsive force.

Allen[1] investigated the factors involved in the propulsive force of the leg kick and the contributions of the kick to the whole stroke. Twenty-two male high school swimming team members were tested for five trials of ten yards each for two methods of arm stroke (legs supported, legs not supported), four types of kick (normal, narrow--twelve inches, medium--eighteen inches, wide--twenty-four inches), and speed of the whole stroke. Computations were made using the average time and the best time for the five trials. Allen concluded that pulling with the legs unsupported resulted in an unnatural lateral movement of the hip and added to the resistance.

A graph was constructed to show the relationship of the legs and arms to the whole stroke. The results indicated that the contributions by the legs varies with the leg speed, with the slower kick assisting less. A kick with a foot spread of approximately twelve inches seemed to be the most effective.

[1]Robert H. Allen, "A Study of the Leg Stroke in Swimming the Crawl Stroke" (unpublished Master's thesis, State University of Iowa, 1948), pp. 1-25.

The wider the spread of the kick, the slower the velocity of the legs. On the basis of these findings, Allen concluded that the amount of propulsion provided by the legs depends upon the depth and speed of the kick. Also, the most efficient kick appears to be a narrow kick, with the feet separated approximately twelve inches.

Bandy[1] investigated the factors of resistance and propulsion for the flutter kick. Nine subjects (seven from the State University of Iowa varsity swimming team, one high school competitive swimmer and the college assistant swimming coach) were tested for three trials each for drag and for the flutter kick while being towed. Recordings were taken for six different velocities. Five time trials were also conducted to determine free kicking velocity and free whole stroke velocity.

Each subject's data were analyzed separately. Graphs were made showing drag, towing force, average maximum free kicking velocity, and average maximum free whole stroke velocity. The data were then divided into two groups according to the four fastest free whole stroke velocities and the four slowest free whole stroke velocities. The ninth subject was not mentioned. The drag for both groups increased at approximately in the same proportion, but the towing forces

[1]James Allen Bandy, "A Study of the Relationship of the Front Crawl Flutter Kick and the Drag" (unpublished Master's thesis, State University of Iowa, 1951), pp. 1-48.

increased more rapidly for the slower group than for the faster group. The free velocity measurements indicated a swimmer kicked at approximately three feet per second and swam at approximately five and one-half feet per second.

Alley[1] explored the problem of water resistance and propulsion in swimming by analyzing the performance of one male subject who was an All-American swimmer from the State University of Iowa's swimming team. The subject was towed through the water at controlled speeds by means of a mechanical apparatus. Five trials were executed at each velocity for nine different tests in the categories of drag, arm stroke, leg kick, and the whole stroke. Alley used the term "surplus-propulsion force" which, briefly defined, is that force a swimmer exerts at a given velocity above the force required to overcome water resistance at that velocity. Between velocities of two and five feet per second, the legs assumed a horizontal position, but above these speeds, the legs were found to rise too high and an unnatural position occurred.

A formula was used to determine the coefficient of thrust for the various arm-leg combinations. On the basis of his findings, Alley drew the following conclusions: a bow wave develops at speeds greater than five feet per second and may be an important factor in limiting the speed of the swimmer. The surplus-propulsive force of the normal kick (twelve inches in width) is greater than the short kick (six inches

[1]Alley, pp. 253-70.

in width) at each velocity. More power was evident in the whole stroke with a normal kick than with the short kick. The proportion of the total stroke attributed to the leg force was not computed, but appeared to vary greatly at different velocities.

Counsilman[1] studied the relationship of resistive and propulsive forces when swimming the crawl stroke with a gliding or a continuous arm action. An apparatus similar to that used by Alley was employed to tow three male subjects through the water at ten different speeds. The subjects were All-American swimmers from the State University of Iowa. The data were collected from a galvanometer and recording device, as well as by the stop watch method. Each subject was tested in four drag positions (prone, side, being rolled, and self-rolling) over a thirty-foot course. The subjects swam away from the apparatus for measurements of the gliding and continuous tempo and stroke, and were towed toward the apparatus for resistance measurements. Three trials were recorded for each of the ten speeds. Two different tempos were tested for each of the two strokes (glide and continuous). The two stroke tempos were established from observing the ten fastest male swimmers in the 100-yard (1.20 strokes per second) and the 1500-yard freestyle event (1.74 strokes per second) at the 1951 National AAU Indoor Swimming Meet. Graphs were drawn representing the data.

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[1]James E. Counsilman, "Forces in Swimming Two Types of Crawl Stroke," Research Quarterly, XXVI (May, 1955), 127-39.

On the basis of the data, the following conclusions were stated: The four drag positions tested listed in order of least resistance, were the prone, side, prone while being rolled, and prone while self-rolling. Regardless of the position, the bow wave appeared at about the same velocity and in the same magnitude. The continuous stroke was faster and created more propulsion than did the glide stroke at similar tempos and velocities. The glide stroke created greater fluctuation in force, at which time the kick aided in propulsion during the recovery phase of the arms. Because of roll and resistance factors, a swimmer should breathe on the opposite side from his stronger arm.

Foster[1] proposed to develop a teaching method based on mechanical principles for the optimum use of force with a minimum of body resistance. Forty-nine freshman and twenty-one sophomore women at the University of Wisconsin were tested for a length endurance test (total number of continuous lengths the subject could swim), a five minute length test (total number of lengths the subject could swim in five minutes), a combination test (performance of skills basic to swimming), and a proficiency test (proficiency of stroke per effort in terms of velocity). Practice sessions were thirty-five minutes long, three days a week for forty-one sessions. The

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[1]Margaret Virginia Foster, "The Development of a Method of Swimming Instruction Based on Efficiency of Propulsion Including a Comparative Study of Fear Reduction" (unpublished Master's thesis, University of Wisconsin, 1963), pp. 1-122.

control and experimental groups practiced the same swimming program, however, the experimental group used Lanone's down-proofing method in addition to the regular lesson each day.

An analysis of covariance was used to compare the data as the two groups were not equated at the beginning of the experiment. The analysis revealed the combination test was significant at the .05 level of confidence in favor of the experimental group. Conclusions reached by the experimenter indicate that an emphasis on goal achievement rather than technique will result in a higher achievement level and will be consistent with current theories of learning.

Karpovich[1] undertook a study of eleven men and three women to devise a method from which a formula could be developed to measure the resistance of a human being propelled through the water. The surface area of the skin (measured in square feet), weight and height were recorded for each subject. A special mechanical apparatus comprised of pulleys, two ropes and a kymograph was constructed to allow subjects to be propelled through the water at various rates of speed by means of a three-horsepower motor. Each subject was tested in a prone and a supine position. Other factors included in the study were positions of the head, turning the head to breathe, lifting the head to look back, changing speeds, and the wearing of different types of swimming apparel.

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[1]Peter V. Karpovich, "Water Resistance In Swimming," Research Quarterly, IV (October, 1933), 21-28.

Several graphs and charts were constructed from recordings obtained from the resistograph to show the differences between the prone and back glide positions, between male and female's resistance in the water, and the general differences caused by body size.

The investigator made the following conclusions: (1) lifting the head high enough for just the eyes to come above water level does not affect resistance, (2) hydroplaning does not increase water resistance, (3) turning the head to breathe increases water resistance, (4) lifting the head to look back increases water resistance at different speeds, (5) increasing speed rather than maintaining a constant speed increases water resistance, and (6) wearing suits of particular styles increase water resistance.

Karpovich[1,2] analyzed the propelling force to determine the arm-leg ratio in the front crawl. Procedures used were similar to those of Cureton's study. Fifty-five male students at Springfield College swam lengths of the pool using legs only, arms only, and the whole stroke. Through the use of various formulae, Karpovich deduced the following laws: "When speed is constant, the propelling force is equal to the water resistance."[3] "The square of the speed of the whole

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[1]Peter V. Karpovich, "A Mathematical Analysis of the Crawl Stroke," Scholastic Coach, VII (December, 1937), 24.

[2]Peter V. Karpovich, "Analysis of the Propelling Force in the Crawl Stroke," Research Quarterly, XXXV (May, 1935 Supplement), 49-58.

[3]*Ibid.*, p. 50.

stroke is equal to the sum of squares of speeds developed with the arms and legs separately. This can be represented graphically[1]. . .as the Pythagorean theorem. . .that the sum of the squares of the sides of a right angle is equal to the square of the hypotenuse."[2] The subjects were divided into five groups on the basis of the time it took them to swim the sixty feet. The formulas were then applied to the data obtained from the subjects.

> In order to find the arm-leg ratio contribution to the propelling force in a crawl stroke, divide the square of the arm speed by the square of the leg speed. To find the percent contribution by the arms (or legs) divide the square of the arm (or leg) speed by the square of the speed of the whole stroke and multiply by one hundred.[3]

The sum loss of kinetic energy during arm and leg tests is equal to the loss during the whole stroke, and therefore does not affect the calculations.[4] A table was constructed which enables one to predict quickly the speed of the whole stroke from the times of legs only and arms only. If the subject was slower than the predicted time, Karpovich declared that he was not able to use his legs efficiently and should begin appropriate exercises. On the basis of the findings, it was determined that for a swimmer who was able to perform the crawl well, about 70 per cent of the power is contributed by

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[1] Ibid., p. 51.

[2] Karpovich, "Mathematical Analysis," p. 22.

[3] Karpovich, "Propelling Force," p. 53.

[4] Ibid., p. 54.

the arms and 30 per cent by the legs. Poor swimmers obtain approximately 77 per cent from the arms and 23 per cent from the legs.

Jaeger[1] used a pulley and weight system to tow fifteen subjects for a distance of sixty feet to determine the resistant affect of water in relationship to speed in swimming. Five readings were taken for each subject with three different weights being used as resistance. The subjects were then timed for a sixty foot speed swim. A resistance formula was then devised using the speed of 5.66 feet per second to calculate the resistance for each subject. The correlation between resistance and velocity was much less than he had expected. No specific conclusions were made.

Lewis[2] investigated the relationship between body build and the ability of the swimmer to develop speed. A box-platform apparatus was fabricated to test sixty-one female students, ranging from seventeen to twenty-six years of age, at the University of Oregon. After recording height, weight and chest circumference, five swimming tests of force were administered to the subjects.

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[1]Lee Daehn Jaeger, "Resistance of Water as a Limiting Factor of Speed in Swimming" (unpublished Master's thesis, State University of Iowa, 1937), pp. 1-19.

[2]Helen B. Lewis, "A Preliminary Study of the Relationship of the Factors of Propelling Force and Body Build to the Ability of Women to Develop Speed in Swimming the Front Crawl" (unpublished Master's thesis, University of Oregon, 1941), pp. 1-51.

Lewis indicated that the legs contribute nearly as much to propulsion as do the arms. The findings also agreed with Cureton in that the total propelling force of the whole stroke did not equal the sum of the propelling force and the arm stroke and that of the flutter kick. The difference in the sums was attributed to coordination, physical condition, skill, slippage of the arm pull in the water and other factors not measured. The coefficients of correlation indicated that as the distance increased there was an increase in the proportion of forward propulsion contributed by the kick as compared to the arm stroke.

Lopin[1] explored the possibility of predicting speed in swimming by measuring water resistance and propulsive forces for an individual without expensive equipment. Thirty-one subjects were towed by a block and tackle system for sixty feet, the first thirty-five feet of which was used to obtain a constant speed. The remaining twenty-five feet were recorded on a kymograph. The subjects also plunged for distance in thirty seconds and swam three thirty-foot trials for speed. Propulsive force was calculated from planimeter readings. Lopin summarized his findings by stating that prediction of speed in swimming the crawl stroke is possible (.7896) through the use of the multiple regression equation using the variables of towing time, weight and propulsive force.

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[1]Vito Lopin, "A Diagnostic Test for Speed in Swimming the Crawl Stroke" (unpublished Master's thesis, State University of Iowa, 1958), pp. 1-24.

Poulos[1] completed a study at the State University of Iowa regarding the amount of force contributed by the arms and legs to the total crawl stroke. Twenty-five subjects, five of whom were average swimmers and twenty of whom were competitive swimmers, were tested for speed (ten yards), for three types of kicks (narrow, normal and wide) and for two arm strokes (long and short). The wide kick proved to be so slow that it was dropped from the study. Nineteen of the twenty-five recorded faster times with the narrow kick than with the normal kick. The average times for the tests of the long pull were faster than for the short pull.

A prediction formula was constructed to compute the time for the whole stroke from the times of the legs alone and the arms alone. It was concluded that the amount of propulsion contributed to the whole stroke by the leg drive is determined by finding the difference between the velocity of the arms alone and the legs alone. The greater the difference the more the leg propulsion contributes to total speed; the smaller the difference, the less the leg propulsion contributes to total speed. An eight beat kick was recommended for use with a long pull and a six-beat kick for the short pull.

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[1]George L. Poulos, "An Analysis of the Propulsion Factors in the American Crawl Stroke" (unpublished Master's thesis, State University of Iowa, 1949), pp. 1-24.

Wallace[1] was interested in the use of swim fins. Thirty-six female non-swimmers and beginners at Brigham Young University were tested to determine the time required to kick thirty-five feet and the distance covered while kicking for fifteen seconds. Two groups, one wearing fins and one not wearing fins, were equated on the basis of the results on the Johnson-Metheny Motor Educability Test. The best score of three trials was used for the computations. The practice sessions were fifteen to twenty-five minutes, two days a week for ten weeks. During this time instruction was given to stress important aspects of the flutter kick. No significant difference was found between the group using the fins and the group practicing without the fins. The use of fins to develop the flutter kick was determined to be only a matter of individual choice.

Thrall[2] undertook a study to investigate the relationship of size and shape of the foot and frequency of the kick to the propulsive force of the flutter kick. The equipment used for testing included a towing device, a measurement recording mechanism, a sounding instrument, and swim fins. The fins were used to establish a constant for foot size. The subjects were three male members of the varsity swimming team at Kansas State University who participated in thirty-one

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[1]Lulu Wallace, "Swim Fins as an Aid in Teaching the Flutter Kick for the Front Crawl" (unpublished Master's thesis, Washington State University, 1960), pp. 1-78.

[2]Thrall, pp. 1-75.

testing sessions for a total of 186 trials each. The arm stroke was performed at the rate of one stroke per second as synchronized by a metronome. Subjects were towed at six different velocities while performing each of six kicks (normal, normal with wide fins, normal with narrow fins, feathered, feathered with wide fins, and feathered with narrow fins). Drag measurements were also taken at each velocity.

It was found that the effective propulsive force of the kick at any given velocity was the difference between the drag and the towing force. The normal kick provided the most effective propulsive force, particularly at slower velocities. Above the rate of five feet per second subjects had difficulty keeping the feet under water, and at the rate of six and seven feet per second the effect of the kick was lost. While the use of fins increased the free velocity of kicking, they increased drag and made a negligible increase in the free velocity of swimming. There was no apparent difference in propulsion or resistance due to the size of the fin.

In conclusion, Thrall states that the action of the flutter kick should originate in the hip, be transmitted through the thigh to the knee joint, then to the lower leg, and finally a whiplike movement by way of a flexible ankle. The width of the flutter kick should be approximately twelve inches. The feet should be kept close to the surface to reduce resistance. Although there was no apparent difference in the results obtained from the different size fins, the author states that the ideal foot for a swimmer would be long, flexible and have a large surface area with which to exert force. The six beat kick was recommended.

Wilson[1] conducted a study to determine the relative amounts of propulsion contributed by the arms and legs to the total stroke. Sixty male students (thirty-one varsity swimmers, fifteen sophomore average swimmers, and fourteen poor swimmers from the freshman secretarial class) from Springfield College were given a land drill test, Olson's Midget bath test, a suspension test, and selected velocity tests. Wilson refers to "coordination" as being synonymous with "efficiency." For the velocity tests an additional forty-one swimmers for breaststroke and thirty-five swimmers for backstroke were included in the study. Wilson used the formula: velocity (arms) + velocity (legs) = velocity (whole) + Loss RC. The R stands for the amount of water resistance to the body, and the C for changes due to slippage in the water. The formula was tested for accuracy by attaching an outboard motor to either end of a small boat. When reporting the same study later, Wilson[2] attributed the loss of efficiency to

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[1]Colin Theodore Wilson, "Coordination Tests in Swimming" (unpublished Master's thesis, International Young Men's Christian Association College, Springfield, Massachusetts, 1933), pp. 1-97.

[2]Colin Theodore Wilson, "Coordination Tests in Swimming," Research Quarterly, V (December, 1934), 81-88.

three factors rather than two: resistance loss, neurological loss by subjects coordination, and loss due to slippage. The loss in efficiency was found to vary with the ability of the swimmer to swim at high speeds. Thus, the faster swimmers experienced more loss in efficiency than did the slow swimmers. It was established further that the arms contributed approximately 1.7 times as much to the speed in the crawl stroke as did the legs.

Moyle[1] undertook a study to determine the relationship of heart size to swimming endurance, swimming speed to swimming endurance, and the relative contributions and integration of the arms and legs. Seven anthropometric measures were recorded for twenty male members of the State University of Iowa swimming team. Subjects were timed for maximum speed over ten yards and twenty yards using arms only, legs only, and whole stroke. The best time of three trials was used from computations. The subjects swam ten to fifteen yards to obtain a constant speed and then passed the starting line. Three trials of 100-yards each were also administered. An endurance ratio was established by dividing the time for the 100-yard swim by the best time for the ten yard swim.

Eight coefficients of correlation were calculated for the ten yard tests. Three partial correlations of endurance

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[1]William J. Moyle, "A Study of Speed and Heart Size as Related to Endurance in Swimming" (unpublished Master's thesis, State University of Iowa, 1936), pp. 1-27.

and one multiple-R were also computed. The relative contributions of the arms and legs to the whole stroke in terms of correlation of velocities squared were: whole stroke with arms only (.8303), whole stroke with legs only (.5951), arms only with legs only (.3190), and the whole stroke with arms and legs (multiple-R, .9005). Moyle found that the arms contributed more to the total propulsion in the front crawl than did the legs. There was little relationship between the effectiveness of the arms alone and the legs alone. The multiple correlation proved to be an acceptable method of determining coordination as the per cent of error in predicting swimming time from the speed of arms alone and legs alone was 7.2 per cent.

Adrian, Singh and Karpovich[1] undertook a study to determine the relative energy cost of performing with the legs alone, arms alone, and the whole stroke. Twelve college swimmers, nine male and three female, were administered one twenty-five yard swimming test each day for three days. A Collins two-way J-valve and Douglas bag were used to collect expiration samples. Traveling at the speed of three feet per second, oxygen was consumed at the rate of sixteen liters per minute for legs only and four liters per minute for arms only. At the speed of 3.5 feet per second oxygen was consumed at the rate of 24.5 liters per minute for legs only and seven liters

[1]Marlene J. Adrian, Mohan Singh, and Peter V. Karpovich, "Energy Cost of the Leg Kick, Arm Stroke, and Whole Crawl Stroke," Journal of Applied Physiology, XXI (November, 1966), 1763-66.

per minute for arms only. The leg kick required, therefore, three to four times as much oxygen as the arm stroke. The practice of reducing the leg kick in long distance swimming seems to be justified from these findings. The efficiency of the legs ranged from .05-1.23 per cent whereas the efficiency for the arm stroke ranged from .56-6.92 per cent.

Flexibility

As indicated in the introduction, authorities differ in their opinions as to the importance of ankle flexibility to a swimmer. The following studies present research evidence with regard to flexibility and swimming.

Jacobson[1] undertook a study to determine the amount of flexibility of the hamstrings and lower back which was retained by competitive swimmers following selected stretching exercises. Forty-three male subjects (thirty-one competitive swimmers and twelve non-swimmers) from a high school in Los Angeles were pretested for hamstring and lower back flexibility before a three week stretching program. Post-tests were administered at intervals of four, eight, twenty-four and forty-eight hours and one, two, three, and four weeks after the final exercise session. Five stretches were repeated fifteen times each day in three different positions.

[1]Richard Lee Jacobson, "An Experimental Study of Flexibility and Its Retention in Competitive Swimmers" (unpublished Master's thesis, University of California at Los Angeles, 1967), pp. 1-65.

Massey's correlation table and "t" ratios were used to determine significance for flexibility measurements.

The results indicated that swimmers are more flexible in the lower back and hamstring muscles than are non-swimmers. Swimmers were significantly more flexible at the start of the study and continued to show greater flexibility throughout the experiment. Both groups showed significant improvement in flexibility at the .01 level of confidence by the completion of the experiment. Swimmers retained flexibility at a significant level for seven days, however, non-swimmers showed retention for only forty-eight hours. Swimmers showed some retention, though not significant, for four weeks after the conclusion of the exercise sessions. In summary, body build is not a significant factor for flexibility. Both swimmers and non-swimmers improve in flexibility through participating in a stretching program. Swimmers improve more and retain flexibility longer than do non-swimmers.

Pickens[1] conducted a study to determine the relative amount of flexibility possessed by a swimmer in comparison to other athletes and to the general college male population. Fifty male competitive swimmers from four different colleges were compared with 100 football players, 56 service class students, 30 baseball players, 100 basketball players and 100

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[1]William Lamar Pickens, "A Study of Flexibility in Swimming" (unpublished Master's thesis, University of Oregon, 1950), pp. 1-53.

college males eighteen years of age. A total of sixty readings from a Leighton Flexometer were taken for nineteen different locations. Ankle measurements included in the tests were flexion and extension, and inversion and eversion. Coefficients of correlation and critical t-ratios were computed. Swimmers had significantly greater flexibility when compared with football players and service classes for flexion and extension, with baseball players for right ankle flexion, extension, inversion and eversion, and with college males and basketball players for flexion, extension, inversion and eversion. In a rank order correlation for ankle flexibility for the six groups, swimmers ranked second for flexion and extension and first for inversion and eversion. It was concluded that swimmers have more ankle flexibility than did members of the other groups tested.

Cureton[1] compared four measures of flexibility of 150 male Springfield College freshmen with those of Yale varsity swimmers. The members of the swimming team had greater flexibility than the freshmen in trunk flexibility forward, trunk flexibility backward, shoulder flexibility and ankle flexibility. Cureton concluded that, "There is no doubt that better speed and endurance swimming performances parallel greater flexibility in the major joints . . ."[2] and that ankle

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[1]Thomas Kirk Cureton, Jr., "Flexibility as an Aspect of Physical Fitness," Research Quarterly, XII (May, 1941 Supplement), 381-90.

[2]*Ibid.*, p. 384.

flexibility is necessary to provide the whiplike action of the flutter kick.

Hockey[1] conducted a study to determine the relationship between flexibility and swimming speed, to identify the changes that occur in flexibility after participating in a three week swimming program, and to establish flexibility norms for twelve year old boys. Twenty-two boys from an Oregon elementary school who had had no competitive experience were given eighteen tests of flexibility using a Leighton Flexometer. Included in the eighteen measurements were tests of ankle flexion and extension, and ankle eversion and inversion. Tests were administered at the beginning of the experimental period, after three weeks of no activity just prior to the swimming class, and after three weeks of swimming daily. Swimming instruction included basic instructions and a ten minute swim for endurance at the end of each practice. No special practice was included for the legs or ankles.

Reliability, by the test-retest method, was established at .946 for ankle flexion and extension and .973 for ankle inversion and eversion. Eleven of eighteen tests were significantly different at the .05 level of significance, including both ankle measurements, hip rotation and knee flexion and extension. A rank order correlation of a twenty-five

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[1]Robert Hockey, "Flexibility Changes Following Participating on a Three Week Swimming Program," (unpublished Master's thesis, University of Oregon, 1965), pp. 1-95.

yard swim and flexibility measurements was calculated but no significant correlations were found with any flexibility measurement. In conclusion, participation in a swimming program did significantly improve flexibility but flexibility was not found to be significantly related to speed.

Healey[1] completed a study of the relationship between plantar flexion at the ankle joint and the amount of propulsion developed. Twenty-seven subjects were selected from two co-educational intermediate swimming classes at the University of Utah. Practice was conducted for fifty minutes, two times per week for six weeks. The best time of two trials for three types of kick (prone flutter, supine flutter and dolphin) and ankle flexibility measurements as measured by a Leighton Flexometer, were used to create two equal groups. Both groups participated in identical swimming programs, but the control group supplemented the practice with three selected ankle plantar flexibility exercises for five minutes at the end of each class. Both groups improved significantly at the .01 level on all three kicks. Pre-test and post-test comparisons indicate that improvement in plantar flexibility was significant at the .05 level for the control group and .01 level for the experimental group. A significant difference was also found between the control and experimental

[1]John H. Healey, "A Comparative Study to Determine the Relationship Between Plantar Flexion at the Ankle Joint and Success in Selected Swimming Skills" (unpublished Ph. D. dissertation, University of Utah, 1970), pp. 1-86.

groups for the prone flutter kick and the dolphin kick. The investigator concluded that the amount of time spent on exercise was apparently justified and that individuals with the greatest degree of plantar flexibility have the greater ability to propel themselves through the water.

Robertson[1] examined the relationship of selected muscle groups and ankle flexibility to velocity and propulsive force generated by the flutter kick. Twenty-one male subjects (seventeen varsity swim team members and four graduate students who had completed one year previously) from the State University of Iowa were administered six tests. A cable tensiometer was used to determine strength; a device utilizing a plumb line, protractor and spring scales was employed to determine flexibility; the stop watch method was used to determine speed; and an apparatus similar to that used by Tews and Lopin was employed to measure propulsive force. Three trials were conducted for each test (hip flexion, hip extension, knee extension, ankle flexibility, velocity of flutter kick, and propulsive force of flutter kick). Combination scores were determined for total hip strength (hip flexion plus hip extension scores) and total leg strength (total hip strength plus knee extension strength).

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[1]David F. Robertson, "Relationship of Strength of Selected Muscle Groups and Ankle Flexibility to the Flutter Kick in Swimming" (unpublished Master's thesis, State University of Iowa, 1960), pp. 1-36.

A correlation of .575 between velocity and propulsive force was significant at the .01 level. A correlation of .545 between ankle flexibility and propulsive force was significant at the .05 level. Partial correlations significant at the .01 level were found between ankle flexibility and propulsive force with knee extension held constant and between ankle flexibility and propulsive force with total leg strength held constant. On the basis of these results, the author concluded that above-average ankle flexibility is desirable for the performance of the flutter kick.

Exercise, Weight Training and Leg Strength

Leg strength appears to be necessary to perform the flutter kick proficiently. Reference is given in Chapter I regarding the importance of the flutter kick, and therefore the legs, to the performance of the whole stroke, and more specifically for the competitive swimmer. Literature on weight training and leg strength is voluminous. The following reviews are limited to those related specifically to swimming.

Smith[1] undertook a study to determine the relationship between leg strength and the time required to flutter kick twenty yards. Forty-three male freshman and sophomore students in the required physical education program at

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[1]Ronald George Smith, "A Study of the Relationship Between Leg Strength and Swimming Speed Using a Flutter Kick in the Prone Position" (unpublished Master's thesis, Montana State University, 1962), pp. 1-74.

Montana State University who had the ability to plantar flex the ankle at least forty-five degrees and who were classified as at least intermediate swimmers, were administered three speed trials of kicking for twenty yards, and five tests of strength and flexibility as measured by a cable tensiometer. The major muscle groups tested for the upstroke were the hip extensors, knee flexors, and ankle plantar flexors. For the downstroke the hip flexors and knee extensors were tested. Rank orders were established on the basis of both best times and average times in the speed tests.

Coefficients of correlation were calculated for total leg strength with kicking speed ($r = .24$), for strength of the upstroke for both legs and kicking speed ($r = .24$), for strength of the downstroke for both legs and kicking speed ($r = .24$), and for ankle plantar flexion and kicking speed ($r = .12$). A comparison between the strength of the muscles involved in the upstroke with those involved in the downstroke was made by collating the means of the muscle strength of the knee extensors and hip flexors used on the downstroke with the muscle strength of the knee flexors and hip extensors used on the upstroke. The downswing had a mean of 814 pounds compared to 504.5 pounds for the upswing, indicating 309.5 pounds more force was applied on the downswing. A coefficient of correlation revealed a slight relationship between kicking time, total leg strength and total upstroke and total downstroke.

The researcher further concluded that there is a negligible relationship between best time and ankle plantar flexion.

Kingston[1] conducted a study to determine the outcome of two different training programs on abdominal strength, leg strength, shoulder strength, vital capacity, oxygen consumption, a cardiovascular efficiency, and swimming speed of college women. Two groups (swimming only and exercise-swimming) of six subjects each were equated from seven freshman and five sophomore women from the University of North Carolina at Greensboro who had a minimum of a junior life saving certificate and who could swim one hundred yards. The groups met for three hours each week for eight weeks. Subjects were pre-tested, and then tested again at the end of one month of training and again after two months of training. During the first month one group performed prescribed exercises only and did not swim while the second group swam and did not exercise. Both groups swam during the second month.

Analysis of the data revealed that both groups made a significant improvement in leg strength after one month of training. Considering the second month of training as an isolated factor, however, only the exercise group made a significant improvement in leg strength. When comparing the total treatment period results, both groups made significant

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[1]Margaret Kingston, "The Effects of Two Training Programs on Swimming Speed, Physiological Efficiency, and Strength of College Women" (unpublished Master's thesis, University of North Carolina at Greensboro, 1961), pp. 1-129.

improvement in leg strength at the .01 level of significance. There was no significant difference in leg strength between the two groups on any of the three tests.

A significant difference at the .05 level occurred favoring the swimming group in speed at the final test. While the mean speed of both groups improved steadily, a greater change was found during the second month of training for the swimming group. There was not a significant difference for the total group between the initial and final tests.

The author concluded that for the development of leg strength, exercise periods and swimming were both beneficial; however, the swimming group was measured slightly higher in leg strength than the exercise group. To improve swimming speed, swimming practice appeared to achieve better results than did combining exercise and swimming.

Parchman[1] compared the development of leg strength and endurance of college women after participating in a basketball or swimming class. Thirty-one freshman and sophomore women, fourteen in basketball class and seventeen in a swimming class, at the University of Illinois volunteered to participate in the study which covered a total of ninety minutes per week for fourteen weeks. Both classes were taught by the investigator. Leg strength was measured by a dynamometer

[1]Linda Lou Parchman, "A Comparative Study of the Development of Leg Strength and Endurance of College Women in Basketball and Swimming" (unpublished Master's thesis, University of Illinois, 1961), pp. 1-47.

with a belt attached and endurance was determined by a bicycle ergometer. The better scores of two trials were used to calculate t-values and F ratios in terms of "gains" within and between the groups.

Analysis of the data was presented from three different aspects: pre- and post-test comparisons, within group gains, and between group gains. In the pre- and post-test comparisons, the basketball groups improved more than the swimming group in leg strength, however, the gain was not significant. In regards to endurance, the swimming group improved more than the basketball group, but again, the gain was not significant.

For gains within groups the basketball group achieved a significant improvement in leg strength at the .01 level. A significant improvement in leg strength did not occur for the swimming group. No significant improvement in endurance was found for either group. The investigator concluded that participating in basketball increased leg strength more than participating in swimming but that neither activity resulted in a significant change in endurance.

For gains between groups, the basketball group improved more than the swimming group in leg strength, but not at a significant level. The swimming group improved more than the basketball group in endurance at the .01 level of significance.

In compendium, participating in basketball or swimming did not result in a significant change in leg strength or endurance during the experimental period as determined by a pre-test and post-test comparison. Within group gains resulted in a significant improvement at the .01 level in leg strength for the basketball group. Between group gains resulted in a significant improvement at the .01 level in endurance for the swimming group, however, the swimming group improved more in endurance than the basketball group.

Gray[1] dispatched questionnaires to 169 coaches listed in the 1950 Official National Collegiate Athletic Association Swimming Guide of which 112 were returned. Fifty-seven per cent of the coaches had some pre-season body-building program. Sixty per cent of the respondents recommended exercises for the development of lower back and abdominal strength as well as general flexibility. The remainder of the study considered such factors as fads, nutrition, training rules, and pool conditions.

Timmons[2] sent questionnaires to the coaches of the 1958 state high school champions and seventeen other strong teams. Twenty championship teams and the seventeen strong teams returned the questionnaires. The following results are

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[1]Norman A. Gray, "Training and Conditioning for Competitive Swimming," The Athletic Journal, XXXII (February, 1952), 14-15, 40.

[2]Bob Timmons, "Championship Swimming and Diving Coaches Methods," Scholastic Coach, XXIX (February, 1960), 46-49, 60-61.

relevant to this study: two of the thirty-seven used kicking ability as the basis for making cuts from the squad, twenty-two used weight training, nineteen employed overdistance, thirty-six recommended pacing, four worked more on kicking than other skills, thirty-one used repeated intervals and one made the comment that all kicking drills should be competitive.

Essick[1] sent questionnaires to the members of the 1956 United States Olympic swimming team. The questionnaire was based on the form used by Cureton for the investigation of the 1936 Olympic athletes. Three methods were used to score various sections of the questionnaire: short essay, "yes" or "no," and a ten-point rating scale.

The value of "kicking legs many lengths" was one of six items to be rated as "very highly preferred" and achieved a rating of 9.25 on the ten-point scale. "Kicking legs many lengths on a flutter board" was "highly preferred" (8.66 rating), while "kicking legs many lengths with hands at sides and practicing breathing" was "moderately preferred" (4.33 rating). All phases of kicking as a training method were ranked higher by the 1956 team than in Cureton's report of the 1936 team. Interval training was reported as the most preferred method of training. The researcher concluded that kicking the legs many lengths was a "very highly desirable" technique for training competitive swimmers.

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[1]Raymond Brooke Essick, "The Training Habits of the 1956 United States Men's Olympic Swimming Team" (unpublished Master's thesis, University of Illinois, 1958), pp. 1-72.

Lawrence[1] sent a questionnaire to 288 coaches listed in the 1965 Official National Collegiate Athletic Association Swimming Guide of which 158 were returned. The purpose of the study was threefold: 1) to gather information about conditioning practices currently used by coaches, 2) to compare collegiate coaching methods for swimming, and 3) to develop improved training methods from the compiled information.

Conditioning techniques were divided into two categories: "out-of-the-water conditioning" and "in-the-water conditioning." Ninety-four per cent of the coaches reported the use of some form of out-of-the-water conditioning programs, the most popular methods being pulley weights (67 per cent), barbells (61 per cent), calisthenics (69 per cent), and isometrics (61 per cent). More than half of those using pulley weights and barbells employed progressive resistance exercises. For in-the-water conditioning, 151 of the 158 coaches reported using kickboards for using legs only practice and twenty-three claimed to use fins. Sixteen used fins to increase ankle flexibility and twelve employed them to strengthen the hips.

A table was compiled to show the relationship of the amount of practice involving the use of arms only to that involving legs only. Coaches were instructed to compute the ratio to total 100 per cent. The three most common ratios

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[1]Lee Woods Lawrence, "Practices in Conditioning of Competitive Swimmers" (unpublished Master's thesis, Springfield College, 1965), pp. 1-107.

were: 50 per cent arms and 50 per cent legs (seventy-three teams), 60 per cent arms and 40 per cent legs (ten teams), and 75 per cent arms and 25 per cent legs (nine teams). All but one of the coaches used an interval training technique, with "repeats" being the most common. Two coaches reported they did not recommend practice using legs only while three stated they did not recommend the use of arms only. As a result of these findings, it was concluded that nearly all coaches use out-of-the-water conditioning, interval training techniques, and arms only-legs only practices. Kickboards are most commonly used for practice involving drills using the legs only.

Davis[1] undertook a study to determine the relationship of weight training to speed in swimming. Seventeen male college students who were former competitive swimmers or who were highly skilled, were administered two twenty-five yard speed tests and two fifty yard speed tests for the front crawl. In addition, the subjects practiced a series of eight weight exercises of eight to eleven repetitions each, three times a week for ten weeks. Pre-test and post-test times were compared and the mean difference changed significantly for both the twenty-five yard and fifty yard tests. The author concluded that weight training aided all subjects in increasing their speeds.

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[1]Jack F. Davis, "The Effect of Weight Training on Speed in Swimming," The Physical Educator, XII (March, 1955), 28-29.

Thompson and Stull[1] studied the relationship of five training programs to speed in swimming after six weeks. Eighty-one male students, aged seventeen to twenty-six, were randomly assigned to one of six groups: a control group, a weight training group, a swimming group which swam three times a week, a weight training-swimming group, a swimming group which swam six times weekly, and a swimming group which swam only sprints six times a week.

Significant improvement resulted for each group except for the control group and the weight training group. Each of the three swimming groups made greater improvement in speed than did the weight training-swimming group.

Training--Overload Principle and Interval Training

The main purpose of this section is to provide evidence of precedences which apply the overload principle and the concept of interval training to swimming. A great number of studies have been conducted on these two topics in a variety of sports. The reviews included here were chosen because of their particular pertinence to swimming.

Murray[2] completed a study to determine the relationship between exercising with pulley weights to the increase

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[1]Hugh L. Thompson and G. Alan Stull, "Effects of Various Training Programs on Speed of Swimming," Research Quarterly, XXX (December, 1959), 469-85.

[2]John L. Murray, "Effects of Precisely Prescribed Progressive Resistance Exercises with Pulley Weights on Speed and Endurance in Swimming" (unpublished Master's thesis, The Pennsylvania State University, 1962), pp. 1-128.

of speed and endurance in swimming. Thirty-one male swimmers at The Pennsylvania State University practiced forty minutes three times a week for six and one-half weeks with a week and a half layoff. Three speed tests of twenty yards each for kicking only, arm stroke only and the total stroke were administered as well as an endurance swim in which the swimmer had to maintain the rate of one yard per second. Eight tests of strength were measured by a cable tensiometer and harness. To complement the tests used in the study the three main aspects of the training program for the back crawl were kicking, swimming endurance and swimming speed. Swimming practice was the same for both groups, but the experimental group used pulley weights to supplement the swimming. When the subject could do three bouts of ten repetitions each for one weight exercise, the weight was increased.

Results were measured in terms of coefficients of correlation and "t" ratios between pre-test and post-tests. Significant correlations for both groups were found between swimming speed and kicking, and between kicking speed and swimming endurance. The gains in kicking speed favored the experimental group at the .05 level of significance. Both groups made significant improvements on the four swimming tests. In light of the findings, it was stated that a precisely prescribed progressive resistance weight program using pulley weights plus swimming practice resulted in a significant improvement in swimming speed for the whole stroke, arms only, legs only, and swimming endurance.

Lietuvietis[1] undertook a study to ascertain the relationship of isotonic and isometric leg exercises to the ability to propel oneself through the water with the front flutter, back flutter, and scissor kick. Fifty-five female students in the second semester of senior life saving at the State University of Iowa were divided into three groups. The isotonic group participated for four and one-half weeks in a progressive weight resistance leg exercise program, the isometric group with static leg contractions, and the control group with no exercises. A modified Fox Power Test and a Clarke cable tensiometer were used to obtain measurements for swimming and strength respectively. Composite means were calculated and mean gains were computed for individual kicking and strength tests. No significant mean gains resulted. There was little correlation between strength gains and swimming kick gains. In conclusion the author states that both of the exercise groups made more improvement than the control group, but not significantly so.

Clark[2] compared the results of swimming practice augmented by isometric exercises with those of swimming practice

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[1] Kaija Lietuvietis, "The Effect of Isotonic and Isometric Leg Exercises on Selected Swimming Kicks" (unpublished Master's thesis, State University of Iowa, 1958), pp. 1-55.

[2] David F. Clark, "The Effect of Prescribed Isometric Exercise on Strength, Speed and Endurance in Swimming the Crawl Stroke" (unpublished Master's thesis, Central Michigan State University, 1965), pp. 1-72.

alone. Clark's study parallels that of Murray with the exception that isometric exercises were employed rather than pulley-weight exercises. Thirty-two male freshmen and sophomores from the required physical education program who were classified as intermediate swimmers were tested for swimming speed, swimming endurance, arm strength, leg strength, and total arm and leg strength. Subjects were paired on the basis of strength and divided arbitrarily into two groups of sixteen each. A cable tensiometer attached to a harness was used for strength measurements. While in the harness the swimmer was tested for ten seconds for kicking, pulling and the whole stroke. The experimental group completed ten minutes of isometric exercises five times each week for eight weeks. Both groups swam for thirty-five minutes each day. The isometric exercises were performed in a prone position and simulated those movements used in swimming. Both groups made significant improvements in speed and endurance, but only the experimental group's improvement was significant for thrust. ["Thrust" was not defined in this study. The term appeared in the analysis of the data when Clark was referring to the measurements obtained from the harness tests.] In comparing the post-tests of the two groups, the experimental group made significant improvement over the control group in both thrust (.01 level) and speed (.05 level), but not in endurance.

Turkington[1] compared an interval training technique with a traditional method (warm-up, arms only, legs only, whole stroke, warm-down) for competitive swimming. Eighteen freshman and sophomore males who were candidates for the State College of Washington's swimming teams swam one hour a day, five days a week for five weeks. Two groups were established on the basis of time for two trials of 100-yards freestyle. The swimmers participated in a three-week pre-conditioning program to establish a base level for performance. No significant difference was found between the two groups, but the interval group improved two seconds more than the traditional group. It was also stated that the interval method was more interesting and motivating to the swimmers.

Rilea[2] undertook a study to determine if a significant difference in performance of the back crawl would occur while working in a fatigued as compared to a non-fatigued condition. The terms fatigue and overload were used synonymously. Twenty-five freshman and sophomore women from required physical education classes at Florida State University were selected on the basis of scores from Scott's Motor Ability Test, form while executing the back crawl, and

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[1]Harold David Turkington, "A Comparative Study of an Interval and a Traditional Method of Training for Competitive Swimming" (unpublished Master's thesis, State College of Washington, 1959), pp. 1-35.

[2]Rose Ellen Rilea, "The Application of the Overload Principle of the Improvement of Swimming Performance" (unpublished Master's thesis, Florida State University, 1960), pp. 1-22.

performance of practical tests in the water. The fatigue group swam the back crawl for endurance until the best swimmer was fatigued. The non-fatigue group swam until the weakest swimmer began to show signs of fatigue. The average time for three trials was used to compute critical ratios. No significant differences occurred between the two groups. The author concluded, however, that the fatigue group learned the same amount with equally good form in less time.

Davis[1] conducted a study to determine the relationship of two types of training to swimming speed. Forty-six advanced or competitive swimmers from the required physical education program at The Pennsylvania State University were divided into two groups. Practice sessions were held for forty-five minutes, three times a week for four weeks. The two groups swam the same distance each day but under different programs. Group A's program was comprised of a warm-up period, a kicking bout at eighty per cent pace, a pulling bout at eighty per cent pace, and a swimming bout of the whole stroke at maximum effort. Group B's program consisted of a warm-up period, a swimming bout of the whole stroke at eighty per cent pace and swimming bout of the whole stroke at maximum effort. A pre-experimental conditioning program of two weeks was used to reach a base physical performance level.

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[1]Michael Gary Davis, "Relative Effects of Two Types of Training on Speed Swimming" (unpublished Master's thesis, The Pennsylvania State University, 1965), pp. 1-67.

A comparison of pre-test with post-test scores indicated that both groups improved significantly in speed for the arm stroke, the kick and the total stroke. Post-test differences between groups were not significant for any of the three tests. Group A's scores were slightly faster for the kicking and the pulling bouts, but Group B was slightly faster when performing the whole stroke. The researcher concluded that neither method was significantly better than the other and both methods seem to be acceptable for improving the swimming speed.

Summary

Chapter II has presented a survey of literature which is relevant to the present study. For the most part, studies were selected which were conducted with swimmers. The literature was divided into five sections: analysis of the flutter kick; water resistance and propulsion; flexibility; exercise, weight training, and leg strength; and training--overload principles and interval training.

A survey of related literature revealed that swimming is indeed a complex activity involving many variables. In an attempt to clarify some of the more important aspects of swimming skills, researchers have found many opposing results. A summary of these results is shown in Table 1.

TABLE 1

SUMMARY OF LITERATURE RELATED TO THE FLUTTER KICK

Topic	Investigator	Year	Comment
Ankle and Flexibility	Cureton	1930	ankle flexibility directly related to speed.
	Cureton	1941	swimmers more flexible than general college population.
	Pickens	1950	swimmers more flexible than general college population selected athletic groups, particularly at the ankle.
	Robertson	1960	above average ankle flexibility is desirable.
	Smith	1962	ankle flexibility not related to speed.
	Hockey	1965	ankle flexibility not related to speed.
	Jacobsen	1967	swimmers more flexible than high school non-swimmers.
	Collins	1968	ankle flexibility directly related to speed.
Relationship of Arms and Legs to the Whole Stroke	Cureton	1930	contribution of arms and contribution of legs = over 100%.
	Wilson	1933	arms contribute 1.7 times more than legs.
	Karpovich	1935	contributions of arms to legs dependent upon the ability of the swimmer--poor = 77% arms, 23% legs; skilled = 70% arms, 30% legs.
	Moyle	1936	modified Karpovich's prediction formula for whole stroke from known arms and leg velocities.
	Lewis	1941	contributions of arms and contributions of legs = over 100%; legs contribute more than Karpovich and Wilson state.
	Allen	1948	depends on depth and speed of legs; slower kick assists less; arms contribute 1.40 times more than legs from skilled swimmer.

TABLE 1--Continued

Topic	Investigator	Year	Comment
	Puolos	1949	modified Karpovich's prediction formula for whole stroke from known arm and leg velocities.
	Alley	1952	depends on depth and speeds of legs.
	Thrall	1960	depends on depth and speeds of legs.
	Adrian, et al	1966	legs require 3-4 times as much oxygen as arms.
Leg Strength	Kingston	1961	swimming will increase leg strength.
	Parchman	1961	swimming will not increase leg strength.
Width of Kick	Cureton	1930	depends upon physique of swimmer.
	Allen	1948	approximately 12" is most effective.
	Puolos	1949	approximately 12" is most effective.
	Alley	1952	approximately 12" is most effective.
	Thrall	1960	approximately 12" is most effective.
Exercise and Weight Training	J. Davis	1955	weight training and swimming effective.
	Lietuvietis	1958	isometrics not significant but trend is evident.
	Thompson & Stull	1959	weight training and swimming effective.
	Kingston	1961	swimming more significant than exercise.
	Murray	1962	pulley weights and swimming effective.
	Clark	1965	isometrics effective.
Methods of Training	Turkington	1959	traditional vs. interval, not significant.
	Rilea	1960	overload, trend but not significant.
	M. Davis	1965	traditional vs. interval, not significant.

CHAPTER III

PROCEDURES

The present investigation was designed to determine whether training in a horizontal body position or a vertical body position resulted in a significant difference in the ability to perform the flutter kick with relationship to kicking speed, velocity of the legs, and ankle flexibility. Eleven college women who were members of the Texas Woman's University competitive swimming team during the spring semester of the academic year 1970-1971 and eleven college women who had at some time been a member of a competitive team, were divided into four equated groups for training purposes.

This chapter presents the procedures used in collecting data and has been divided into eight sections: sources of data, preliminary procedures, selection of subjects, procedures and organization prior to testing, development of the training program, collection of the data, treatment of the data and the final report. A brief summary of the procedures will be presented at the conclusion of the chapter.

Sources of Data

The data utilized in the present study were gathered from both documentary and human sources. The human sources included twenty-two college women, eleven competitive swimmers and eleven ex-competitive swimmers who were enrolled at the Texas Woman's University during the spring semester of the academic year 1970-1971. Other human sources included correspondence with selected authorities in the field of swimming: Dr. James Counsilman, Dr. Peter Karpovich, Dr. Thomas Cureton, and Albert Schoenfield, the editor of Swimming World magazine.

The documentary sources included books, periodicals, pamphlets, handbooks and bulletins related to the subject area. Theses, dissertations and other unpublished materials were also consulted. Relevant microcards and microfilms were viewed.

Preliminary Procedures

A comprehensive survey, study and assimulation of documentary information were conducted prior to the actual collection of data. Criteria was established for the selection and construction of the daily treatment program and for the selection of instruments to be used for the measurement of kicking speed, velocity of the legs and ankle flexibility. The swimming coach at the Texas Woman's University was contacted and permission was obtained to allow the competitive swimming team to participate as subjects for the experiment. A tentative outline was developed and presented at a Graduate Seminar with the approval of the dissertation committee. A copy of the outline was filed as a Prospectus in the Office of the Dean of Graduate Studies at the Texas Woman's University, Denton, Texas.

Selection of Subjects

During the first week of March, the investigator visited each of the swimming classes being offered at the Texas Woman's University spring semester of 1971. Permission was received from each instructor to ask if anyone in the class had had previous competitive experience in swimming. ("Competitive" was defined as having been in a race that was conducted in an official manner, such as in city recreation meets, at camp, or in a school activity.) Those meeting the criteria were asked to raise their hands and then meet briefly with the investigator for the purpose of explaining the investigation procedures. Women who were willing to participate in the study were asked to report to the pool deck Thursday, March 11 at 5 P.M. The number of subjects obtained in this manner was not sufficient so two alternate methods were used to obtain the additional number of ex-competitive swimmers needed for the study.

The second method used to obtain subjects was to follow the same procedures in classes for physical education majors. The number was still not sufficient. The investigator then asked subjects who had already volunteered for the study to appeal to friends or acquaintances who might be willing to participate in the study. As a fairly high drop out rate was anticipated due to the demands of the treatment, the goal was to obtain twenty ex-competitive swimmers, but only seventeen were obtained by the day the experiment was scheduled to begin.

The competitive swimmers were obtained by permission of the swimming coach. At the beginning of the experiment, the competitive group consisted of thirteen swimmers.

Procedures and Organization Prior to Testing

Prior to the first testing and training session pilot projects were conducted, handout sheets were constructed, and a testing, filming and workout schedule was developed. The procedures used to create the training program are presented in the section entitled "Development of the Training Program."

Pilot Projects

Prior to the first testing period and workout, two preliminary investigations were conducted. To determine the correct speed for filming and to anticipate any lighting problems that might occur, two swimmers from the recreational swimming period were asked to perform in front of the underwater observation window. Films were taken at the rate of sixty-four and thirty-two frames per second. Two lighting conditions were tested, that of overhead lights only and that of overhead lights supplemented by underwater lights. It was determined by these tests that thirty-two frames per second with only the overhead lights in use provided the best conditions for this investigation.

The second preliminary test was conducted with regard to the unit of time to be used for the first week of workouts for the ex-competitive groups. The investigator visited a lifesaving class and asked the entire group to kick in a vertical position to determine the length of time that they could maintain themselves in the water. The students were instructed to kick as hard as possible and to try to raise their shoulders as far out of the water as possible by the force of their kick. The subjects could maintain maximum elevation for the total time of three to five seconds. This time was used as a basis to determine the work intervals for the ex-competitive groups in the workout schedule. No member of the experiment was in the class used for the pilot study.

Handouts

A "Swimmer's Data Sheet" which was to be distributed at the first session was constructed (see Appendix A). The data sheets were divided into two groups, one to be marked with red ink and one with blue. The sheets were numbered "1" and "2" alternately in the upper left-hand corner in the space marked "Test Group." In addition to obtaining background information and recording test scores for speed of kicking, supplementary uses of the sheet were made as is explained in the section, "Collection of the Data--General."

A second handout sheet, "Instruction and Information Sheet for the Flutter Kick Experiment," was prepared in order to give the subjects printed information about the general procedures for the experiment and to give instructions to the vertical group (see Appendix B). The sheet served the purpose also of a reminder of the subject's commitment to the project once it began.

Schedule

The program of testing, filming and training was to extend for a period of approximately six weeks including a one week layoff for spring holidays (see Appendix C). The first testing and filming dates were scheduled for 5 P.M. Thursday and Friday, March 11 and 12, at the swimming pool of the Texas Woman's University, Denton, Texas. The second testing and filming were administered at the conclusion of the third week of practice after fourteen daily workouts. The third speed testing session was conducted on the Wednesday that the students returned from vacation. The final speed testing session was held Friday, April 23, six weeks after the commencement of the initial training session. Workouts were conducted after testing and filming on the days of testing with the exception of the first and final test.

Development of the Training Program

Primary concepts from the principle of overload, interval training, sets of repeats and progressive weight training theories were incorporated into the training schedules. Maglischo explains the principle of overload as:

> It is a physiological fact that strength can be increased only by the muscle contraction against a resistance that calls forth effort. The degree of increase depends upon the degree of resistance, with maximal strength being produced by maximal effort. During training, as a muscle increases in size and strength, the load against which the muscle is working (developing tension) must become progressively greater and greater. This is the overload principle. To develop muscle strength and increase muscle size, muscles must be driven to do work beyond the work that is performed easily and comfortably.[1]

Walters[2] states further that "The Overload Principle is the universally accepted method of developing strength. Working in Overload means performing against increased resistance."

Maglischo also provides a definition of interval training as:

> By definition, the interval system requires the athlete to swim a certain distance a specified number of times (repeats) at a given rate of speed, with a uniform interval of rest between repeats. This suggests four variables: (1) the number of repeats, (2) the distance per repeat, (3) the rest interval between repeats, and (4) the rate of speed per repeat. . . .The two most commonly used methods of 'grading the intensity,' or overloading are: (1) increasing the number of repeats, and (2) decreasing the rest interval.[3]

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[1]Ernest W. Maglischo, "Overload Principles in Swimming Conditioning," Scholastic Coach, XXXIV (September, 1964), 66.

[2]C. Etta Walters, "Scientific Foundations of the Overload Principle," Scholastic Coach, XXVII (April, 1958), 20.

[3]Maglischo, p. 67.

Kinnear relates these principles to swimming as:

> . . . (a) repeated speed work on short distances (i.e. less than racing distance) is better than overdistance repetitions; (b) the pace and intensity of work must progressively increase as the season develops; (c) the swimmer experiences fatigue and learns to combat and overcome the symptoms; confidence is therefore gained.[1]

Counsilman makes further reference to interval training and swimming:

> The less the amount of rest, the slower the repeat will be, and soon the swimmer will lose the benefit of being able to swim at or near racing speed. Sometimes a longer period of rest is allowed between repeat swims to permit the swimmer to go all-out.[2]

In his book Counsilman refers to interval training as DIRT--Distance to be swum, Interval for rest, Repetitions for number of repeats and T for time or pace ("effort").[3] He also points out that the differences in definitions for "interval training," "repetition training," and "repeat swims" are very slight and sometimes, though incorrectly, used interchangeably.[4] Doherty[5] confirms this statement by explaining that even the principle of interval training is not new, but

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[1]Bert Kinnear, "A System of Training," in Swimming as Taught by Experts, ed. by Bill (W. J.) Juba (New York: Arco Publishing Company, Inc., 1961), p. 63.

[2]Counsilman, Science of Swimming, p. 83.

[3]Ibid., p. 205.

[4]Ibid., p. 214, 215, 216.

[5]Ken Doherty, "Interval Training, Part II, Setting Up a Basic Program," Scholastic Coach, XXV (March, 1956), 24.

is simply a new terminology. Over the past forty-five years, terms such as "ins and outs," "wind sprints," "repeated speed work," and "Fartlek" have been used, but these all were based on the same cardinal principle as the current "interval training."

Criteria and the Resultant Development of the Training Program Sequence

In addition to the above information regarding training programs as applied to swimming, selected statements representative of several authors' opinions, as criteria for the development of the program constructed for this study are as follows:

1. Choice of the overload and interval training with progressive weight resistance incorporated:

   Murray:[1] "The modern theory is that strength is best developed through exercises against an extra overload on the muscles and increasing resistance to movement."

   Kinnear:[2] Progressive overload or resistance is essential to the development of maximum potential.

   Lietuvietis:[3] "Progressive resistance exercises are exercises done against a progressively increased resistance load utilizing the overload principle."

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[1]Murray, p. 1.

[2]Kinnear, p. 62.

[3]Lietuvietis, p. 4.

Kingston:[1] The body itself may be used as a resistance. Resultant: The vertical position assumes the application of the principles of overload and progressive weight resistance. Progressive weight resistance was assumed to be a "built-in" factor for the vertical position, i.e., the stronger the kick, the higher the body rises out of the water; the higher the body rises, the more resistance (weight) for the legs to overcome. The body was considered the resistance weight.

2. Choice of the title and program sequence:

Carlile:[2] "Interval" training is a broad term that must be modified by another term to be meaningful communication.

Young:[3] A "locomotive" swim is a progression of building up and reducing the number of lengths in sequence, i.e., one, two, three, two and one.

Counsilman:[4] There are nine types of "sets of repeat swims." A "mixed set" implies neither the distance nor the rest interval are held constant. A "broken set" implies a number of repeat swims with short rest intervals, followed by a long rest and then another set of repeat swims.

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[1] Kingston, p. 9.

[2] Carlile, p. 25.

[3] Leonard Young, "Characteristics of In-Water Training," Scholastic Coach, XXXIV (September, 1964), 105.

[4] Counsilman, Science of Swimming, pp. 217-224.

Resultant: The program sequence was constructed on the principle of "locomotive-repetition interval training with mixed and broken sets."

3. Choice of the program time limit:

Counsilman:[1] If the psychological principles of learning are applied no one drill should be conducted for over a maximum of twenty minutes.

Armbruster and Morehouse:[2] Approximately one-fourth of the workout time should be used for kicking drills.

Resultant: Total program for each day was fifteen minutes.

4. Choice of the work-rest intervals:

Kinnear:[3] The distance swum in a repeat should be less than or the same distance the swimmer is training for.

Counsilman:[4] Overdistance contributes to the development of endurance, short distances to speed. Correspondingly a shorter rest interval contributes to the development of endurance, a longer rest to speed.

Counsilman:[5] During the rest intervals the swimmer may stop completely, but remain in the water; stop completely and get out of the pool; or swim easily.

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[1]James E. Counsilman, "Principles of Training," The Athletic Journal, XLII (September, 1961), 20, 80-84.

[2]Armbruster and Morehouse, p. 197.

[3]Kinnear, p. 63.

[4]Counsilman, Science of Swimming, p. 229.

[5]Ibid., p. 231-32.

Resultant: Work and rest intervals were determined for the ex-competitive group by the time of the slowest swimmer for kicking twenty-five yards and by the length of time the pilot study indicated for persons who were not in condition to kick in the vertical position. Work and rest intervals for the ex-competitive and competitive groups differed although the total time for each work-rest interval sequence was the same. Rest intervals for the competitive group were calculated at approximately one-half to one-third of the work interval. The rest intervals for the ex-competitive group were comparatively longer to allow the subjects to maintain the quality of their performance and to allow both groups to start each interval sequence at the same time. No instructions were given to the subjects regarding the rest interval. Short time sequences were employed with the purpose of developing speed, with one long sequence at the top of the "locomotive" included for increasing endurance.

5. Choice of the number of repeats:

Counsilman:[1] The number of repeat swims depends upon the time available for practice and the event for which the swimmer is training.

Maglischo:[2] Controlled progression within an interval system enables the swimmer to achieve a higher level of

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[1] Ibid., p. 229.

[2] Maglischo, p. 66.

endurance in a shorter period of time than other methods.

Resultant: The number of repeats included was based upon the total time chosen for practice (fifteen minutes) and the length (twenty-five yards) of the event for which the swimmers were training. Controlled progressions were based on mixed and broken sets within the basic framework of the locomotive pattern.

6. Choice of shortest interval:

Young:[1] Workouts should end with a few short power sprints.

Matthews:[2] Sprints should be "all out" with short intervals between sprints.

Resultant: Workouts began and concluded with a series of short intervals for the purposes of warm-ups and power-finishes respectively.

The workout pattern sequence developed from this criteria (see Appendix E) was used to devise a weekly training program (see Appendix D). Explanation for the use of the program is found in the section entitled, "Collection of the Data--General Procedures."

Collection of the Data

A review of the literature regarding testing procedures used in swimming investigations revealed that direct

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[1]Young, p. 102.

[2]Dave Matthews, "Interval Training in Swimming," Scholastic Coach, XXVIII (November, 1958), 61.

observation (Cureton[1] and Armbruster and Morehouse[2]), motion picture films (Collins[3] and Sanders[4]), towing mechanisms (Alley,[5] Thrall[6] and Hairabedian[7]), natographs (Karpovich[8] and Alteveer[9]), mechanical devices (Lewis[10] and Robinson[11]), and graph analysis (Mosterd and Jongbloed[12] and Osborn[13]) appear to be acceptable methods of collecting data. The two methods of collecting data used in this investigation were Cureton's Stop Watch Method[14] to measure kicking speed and a

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[1]Cureton, "Mechanics and Kinesiology," p. 102.

[2]Armbruster and Morehouse, p. 7.

[3]P. Collins, pp. 1-176.

[4]C. Sanders, pp. 1-49.

[5]Alley, p. 253.

[6]Thrall, p. 19.

[7]Ara Hairabedian, "Kinetic Resistance Factors Related to Body Positions in Swimming" (unpublished Ed. D. dissertation, Stanford University, 1964), pp. 1-58.

[8]Karpovich, "Speed Analyzed," p. 224.

[9]Robert J. G. Alteveer, "A Natographic Study of Various Swimming Strokes (unpublished Master's thesis, Springfield College, 1958), pp. 1-72.

[10]Lewis, p. 7.

[11]Robinson, p. 8.

[12]Mosterd and Jongbloed, p. 288.

[13]Osborn, p. 60.

[14]Thomas Kirk Cureton, "The Stop Watch Method for Testing Speed," Beach and Pool, IV (February, 1930), 15, 17-19, 32-34.

motion picture frame analysis to determine velocity of the legs and flexibility of the ankles. All measurements were taken while the subject was performing in the water.

This section is divided into three topic areas: general procedures, kicking speed, and velocity of the legs and ankle flexibility. The general procedures provide an overall picture of the collection procedures while the remaining two sections are specific in content.

General Procedures

During the first meeting, subjects were given the "Swimmer's Data Sheet" (see Appendix A). The data sheets had been previously divided into two groups, one marked with red ink and one marked with blue ink. As the subjects arrived at the pool deck they were asked whether they were a team member or an ex-competitive swimmer. The competitive team members were given sheets in red ink, while the ex-competitive group received those marked in blue ink. The data sheets were used both to obtain background information about the subjects as well as to obtain a random selection for those subjects who would be performing their first trial from either the deep ("1's") or shallow end of the pool ("2's").

Two days were allowed for the pre-testing sessions. An orientation to the study was given to the subjects during the first meeting (see Appendix F). Testing equipment was collected and examined prior to the subjects' arrival at the pool. Personnel used for the testing session were instructed to arrive fifteen minutes earlier than the subjects (see Appendix G). The tester, assistant tester, and second assistant had been given instructions prior to the testing period (see Appendix H).

A summary of the general procedures used in the collection of data and brief statements of the information contained in Appendixes A, B and F are as follows: Subjects were handed the appropriate Swimmer's Data Sheet as they arrived at the pool. An orientation period was conducted to explain the experiment and the testing procedures for the day. At the completion of the presentation there was a question and answer period prior to the actual testing. Practice time had previously been established at 5 PM daily, however, due to class conflicts, Tuesday and Thursday practices were changed to 5:30 PM.

The testing procedures for the day were explained to the subjects. Swimmers then went to the appropriate end of the pool for the first kicking trial. The data sheets were handed to the tester just prior to the subject entering the water. At the completion of the three trials, the data sheets were handed to the second assistant who computed the average time of the three trials for each subject. The sheets were divided into two groups according to the red or blue ink numbers with which they were marked. The sheets were arranged in rank order for average time within the two groups. Both the competitive and ex-competitive groups were then divided into two sub-groups according to their average time rank. A coin was flipped to determine which of the two sub-groups of competitive and ex-competitive swimmers would be the experimental or vertical group. The subjects thus assigned to the experimental or vertical groups were marked for filming. Filming procedures were then administered as found in the third portion of this section.

All four groups reported for practice on Monday and the initial training session was conducted. The vertical and horizontal groups executed identical programs. The competitive swimmers training sequence, however, was more difficult than that of the ex-competitive swimmers (see Appendix E). Workouts were progressively more difficult each week for both the competitive and ex-competitive groups, with the exception of the fifth week when the same training schedule as the fourth week was used. The fourth week sequence was of sufficient difficulty for the purpose of this study.

At the beginning of each training session, subjects checked in on a roll sheet. Any absences were made up if at all possible. Any subject missing more than three sessions without making up the sessions was dropped from the study.

Timmons[1] reported that fourteen of the thirty-seven coaches surveyed had teams practice kicking by holding onto the edge of the pool. It was determined that this method was

[1]Timmons, p. 49.

comparable to the vertical position as the legs kicked continuously without interruption from turns, the body was in a relatively stationary position, and the use of a floating object (which might affect the validity of the testing procedure) was avoided.

At the beginning of each session the subjects assumed their appropriate positions for practice. The workout program was established so that training could proceed on a three whistle command program. The investigator was stationed at the edge of the pool with a whistle, stopwatch, and the training program sheet for the week (see Appendix E). At the sound of the first whistle all of the subjects started kicking. On the second whistle the ex-competitive group stopped kicking, and on the third whistle the competitive group stopped. Rest intervals had been determined so that all subjects started to kick again on the next whistle. When the first sequence for the day was completed, the subjects had from three to one minutes rest depending on the week of the workout. Five seconds before the rest period was over the subjects were told to assume their positions again to repeat the workout. The investigator made a checkmark in the appropriate column each time the whistle was blown to assure that the proper sequence was followed.

Kicking Speed

Data to determine changes, if any, in kicking speed were collected from three trials of twenty-five yards kicking only for four testing periods dispersed over a five week period of time. A pre-test was administered during the first session followed by a second test after fourteen training sessions. The third test was administered nine days later after the students had returned from spring vacation. The final tests were given at the end of the sixth week of the experimental period (see Appendix C).

The speed test was constructed on the basis of kicking twenty-five yards "legs only" (Hewitt,[1] Fox,[2] and Wilson[3]), using an inflated ball to support the arms (Hewitt,[4] and Adrian, Singh, and Karpovich[5]), and starting from a "dead start" (Karpovich,[6] R. Smith[7] and Cureton[8]). Karpovich[9] stated that body length is a constant factor for each subject within each trial.

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[1]Jack E. Hewitt, "Achievement Scale Scores for High School Swimming," Research Quarterly, XX (May 1949), 171.

[2]Margaret G. Fox, "Swimming Power Test," Research Quarterly, XXVIII (October, 1957), 233.

[3]Wilson, p. 29.

[4]Hewitt, p. 171.

[5]Adrian, Singh and Karpovich, p. 1763.

[6]Karpovich, "Propelling Force," p. 49.

[7]R. Smith, p. 8.

[8]Cureton, "Stopwatch Method," p. 17.

[9]Karpovich, Ibid., p. 53.

Time trials were conducted with an Apollo "7-Jewell," thirty second sweep hand stop watch number 76798 obtained from the College of Health, Physical Education, and Recreation at the Texas Woman's University. The same watch was used for all testing sessions. The playground ball was also acquired from the College. A seven inch playground ball, rather than a water polo ball as used by the other investigators cited, was used because it is lighter and should, therefore, cause less resistance in the water.

A summary of the testing instructions for the kicking trials, which may be found in Appendix F, Part III, numbered 1-14, is stated as follows: The subjects dispersed to the appropriate end of the pool for the first trial. Subjects entered the water one at a time as it was their turn to perform. A prone floating position was assumed with the arms overhead. A playground ball measuring seven inches in diameter was held with one hand placed directly on each side of the ball. Instructions were given to not push down on the ball while kicking.

The legs were fully extended with the foot plantar flexed to eliminate the possibility of a push-off. The assistant tester held the subject lightly about the ankles to keep the toes in contact with the wall. Testing commands of "one," "two," "go," were given in an even rhythm in an attempt to avoid differences due to reaction time. At the word "go" the assistant released the ankles. On the count of two the subject took a deep breath and on the word "go" the subject lowered her head into the water to approximately eyebrow level, while at the same time the assistant released the ankles. The subjects were instructed not to breathe more often than necessary, but when a breath was needed, the face should be lifted forward (neck hyperextended) and then lowered back into the water. The time trial was completed when the ball touched the edge of the pool at the opposite end from the starting position.

The second trial started at the end of the pool where the first trial was completed, thus, one half of the group performed two trials from the shallow end and one from the deep end of the pool, while the other half executed two trials from the deep end of the pool and one from the shallow. This procedure was included as a means of counteracting any currents that might be present in the pool.

Certain weaknesses were inherit in the method used. The lesser skilled swimmers may push the ball further down into the water than the highly skilled swimmers, resulting in even greater differences in time than already existed. Karpovich[1] has shown that lifting the head to breathe lowers the legs and increases the resistance caused by the legs. Counsilman[2] indicated that rolling from side to side and breathing increases resistance also, so breathing to the side

[1]Karpovich, "Water Resistance," p. 26.

[2]Counsilman, "Forces in Swimming," p. 138.

is not necessarily a better method. A swimmer who was not in good physical condition was most likely to be penalized by breathing more often than the other subjects.

Velocity of the Legs and Ankle Flexibility

Data to determine changes, if any, in velocity of the legs and ankle flexibility while flutter kicking in a vertical position were collected from a frame analysis of filmed records. Two sets of data were collected, a pre-test filming conducted during the first session and a post-test filming after fourteen training sessions (see Appendix C).

Filming procedures were developed mainly from the processes used by Collins[1] and Osborn.[2] Both investigators marked the subjects for filming and then conducted a frame analysis to calculate measurements of velocity and distance. Each frame of film to be analyzed was projected onto a piece of paper. Markings on the subject were then traced on the paper and measured with a micrometer. Reliability was established from remeasuring each frame three times. Calculation of speed was determined from the film speed of the camera.

In this investigation a tripod and 70 H. R. Bell and Howell sixteen millimeter camera with Tri-X black and white reversal film was used to collect data. Films were taken at the speed of thirty-two frames per second through an

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[1]P. Collins, pp. 38-43.

[2]Osborn, pp. 13-15.

underwater observation window measuring seventeen and three-fourths inches by twenty-five and three-fourths inches.

The subjects were marked for filming with a black Eberhard Faber MARKette. Dots the size of a nickel were drawn on the proximal head of the fibula, the lateral malleolus and the side of the small toe on the right leg for filming from the lateral view. The second toe and a mid-point between the malleoli were marked on the right leg for the frontal view (see Appendix I).

A summary of the testing instructions for filming which may be found in Appendix F, Part III, Number 15, is stated as follows: At the completion of the twenty-five yard kicking trials, subjects in the vertical groups reported to the deep end of the pool for filming. On the directive of the tester, subjects entered the water one at a time, faced the wall in front of the observation window, and held onto the edge of the pool with both hands. When given the command "start" the subject released the edge of the pool and placed the palms of their hands on the lateral sides of the thigh. The subjects were told to maintain an upright position and flutter kick as rapidly as possible, while trying to keep the mechanics of the kick as similar as possible to those used in a horizontal position. At the signal "stop," the subjects placed their right hands on the edge of the pool and turned their right side toward the observation window. The same procedure for commands was used to film the kick from a lateral view. The subjects arm length provided a constant for distance from the observation window.

A Dagmar Super Microfilm Reader Model A was used to project the film one frame at a time on a white sheet of paper measuring eight and one-half by eleven inches. The microfilm reader was adjusted so that the projected image of the underwater window measured five and nine-sixty-fourths inches in length which was one-fifth of the actual window size. This procedure provided a multiplier of five which was used to convert the obtained measurements to actual size.

The microfilm reader was positioned so that the front edge of the reader was parallel to the wall on which the film was being projected. The reader projected three frames at one time. The middle frame of those projected was used to avoid the distortion caused by the angle of projection. The center of the middle frame was placed at the center of the lighted area which was produced by the projection light (see Appendix J). A straight edge was placed at the left-hand edge of the middle frame to help assure the placement of the analysis sheet at a right angle to the projected image and to provide a marker for centering each frame. This procedure helped assure constant measurements and avoided lateral distortions. The upper-right hand corner of each analysis sheet was tabbed with black ink. This tab was placed at the top of the frame projected to the right of the frame being analyzed and was used as an additional method of placing the analysis sheet at a right angle to the projected image. Such a placement of the analysis sheet at right angles to the projected image was of particular importance in the velocity measurements as all markings were superimposed on the same analysis sheet. The corners of the window were also traced onto each analysis sheet to assure constant measurement for the velocity measurement and to provide a procedure to verify the size and position of the projected image.

The frontal view of the kicker was analyzed first. The film was scanned to determine in which frame the ankle had reached maximum plantar flexion and inversion. The frame was marked so that it was identified for the reliability retest. The center of the reference dots on each subject's body were marked on the paper and lines were drawn to connect the three dots. The angle was measured with a Sterling protractor number 544 and recorded. The film was rolled forward until the next view of maximum plantar flexion-inversion was observed and the same measurement procedures were followed on a second analysis sheet. Again, the frame was marked for future reference. The entire process was repeated for a third time. An average of the measurements obtained from the three frames was used for the statistical analysis. The marked frames were re-measured on a subsequent day in order to establigh reliability. This procedure was followed for each subject from each set of film data.

The same procedures were used for the lateral view of the kicker to determine velocity of the legs and plantar flexion. The film was scanned to determine in which frame the right leg began forward movement. The three reference points were marked on the analysis sheet. The film was moved forward two frames and the reference points were again marked on the analysis sheet. The film was then moved forward another two frames and the points marked for the third time. Each of the analyzed frames was marked for future reference so that it was identified for the reliability retest. Lines were drawn to connect the reference dots. The distance between the reference dots representing the malleoli was measured with a General Metal Ruler number 309 which measured to one sixty-fourth of an inch. These three composite lines from three separate frames were superimposed on the analysis sheet and resulted in one measurement of velocity. The film was then rolled forward until the right leg was again starting forward motion and the same procedures were followed. The entire process was repeated a third time. These three composite measurements were averaged and used as the statistic for the analysis. An example of the analysis sheet is found in Appendix K.

The distance thus assessed from the frame analysis was multiplied by the "multiplier"[1] (based on actual window

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[1]Thomas Kirk Cureton, "Elementary Principles and Techniques of Cinematographic Analysis," Research Quarterly, X (May, 1939), 8.

size and projection size) and then divided by time to calculate velocity. The time in seconds was determined by using the film speed of the camera. Four frames of exposed film at thirty-two frames per second was equivalent to one eighth of one second. In summary, measurements obtained from the analysis were multiplied by five and then divided by one-eighth to provide the velocity readings in inches per second.

Ankle flexibility measurements for the lateral view were determined from the lines drawn for the velocity readings. The line with the most obtuse angle was the statistic used for the analysis. Procedures explained for ankle flexion-inversion from the frontal view were employed for the lateral view.

Certain weaknesses were inherent in the method used. The subjects had not had previous experience with the vertical position for the first filming. The films may show erratic movements by the kicker as no time was provided for adjustment to the vertical position. Secondly, the twenty-five yard kicking tests conducted prior to the filming may have effected the degree of ankle flexibility as Moore[1] indicates that warm-up increases flexibility from six to thirty-eight per cent. However, all filming was completed after warm-up which should result in a constant error.

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[1]Kenneth Moore, "The Effects of Warm-Up Exercises on the Flexibility of Boys, Twelve, Fourteen and Sixteen Years of Age" (unpublished Master's thesis, University of Oregon, 1953), p. 19.

Treatment of the Data

Procedures used for the treatment of the data include the statistical equation of the vertical and horizontal groups of the competitive and ex-competitive swimmers on the basis of kicking speed. The homogeneity of the two groups was determined on the initial test group of thirteen competitive swimmers and seventeen ex-competitive swimmers. The same statistical device was used to determine if those subjects remaining in the study through the final testing session were still homogeneously grouped on the basis of the initial tests.

The mean, standard deviation and standard error of the mean were computed for each of the four groups from the data obtained from each testing session. Computations were made using either an Olivetti Underwood Programma 101 computer or a Monroe 770 calculator.

A t-test of differences between the means of paired observations was calculated to determine if there was a significant difference in kicking speed after a one week lay-off. A t-test was also utilized in comparing the means of trials one and four. This procedure was necessary as the result of losing two subjects from the ex-competitive horizontal, group within the last three days of the investigation.

The study consists of two research designs. A three-factor mixed design with repeated measures on one factor was used to determine the significance of the data for kicking speed over twenty-five yards. A two-factor mixed design with repeated measures on one factor was used to analyze both the data from the film analysis for ankle flexibility and the data for velocity of the legs. The analysis of the data, supplemented by graphs and tables, is presented in Chapter IV.

Final Report

A final written report of the investigation was prepared. The final chapter of the report included a summary, discussions, conclusions and recommendations based on the statistical analysis of the data and on the observations of the investigator. Bound copies of the study were filed in the appropriate places at the Texas Woman's University.

Summary

Chapter III has presented the procedures used in the development of this study. These procedures included those which were related to the sources of data, preliminary procedures, selection of the subjects, procedures and organization prior to testing, development of the training program, collection of data, treatment of the data, final report and a summary.

Twenty-two women, eleven competitive swimmers and eleven ex-competitive, who were enrolled at the Texas Woman's University during the spring semester of the academic year 1970-1971 were subjects for an investigation to determine whether training in a horizontal or vertical body position resulted in a significant difference in the ability to perform the flutter kick in relationship to kicking speed, velocity of the legs and ankle flexibility. Speed was determined by the stopwatch method while velocity of the legs and ankle flexibility were calculated from a frame analysis of motion picture film.

The subjects were divided into four groups on the basis of the average kicking time for three trials of kicking twenty-five yards. The four groups were competitive, vertical; competitive, horizontal; ex-competitive, vertical; and ex-competitive, horizontal. Both competitive groups performed identical interval workout programs at the same time with body position being the only variable. Both ex-competitive groups performed a similar but less stringent program than that of the competitive group. The four testing sessions for speed of kicking included pre-tests, tests after three weeks of practice, tests after a one week lay-off for spring holidays and tests after two additional weeks of practice. The data from the kicking speed tests were analyzed as a three-factor mixed design with repeated measures on one factor. The two testing sessions for filming were a pre-test and a post-test after three weeks of practice. The data from the frame analyses were treated as a two-factor mixed design with repeated measures on one factor.

Chapter IV will present an analysis of the data. Chapter V will present a summary, discussion, conclusions and recommendations based on the analysis of the data.

CHAPTER IV

ANALYSIS OF THE DATA

This chapter presents a statistical analysis of the data obtained from an investigation of training to perform the flutter kick in a horizontal and a vertical body position. Eleven competitive and eleven ex-competitive college women swimmers trained for fifteen minutes five days a week for three weeks, rested for one week, and continued training for two additional weeks. The two classifications of swimmers were each divided into matched groups, one practicing in a horizontal position and one in a vertical position. Training programs for the two groups were identical, the only variable being the body position. Each group was tested for speed in performing the flutter kick and the vertical groups were filmed from two different views.

The remainder of this chapter is divided into four sections which describe the analysis of data obtained 1) for equating the groups, 2) from the kicking speed tests, 3) from the film analysis, and 4) a summary. Raw data from the speed tests and film analyses are found in Appendix L.

Equating the Groups

Groups were equated on the basis of the average time for three trials of performing the flutter kick during the first test period. Table 2 presents the pre-test results for kicking twenty-five yards using the flutter kick while the arms were supported with an inflated seven-inch playground ball. The competitive vertical group's mean was 27.8660 seconds with a range from 22.900 to 34.600 seconds. The standard deviation was 3.8631 seconds and the standard error of the mean was 1.5771. The competitive horizontal group's mean was 27.6328 with a range of 23.400 to 32.766 seconds. The standard deviation was 3.2521 seconds and the standard error of the mean was 1.3278.

TABLE 2

EQUATING OF GROUPS

Group	N	Mean	Range	SD*	SE_M*	t*	p
Competitive Vertical	6	27.8660	22.900 34.600	3.8631	1.5771	0.1032	
Competitive Horizontal	6	27.6328	23.400 32.766	3.2521	1.3278		
Ex-competitive Vertical	9	34.5663	27.566 44.200	6.0716	2.0239	0.4438	
Ex-competitive Horizontal	8	33.2580	27.600 43.000	5.2467	1.8550		

[1]Table df 8, t (.05) = 2.262
*See Appendix M for Formulas

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[1]James L. Bruning and B. L. Kintz, Computational Handbook of Statistics (Glenview, Illinois: Scott, Foresman and Company, 1968), p. 219.

The ex-competitive vertical group's mean was 34.5663 seconds with a range of 27.566 to 44.200 seconds. The standard deviation was 6.0716 and the standard error of the mean was 2.0239. The ex-competitive horizontal group's mean was 33.2580 with a range from 27.600 to 43.000 seconds. The standard deviation was 5.2467 seconds and the standard error of the mean was 1.8550.

The pre-test difference between the means for the two competitive groups was 0.2332 seconds and yielded a t-ratio of 0.1032 which was not statistically significant and thus indicated that at the beginning of the experiment the two groups were comparable in flutter kicking speed for twenty-five yards. The pre-test difference between the means of the two ex-competitive groups was 1.3083 seconds and yielded a t-ratio of 0.4438 which was not statistically significant and indicated that at the beginning of the experiment the two groups were comparable in flutter kicking speed for twenty-five yards.

Speed Test Analysis

Table 3 summarizes the cell scores used in the computation of the "Three-Factor Mixed Design: Repeated Measures on One Factor" ANOVA table.[1] It will be noted that computations for the ANOVA were based on scores from the first,

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[1]Bruning and Kintz, "Part 2, Analysis of Variance, Section 2.8, Three-Factor Mixed Design: Repeated Measures on One Factor," pp. 61-72.

TABLE 3

CELL SCORE SUMMARIES BY GROUPS AND POSITIONS

		Trials				Grand Mean	Total Diff. Trials 1-4
		1	2	3	4		
Competitive Vertical	Σx	167.2980	154.6650	158.5980	154.1650		
	Σx^2	4739.3481	4047.8611	4260.8618	4021.6862		
	N	6	6	6	6		
	M	27.8830	25.7775	26.4330	25.6941	26.4469	2.1889
	Var	14.9150	12.1962	13.7278	12.1125		
	SD	3.8620	3.4923	3.7051	3.4803		
	SE_M	1.5767	1.4257	1.5126	1.4208		
Competitive Horizontal	Σx	132.9980	136.0980	132.0980	130.8980		
	Σx^2	3559.0671	3756.6125	3525.3218	3455.1486		
	N	5	5	5	5		
	M	26.5996	27.2196	26.4196	26.1796	26.6046	0.4200
	Var	5.3430	13.0191	8.8358	7.0724		
	SD	2.3115	3.6082	2.9725	2.6594		
	SE_M	1.0337	1.6136	1.3293	1.1893		
Ex-competitive Vertical	Σx	205.5650	193.1990	188.8310	182.6640		
	Σx^2	7317.8492	6373.4684	6060.5336	5688.2708		
	N	6	6	6	6		
	M	34.2608	32.1998	31.4718	30.4440	32.0941	3.8168
	Var	55.0060	30.5002	23.5371	25.4490		
	SD	7.4166	5.5227	4.8515	5.0447		
	SE_M	3.0278	2.2546	1.9806	2.0595		

Key--Σx = Sum of Scores
Σx^2 = Sum of Scores Squared
N = Number in group
M = Mean

Var = Variance
SD = Standard deviation
SE_M = Standard error of mean

TABLE 3--Continued

		Trials 1	2	3	4	Grand Mean	Total Diff. Trials 1-4
Ex-competitive Horizontal	Σx	149.4660	151.4990	145.5660	86.1650		
	Σx^2	4489.1132	4621.9595	4252.6971	2486.3408		
	N	5	5	5	3		
	M	29.8932	30.2998	29.1132	28.7216	29.5070	1.1716
	Var	5.2739	7.8922	3.7010	5.7744		
	SD	2.2965	2.8093	1.9238	2.4030		
	SE_M	1.0270	1.2563	0.8604	1.3874		
Vertical Groups	Σx	372.8630	347.8640	347.4290	336.8290		
	Σx^2	12057.1973	10421.3295	10321.3954	9709.9590		
	N	12	12	12	12		
	M	31.0719	28.9886	28.9524	28.0690	29.2705	3.0029
	Var	42.8763	30.6595	23.8671	23.2295		
	SD	6.5480	5.5371	4.8854	4.8197		
	SE_M	1.8902	1.5984	1.4103	1.3913		
Horizontal Groups	Σx	282.4640	287.5970	277.6640	217.0630		
	Σx^2	8048.1800	8378.5720	7778.0189	5941.4894		
	N	10	10	10	8		
	M	28.2464	28.7597	27.7664	27.1328	27.9763	1.1136
	Var	7.7317	11.9294	7.5873	7.4251		
	SD	2.7806	3.4539	2.7545	2.7249		

Key--Σx = Sum of Scores
Σx^2 = Sum of Scores Squared
N = Number in group
M = Mean
Var = Variance
SD = Standard deviation
SE_M = Standard error of mean

TABLE 3--Continued

		Trials				Grand Mean	Total Diff. Trials 1-4
		1	2	3	4		
Competitive Groups	Σx	300.2960	290.7630	290.6960	285.0630		
	Σx^2	8298.4150	7804.4736	7786.1836	7476.8348		
	N	11	11	11	11		
	M	27.2996	26.4330	26.4269	25.9148	26.5186	1.3848
	Var	10.0445	11.8735	10.3987	5.9485		
	SD	3.1693	3.4458	3.2247	2.9914		
	SE_M	0.9557	1.0389	0.9723	0.9019		
Ex-competitive Groups	Σx	355.0310	344.6980	335.3970	268.8290		
	Σx^2	11806.9623	10995.4279	10372.1627	8174.6116		
	N	11	11	11	9		
	M	32.2755	31.3361	30.4906	29.8698	30.9930	2.4057
	Var	34.8171	19.3961	14.5718	18.0957		
	SD	5.9006	4.4041	3.8173	4.2539		
	SE_M	1.7791	1.3279	1.1510	1.4180		
Totals	Σx	655.3270	635.4610	625.0930	553.8920		
	Σx^2	20105.3773	18799.9015	18099.4143	15651.4464		
	N	22	22	22	20		
	M	29.7875	28.8845	28.4133	27.6946	28.6950	2.0911
	Var	27.8510	21.1895	16.1170	16.4009		
	SD	5.2774	4.6032	4.0146	4.0498		
	SE_M	1.1251	0.9814	0.8559	0.9056		

Key--Σx = Sum of Scores
Σx^2 = Sum of Scores Squared
N = Number in group
M = Mean
Var = Variance
SD = Standard deviation
SE_M = Standard error of mean

second and third trials only. Data from trial four was incomplete for the horizontal group because two subjects from that group were unable to take the final test. However, statistics from the fourth trial have been included in discussions and basic statistical information to form a more complete picture of the results of the experiment. The results of trial four are found in the section of the chapter entitled, "Fourth Trial."

The means for the competitive vertical group were 27.8830, 25.7775, 26.4330 and 25.6941 seconds respectively for trials one through four, with a grand mean of 26.4469 and a total change of 2.1889 seconds from the first to fourth trial.

The means for the competitive horizontal group were 26.5996, 27.2196, 26.4196, and 26.1796 seconds respectively for trials one through four, with a grand mean of 26.6046 and a total loss of 0.4200 seconds from the first to fourth trial.

The means for the ex-competitive vertical group were 34.2608, 32.1998, 31.4718 and 30.4440 seconds respectively for trials one through four, with a grand mean of 32.0941 and a total loss of 3.8163 seconds from the first to fourth trial. The means for the ex-competitive horizontal group were 29.8932, 30.2998, 29.1132 and 28.7216 seconds respectively for trials one through four, with a grand mean of 29.5070 and a total loss of 1.1716 seconds from the first to fourth trial. It is to be noted that both of the horizontal groups had a slower mean for the second trial than for the first trial while the two vertical groups improved nearly two seconds each. A graphic representation of the means for each of the four groups over the four trials is found in Illustration 1.

ANOVA Table

The results of the computations for the "Three-Factor Mixed Design: Repeated Measures on One Factor"[1] are found in Table 4. Interpretation of the table is presented in two sections: interactions and main effects.

TABLE 4

+THREE-FACTOR MIXED DESIGN: REPEATED MEASURES ON ONE FACTOR--KICKING SPEED

Source	df	SS	MS	F	p
Between Subjects	21	296.6864	-	-	-
C-Ex. Groups	1	351.7716	351.7716	7.2179	.025*
V-H Positions	1	32.6943	32.6943	.6709	-
Groups X Positions	1	34.9731	34.9731	.7176	-
err_{bet}	18	877.2474	48.7360	-	-
Within Subjects	44	92.8551	-	-	-
Trials	2	21.4583	10.7292	7.9735	.005**
Trials X Groups	2	3.4412	1.7206	1.2787	-
Trials X Positions	2	18.8109	9.4055	6.9898	.005**
Trials X Groups X Positions	2	0.7302	.3651	.2713	-
$err_{w/in}$	36	48.4145	1.3456	-	-
Total	65	1389.5415			

[2]Table $F_{1,18}(.025) = 5.98$*
[3]Table $F_{2,30}(.005) = 6.35$**

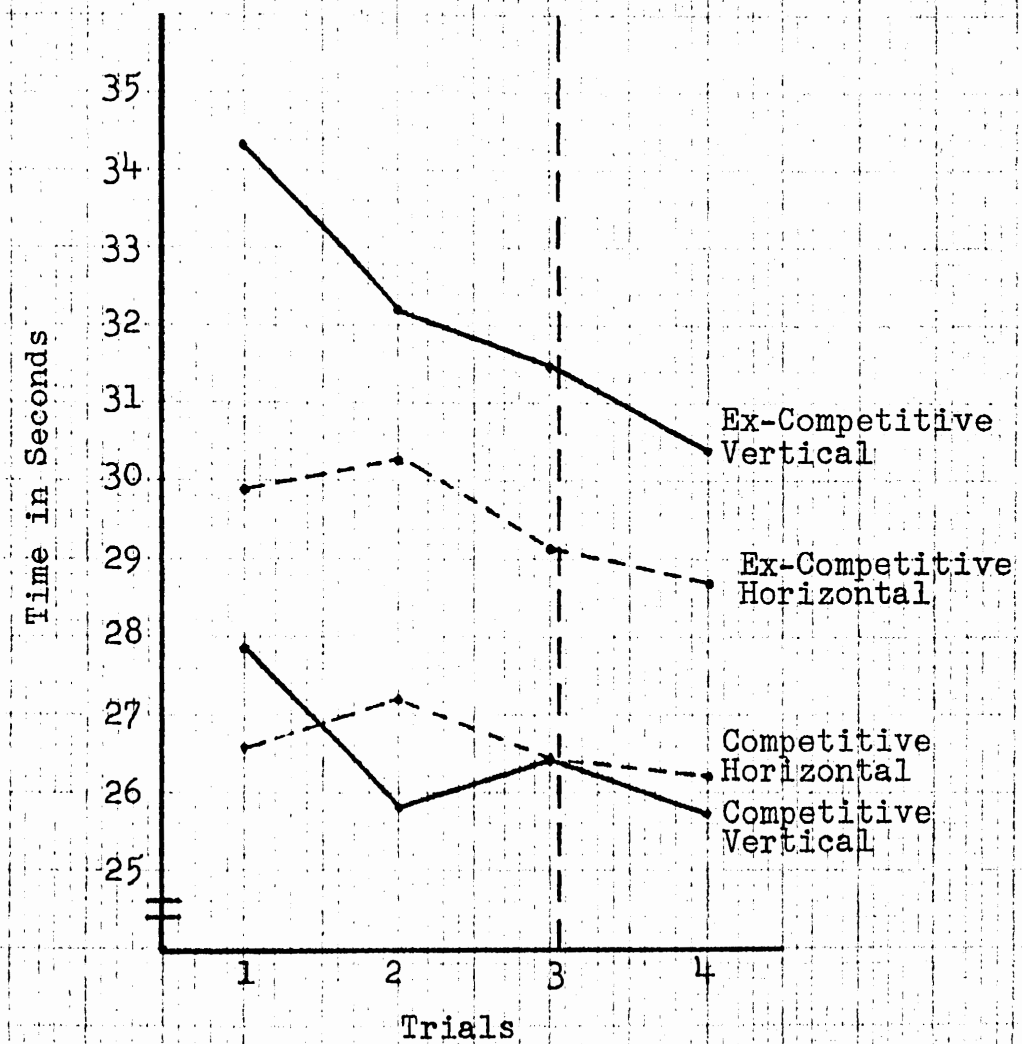
+ANOVA Table modification of Bruning and Kintz, by suggestion of Nick Lund, class notes, "Statistical Theories," Texas Woman's University, Denton, Texas, February, 1971.

[1]Bruning & Kintz, pp. 61-72.

[2]*Ibid*., p. 224. [3]*Ibid*., p. 225.

ILLUSTRATION 1

GROUPS BY POSITIONS BY TRIALS



Trial 1 to 2: Three week practice period

Trial 2 to 3: One week rest period

Trial 3 to 4: Two week practice period

Interactions

Trials by Groups by Positions.--An F ratio of 0.2713 for the interaction of trials by groups by positions indicated that there was no significant difference in the performance of either the competitive or ex-competitive groups in their respective positions over trials. An analysis of Illustration 1 suggests that there might be a significant difference between the performance of certain groups although the patterns of groups by position are similar. Scheffe's Test of All Possible Comparisons, Table 5, was used to determine if significant differences did exist.

Trials by groups by positions was the main consideration for the Scheffe comparisons. Examination of Table 5 reveals that the competitive and ex-competitive groups training in a horizontal position did not improve significantly over the three trials. The difference between trials one and two represents the result of the first treatment period of three weeks. The difference between trials two and three represents the effect of the one week rest period, while the difference between trials one and three compared the treatment period and the rest period combined. No significant difference occurred for any group during the rest period, nonetheless, all groups except the competitive vertical showed some improvement as a result of the rest period as shown in Illustration 1.

Comparing trials one and two an F ratio of 3.2948 for the competitive vertical group indicated a significant

TABLE 5

SCHEFFE'S TEST OF ALL POSSIBLE COMPARISONS[1]

	Trial Comparison	D in Sec.	D^2	F	p
Competitive Vertical (n=6)	1 vs. 2	2.1055	4.4331	3.2948	.05
	2 vs. 3	+0.6555	0.4297	0.3194	
	1 vs. 3	1.4500	2.1025	1.5626	
Competitive Horizontal (n=5)	1 vs. 2	+0.6200	0.3844	0.2381	
	2 vs. 3	0.8000	0.6400	0.3964	
	1 vs. 3	0.1800	0.0324	0.0201	
Ex-Competitive Vertical (n=6)	1 vs. 2	2.0610	4.2477	3.1570	
	2 vs. 3	0.7280	0.5300	0.3939	
	1 vs. 3	2.7890	7.7785	5.7811	.01
Ex-Competitive Horizontal (n=5)	1 vs. 2	+0.4066	0.1653	0.1024	
	2 vs. 3	1.1866	1.4080	0.8720	
	1 vs. 3	0.7800	0.6084	0.4831	
Vertical (n=12)	1 vs. 2	2.0833	4.3401	6.4499	.005
	2 vs. 3	0.0362	0.0013	0.0020	
	1 vs. 3	2.1195	4.4923	6.6760	.005
Horizontal (n=10)	1 vs. 2	+0.5133	0.2635	0.3263	
	2 vs. 3	0.9933	0.9867	1.2220	
	1 vs. 3	0.4800	0.2304	0.2853	
Trials (n=22)	1 vs. 2	0.9030	0.8154	2.2218	
	2 vs. 3	0.4712	0.2220	0.6050	
	1 vs. 3	1.3742	1.8884	5.1456	.025

[2]Table $F_{2,36}$ (.005) = 6.182
[2]Table $F_{2,36}$ (.01) = 5.25
[2]Table $F_{2,36}$ (.025) = 4.102
[2]Table $F_{2,36}$ (.05) = 3.26

(D = difference between means)

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[1]John T. Roscoe, Fundamental Research Statistics for the Behavioral Sciences (New York: Holt, Rinehart and Winston, Inc., 1969), p. 240.

[2]Henry E. Klugh, Statistics--the Essentials for Research (New York: John Wiley & Sons, Inc., 1940), p. 346.

improvement at the .05 level. An F ratio of 3.1570 for the ex-competitive vertical group approached significance at the .05 level. An F ratio of 3.26 was needed for significance at the .05 level. The additional improvement obtained from the rest period increased the ex-competitive vertical group's F ratio to 5.7811 for a trial one to three which was significant at the .01 level.

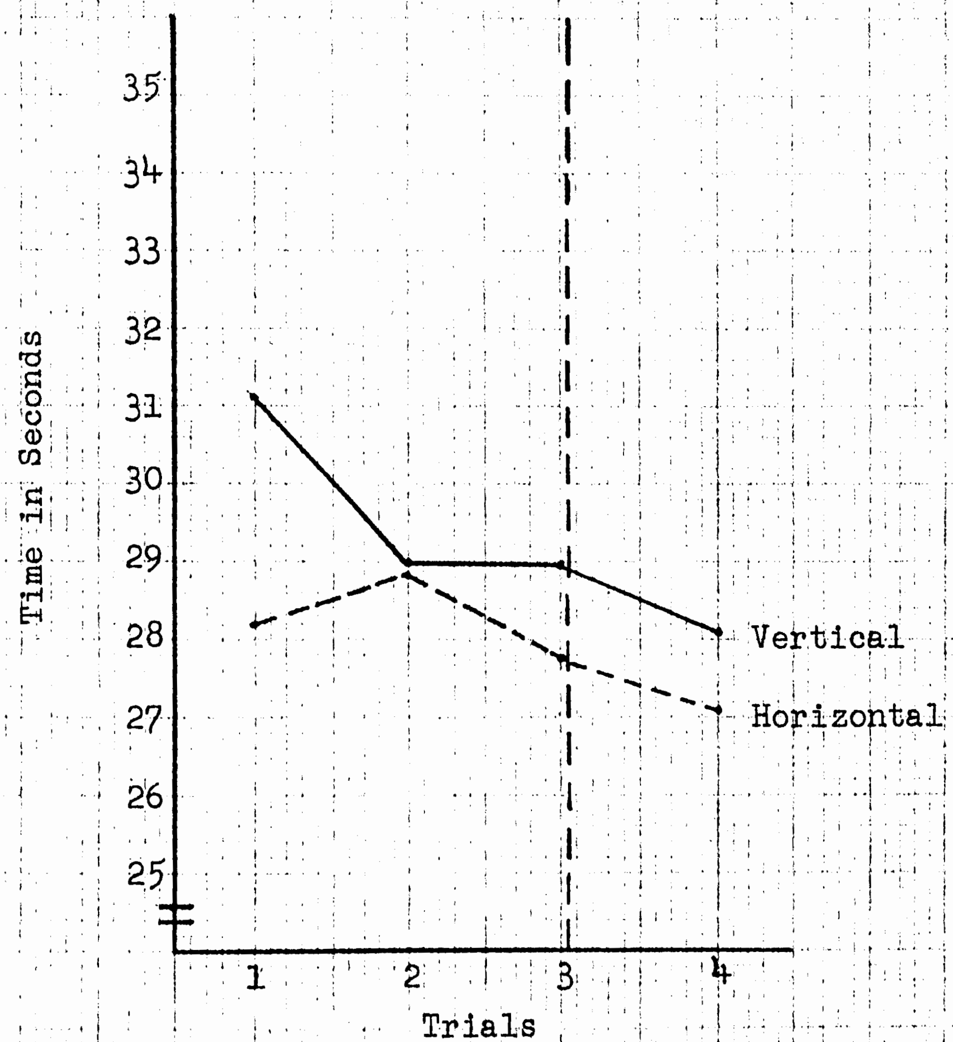
Comparing trials one and two an F ratio of 0.2381 and 0.1024 for the competitive and ex-competitive horizontal groups respectively was not significant. Significant improvements did not occur for either of the horizontal groups for a trial one to three comparison.

It appeared that training in a vertical position resulted in a significant difference in performance for both the competitive and ex-competitive groups. Training in a horizontal position did not result in a significant difference in performance over three trials for either the competitive or the ex-competitive groups.

Trials by Positions.--An F ratio of 6.9898 for the interaction of trials by positions was significant at the .005 level. This significance indicated that the vertical and horizontal groups when the competitive groups and ex-competitive groups were combined performed in a significantly different manner over trials. An analysis of Illustration 2 presents the means of the vertical and horizontal groups over the trials.

ILLUSTRATION 2

POSITIONS BY TRIALS



Trial 1 to 2: Three week practice period

Trial 2 to 3: One week rest period

Trial 3 to 4: Two week practice period

Scheffe's Tests of All Possible Comparisons, Table 5, was used to determine where the significant difference existed. Comparing trials one and two an F ratio of 6.4499 for the combined vertical groups indicated a significant improvement at the .005 level. The rest period yielded a non-significant F ratio of 0.0020. The combined vertical groups F ratio of 6.6760 for a trial one to three comparison was also significant at the .005 level.

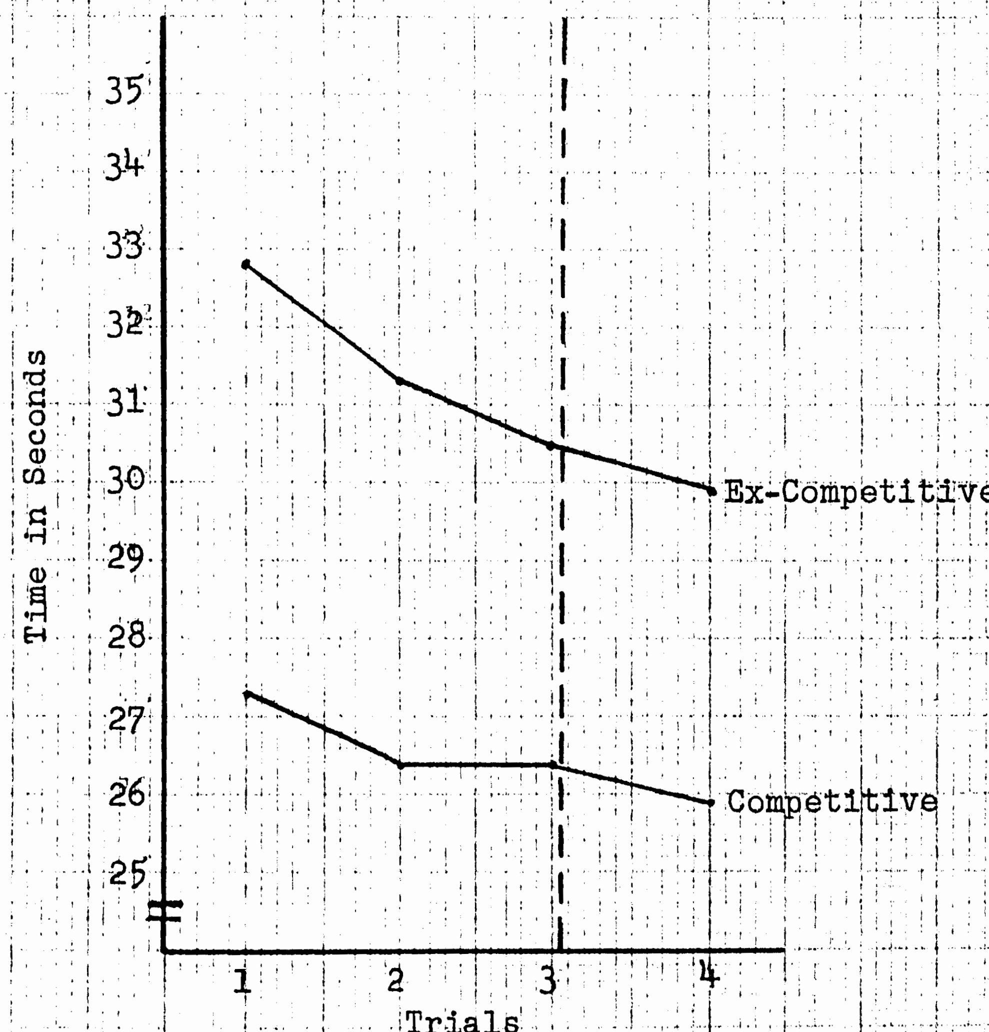
Comparing trials one and two an F ratio of 0.3263 for the combined horizontal groups indicated no significant improvement. The rest period yielded a non-significant F ratio of 1.2220, as did an F ratio of 0.2853 for a trial one to three comparison.

Trials by Groups.--An F ratio of 1.2787 for the interaction of trials by groups was not significant, thus indicating that the competitive and ex-competitive groups performed in a similar manner over trials. Illustration 3 presents the means for the competitive groups and ex-competitive groups, disregarding whether they were practicing in a vertical or horizontal position, appeared to be similar and did not warrant further investigations for the purpose of this study.

Groups by Positions.--An F ratio of 0.7176 for the interaction of groups by positions was not significant, indicating that the competitive and ex-competitive groups improved

ILLUSTRATION 3

GROUPS BY TRIALS



Trial 1 to 2: Three week practice period

Trial 2 to 3: One week rest period

Trial 3 to 4: Two week practice period

in a similar manner in vertical and horizontal positions. However, group by position must be interpreted in light of the significance of trials by positions. As the vertical and horizontal groups performed differently over the trials these results will be reflected in their respective competitive and ex-competitive groups. The Scheffe's Test of All Possible Comparisons, Table 5, revealed the effect of groups by positions.

Main Effects

As significant differences were found for two of the interaction terms, interpretations of the main effects were made with these interaction results in mind. When interaction terms are significant it is erroneous to combine scores for main effect interpretations.[1]

Trials.--An F ratio of 7.9735 for trials was significant at the .005 level. This term indicates that the subjects, regardless of group or position, performed in a significantly different manner over the three trials. An analysis of Illustration 1 indicated that while the general pattern for the groups over trials was similar, the pattern for position over trials was different. The interaction term of trials by positions confirms this analysis, and must be kept in mind when interpreting the effect by trial.

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[1]Nick Lund, private interview held at the Texas Woman's University, Denton, Texas, July, 1971.

The Scheffe's Test of All Possible Comparisons, Table 5, was used to determine where the significance existed. Comparing trials one and two an F ratio of 2.2278 for all groups combined for trials indicated no significant improvement, as did an F ratio of 0.6050 for the rest period. However, the combined groups F ratio of 5.1456 for a trial one to three comparison indicated a significant improvement at the .025 level.

Positions.--An F ratio of 0.6709 for the main effect of positions was not significant, indicating that the position was not a significant factor in performance when groups and trials were not considered. Again, as trials and trials by positions were significant, it is erroneous to combine scores over trials for each position. The Scheffe's Test of All Possible Comparisons, Table 5, revealed the effect of position. As groups performed in a similar manner group scores may be combined and averaged for this comparison.

Groups.--An F ratio of 7.2179 for the main effect of groups was significant at the .025 level. This term indicated that there was a significant difference in the performance of the competitive and ex-competitive groups when position and trials were not considered. This term indicated that an overall comparison of the grand average time over all trials and throughout the entire study for the competitive group was significantly lower than that of the ex-competitive group as would be expected.

Illustrations 1, 2 and 3 and Tables 3 and 4 indicated that the vertical groups whether competitive or ex-competitive performed in a similar pattern over trials and that the horizontal groups whether competitive or ex-competitive performed in a similar pattern over trials. The position in which the training occurred appeared to be the determining factor as to whether improvement over trials was significant. As the difference between the competitive and ex-competitive groups was anticipated, the investigator did not consider further analysis of this variable.

Fourth Trial

It has been noted previously that the loss of two subjects from the final testing session made application of the ANOVA over the fourth and final trial undesirable. Three groups, however, did complete training and were administered the fourth trial of kicking for speed. It was of interest to the investigator to examine the possibility that similar progress for the groups might be made after the rest period. Table 6 presents the results of the t-test of differences between the means of related measures.

Computations represent the difference between the means for each group from the first trial to the fourth trial. The t-ratios of 1.3257 and 1.0442 for the competitive and ex-competitive horizontal groups were not significant. The t-ratios of 3.1069 and 2.9140 for the competitive and

TABLE 6

t-TEST OF MEAN DIFFERENCES FOR RELATED MEASURES:
KICKING SPEED FIRST TO FOURTH TRIAL

Group	Trial	Mean	SD	SE_M	t	p
Competitive Vertical N=6 (df-5)	1st Trial	27.8830	3.8620	1.5767	3.1069	.05*
	4th Trial	25.6941	3.4803	1.4208		
Competitive Horizontal N=5 (df-4)	1st Trial	26.5996	2.3115	1.0337	1.3257	
	4th Trial	26.1796	2.6594	1.1893		
Ex-Competitive Vertical N=6 (df-5)	1st Trial	34.2608	7.4166	3.0278	2.9140	.05*
	4th Trial	30.4440	5.0447	1.9806		
Ex-Competitive Horizontal	1st Trial	N=5 29.8932	2.2965	1.0270	1.0442+	
	4th Trial	N=3 28.7216	2.4030	1.3874		
Vertical N=12 (df-14)	1st Trial	31.0719	6.5480	1.8902	4.0494	.002**
	4th Trial	28.0690	4.8197	1.3913		
Horizontal N=8 (df-7)	1st Trial	28.2464	2.7806	0.8793	0.8794	
	4th Trial	27.1328	2.7249	0.9634		

[1]Table df 2, t (.05) = 4.303
[1]Table df 4, t (.05) = 2.776
[1]Table df 5, t (.05) = 2.571*
[1]Table df 7, t (.05) = 2.365
[2]Table df 11, t (.01) = 3.106
t (.002) = 4.025**

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[1]Bruning & Kintz, p. 219.

[2]William L. Hayes and Robert L. Winkler, Statistics: Probability, Inference and Decision, Vol. I (New York: Holt, Rinehart and Winston, Inc., 1970), p. 603.

+Computed on Olivetti Programma 101 Computer program for the t-Test of Mean Differences for Related Measures based on the times of the three subjects completing the third trial.

ex-competitive vertical groups respectively were significant at the .05 level. The two vertical groups combined mean differences yielded a "t" of 4.0494 which was significant at the .01 level. The two horizontal groups combined mean differences yielded a "t" of 0.8794 which was not significant.

Film Analysis

The raw scores, found in Appendix L, indicate that the competitive and ex-competitive groups have similar degrees of plantar flexion, plantar flexion-inversion, and leg velocity. The film analysis included three variables: plantar flexion-inversion as measured from a frontal view, plantar flexion as measured from a lateral view, and velocity of the legs as measured from a lateral view. In interpreting the results, the forward swing of the leg in a vertical position was assumed to correspond to the downswing in a horizontal position, while the vertical backswing was assumed to correspond to the horizontal upswing. It should be noted, also, that the more acute the angle from the frontal view the greater the plantar flexion-inversion, while from the lateral view, the more obtuse the angle, the greater the plantar flexion.

Reliability

Table 7 presents the Pearson Product-Moment Coefficient of Correlations used to determine the reliability of the measurements based on the test-retest method. The test-retest method was used to determine reliability of the pre-tests and of the post-tests. The retest was conducted on the day following the original test. Frames that had been marked for reference during the first analysis were measured again following the same procedures on new analysis sheets. Thus, two sets of measurements were taken for each subject for each set of data. Plantar flexion-inversion (frontal view) reliability for the pre-test was .98 and .97 for the post-test. Plantar flexion (lateral view) reliability was .94 and .95 for the pre-test and post-test respectively, while reliabilities were .98 for both pre-test and post-test for velocity of the legs.

TABLE 7

RELIABILITY OF FILM ANALYSIS: TEST-RETEST METHOD OF PEARSON'S PRODUCT-MOMENT COEFFICIENT OF CORRELATIONS

Analysis	Pre-test	Post-test
Lateral View: Velocity of Legs	.98	.98
Lateral View: Plantar Flexion	.94	.95
Frontal View Plantar Flexion Inversion	.98	.97

Level of significance for correlation, n-2, .001=.8471

Velocity of the Legs

An analysis of the lateral view was used to determine the velocity of the legs for each subject as measured to the nearest sixty-fourth of an inch. Table 8 presents the pre-test and post-test results of the film analysis. The pre-test mean for the competitive group was 6.6523 inches per second with a standard deviation of 1.1220 and a standard error or the mean of 0.4581. The ex-competitive group had a pre-test mean of 6.6484 inches per second with a standard deviation of 0.7509 and a standard error of the mean of 0.3066. It is to be noted that while the speed test indicates there is a significant difference in the speed of a competitive swimmer as compared to an ex-competitive swimmer, the mean velocity of the legs differs only 0.0039 inches per second in favor of the competitive group.

TABLE 8

STATISTICAL EVALUATION: VELOCITY OF THE LEGS COMPARISONS IN INCHES PER ONE-EIGHTH SECOND--LATERAL VIEW

Group	Means		Standard Deviations		Standard Error of Mean	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Competitive	6.6523	7.5351	1.1220	1.3702	0.4581	0.5594
Ex-Competitive	6.6484	7.6484	0.7509	1.6805	0.3066	0.6861

The post-test mean for the competitive group was 6.6484 inches per second with a standard deviation of 1.3702 and a standard error of the mean of 0.5594. The ex-competitive group had a post-test mean of 7.6484 inches per second with a standard deviation of 1.6805 and a standard error of the mean of

0.6861. It appeared from this data that the competitive and ex-competitive improved in approximately the same pattern which substantiated the finding of the speed tests.

The results of the computations for the "Two-Factor Mixed Design: Repeated Measures on One Factor"[1] are found in Table 9. The interaction term of trials by groups yielded a non-significant F ratio of 0.0225 indicating that neither group performed differently over the trials. An F ratio of 5.8058 for trials was significant at the .05 level which indicated that regardless of the group the subject's performance changed significantly over the trials. As the analysis consisted of two testing periods and as the mean velocity of the legs for both groups increased, no further analysis was deemed necessary by the investigator. An F ratio of 0.0077 between groups was not significant and indicated that the competitive group and ex-competitive group did not have a significant difference for velocity of the legs.

It appeared from the film analysis of the lateral view that a significant difference in velocity of the legs between the competitive group and the ex-competitive group did not exist but that training in a vertical position did result in a significant change in leg velocity as measured in inches per second. In addition, there was no significant difference in velocity of the legs for the interaction of trials by groups.

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[1]Bruning & Kintz, "Part 2, Analysis of Variance, Section 2.7, Two-Factor Mixed Design: Repeated Measures on One Factor," pp. 54-61.

TABLE 9

+TWO-FACTOR MIXED DESIGN: REPEATED MEASURES ON ONE FACTOR: VELOCITY OF THE LEGS AS DETERMINED FROM A LATERAL VIEW FILM ANALYSIS

Source	df	SS	MS	F	p
Between Subjects	11	23.4670	2.1339	-	-
Groups	1	0.0180	0.0180	.0077	-
$Error_{bet}$	10	23.4490	2.3449	-	-
Within Subjects	12	14.4974	1.2081	-	-
Trials	1	5.3175	5.3175	5.8058	.05*
Trials X Groups	1	0.0206	0.0206	0.0225	-
$Error_{w/in}$	10	9.1593	0.9159	-	-
Total	23	37.9649			

[1]Table $F_{1,10}$ (.01) = 10.04
[1]Table $F_{1,10}$ (.05) = 4.96*

Plantar Flexion

An analysis of the lateral view was used to determine plantar flexion for each subject as measured to nearest degree. Table 10 presents the pre-test and post-test results of the film analysis. The pre-test mean for the competitive group was 172.35 degrees with a standard deviation of 5.198 and a standard error of the mean of 2.1221. The ex-competitive group had a pre-test mean of 174.6666 degrees with a standard deviation of 5.1651 and a standard error of the mean of 2.1086.

+ANOVA Table modification of Bruning and Kintz, by Lund, class notes.

[1]Bruning & Kintz, p. 223.

TABLE 10

STATISTICAL EVALUATION: PLANTAR FLEXION COMPARISONS MEASURED TO THE NEAREST DEGREE--LATERAL VIEW

	Means		Standard Deviations		Standard Error of Mean	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Competitive	172.35	171.5666	5.198	4.3494	2.1221	1.7756
Ex-Competitive	174.6666	171.6166	5.1651	8.5779	2.1086	3.5019

The post-test mean for the competitive group was 171.5666 degrees with a standard deviation of 4.3494 and a standard error of the mean of 1.7756. The ex-competitive group had a post-test mean of 171.6166 degrees with a standard deviation of 8.5779 and a standard error of the mean of 3.5019. It is interesting to note that both groups had a decrease in mean measurements. A decrease in degrees indicated a slight loss of plantar flexibility as measured from this particular film analysis.

The results of the computations for the "Two-Factor Mixed Design: Repeated Measures on One Factor"[1] are found in Table 11. The interaction term of trials by groups yielded a non-significant F of 0.4693 indicating that neither group performed differently over the trials. An F of 1.3422 for trials was not significant which indicated that regardless of the group the subject's performance did not change significantly

[1]Bruning and Kintz, pp. 54-61.

over the trials. An F ratio of 0.1483 between groups was not significant and indicated that the competitive group and the ex-competitive group did not have significant differences in ankle plantar flexion.

TABLE 11

+TWO-FACTOR MIXED DESIGN: REPEATED MEASURES ON ONE FACTOR: PLANTAR FLEXION AS DETERMINED FROM A LATERAL VIEW FILM ANALYSIS

Source	df	SS	MS	F	p
Between Subjects	11	574.7900	52.2536	-	-
Groups	1	8.4017	8.4017	0.1483	-
$Error_{bet}$	10	566.3883	56.6388	-	-
Within Subjects	12	193.9700	16.1642	-	-
Trials	1	22.0417	22.0417	1.3422	-
Trials X Groups	1	7.7066	7.7066	0.4693	-
$Error_{w/in}$	10	164.2217	16.4222		
Total	23	768.76			

[1]Table $F_{1,10}$ (.01) = 10.04
[1]Table $F_{1,10}$ (.05) = 4.96

It appeared from the film analysis of the lateral view that a significant difference in plantar flexion of the competitive group and the ex-competitive group did not occur and that training in a vertical position had no significant effect upon such a measurement. In addition, there was no significant difference in plantar flexion for the interaction of trials by groups.

+ANOVA Table modification of Bruning and Kintz, by Lund, class notes.

[1]Bruning & Kintz, p. 223.

Plantar Flexion-Inversion

An analysis of the frontal view was used to determine plantar flexion-inversion ("toe-in") for each subject as measured to the nearest degree. Table 12 presents the pre-test and post-test results of the film analysis. The pre-test mean for the competitive group was 152.8333 degrees with a standard deviation of 13.055 and a standard error of the mean of 5.3297. The ex-competitive group had a pre-test mean of 153.8666 degrees with a standard deviation of 11.542 and a standard error of the mean of 4.7120.

TABLE 12

STATISTICAL EVALUATION: PLANTAR FLEXION-INVERSION COMPARISONS MEASURED TO THE NEAREST DEGREE--FRONTAL VIEW

Group	Means		Standard Deviations		Standard Error of Mean	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Competitive	152.8333	152.3833	13.055	9.176	5.3297	3.7461
Ex-Competitive	153.8666	155.9500	11.542	6.724	4.7120	2.7451

The post-test mean for the competitive group was 152.3833 degrees with a standard deviation of 9.176 and a standard error of the mean of 3.7461. The ex-competitive group had a post-test mean of 155.9500 degrees with a standard deviation of 6.724 and a standard error of the mean of 2.7451.

The results of the computations for the "Two-Factor Mixed Design: Repeated Measures on One Factor"[1] are found in Table 13. The interaction term of trials by groups yielded a non-significant F ratio of 0.2179 indicating that groups performed in a similar manner over the trials. An F ratio of 0.0959 for trials was not significant which indicated that regardless of the group the subject's performance did not change significantly over the trials. An F ratio of 0.1842 between groups was not significant and indicated that the competitive group and ex-competitive group did not have significant differences in ankle plantar flexion-inversion.

TABLE 13

+TWO-FACTOR MIXED DESIGN: REPEATED MEASURE ON ONE FACTOR: PLANTAR FLEXION-INVERSION AS DETERMINED FROM A FRONTAL VIEW FILM ANALYSIS

Source	df	SS	MS	F	p
Between Subjects	11	1755.2783	159.5708	-	-
Groups	1	31.7400	31.7400	0.1842	-
$Error_{bet}$	10	1723.5383	172.3538	-	-
Within Subjects	12	455.3400	37.945	-	-
Trials	1	4.0016	4.0016	0.0959	-
Trials X Groups	1	9.6267	9.6267	0.2179	-
$Error_{w/in}$	10	441.7117	44.1772	-	-
Total	23	2210.6183			

[2]Table $F_{1,10}$ (.01) = 10.04
[2]Table $F_{1,10}$ (.05) = 4.96

+ANOVA Table modification of Bruning & Kintz, by Lund, class notes.

[1]Bruning & Kintz, pp. 54-61.

[2]*Ibid.*, p. 223.

It appeared from the film analysis of the frontal view that a significant difference in plantar-flexion-inversion between the competitive and ex-competitive group did not occur and that training in a vertical position had no significant effect upon such a measurement. In addition, there was no significant difference in plantar flexion-inversion for the interaction of trials by groups.

Summary

Chapter IV has presented the results of this study in narrative and tabular form. A t-test for differences between means was computed to show the equation of groups. An ANOVA was computed for the kicking speed tests and for each of the three variables measured by a film analysis. A t-test for related measures was used to determine the significance of the difference between the first and fourth trials for kicking speed.

The analysis of the speed test revealed that training in a vertical position for two weeks and resting one week resulted in a significant change in performance over trials for both the competitive and ex-competitive swimmer. Training in a horizontal body position did not result in a significant difference in performance for either the competitive or ex-competitive group.

It appeared that training in a vertical position for three weeks, resting one week, and training for an additional two weeks resulted in a significant improvement in kicking speed for both the competitive and ex-competitive swimmers in this experiment. Training in a horizontal position for the same period of time while performing an identical program to that of the vertical group, did not result in a significant improvement for either the competitive or the ex-competitive group.

The film analysis indicated that ankle plantar flexion-inversion ("toe-in") and ankle plantar flexion of competitive and ex-competitive swimmers were similar and that training to perform the flutter kick in a vertical position did not result in a significant change in either variable. An analysis of the velocity of the legs for the competitive and ex-competitive swimmer, however, revealed that training in a vertical position resulted in a significant change in performance for both groups. It also appeared that the pattern of increase in the velocity of the legs was similar for both groups.

Chapter V will present a further discussion of the results relative to the hypotheses of this study and theoretical assumptions by the investigator regarding the vertical body position as a method of training to perform the flutter kick. On the basis of the findings conclusions will be drawn and recommendations will be made for further studies.

CHAPTER V

SUMMARY, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDIES

Summary

Swimming is one of the oldest forms of physical activity known to man. The magnitude of the role of swimming to the ancients is indicated by the numerous references to swimming in art relics and classic literature. The most complete book on the history of swimming was written in the late 1800's, while research regarding swimming skills became prominent around 1930.

Many of the studies in swimming are concerned with the application of force and the reduction of body resistance in the water. The application of force for the flutter kick remains a question of debate. While the kick provides a smaller proportion of the forward propulsive force than does the pull, the legs play an important role in the execution of the total crawl stroke. Kinesiological analyses, ankle flexibility, weight training, and leg conditioning methods are topics of research related to the flutter kick.

Various methods of training are used to increase swimming speed. "Legs only" practice is used as an important component of the part-whole method of training for the competitive swimmer. The most common method of practicing the flutter kick employs the use of a kickboard. Various authorities on swimming indicate that the use of the kickboard to practice the flutter kick may be detrimental to the swimmer. If bad habits may be learned from practicing in a recommended manner, then a new method of training to perform the flutter kick seemed feasible.

This investigation entailed the study of eleven college women who were members of the Texas Woman's University competitive swimming team during the spring semester of the academic year 1970-1971 and eleven college women who had swum, at some time, on a competitive team but who were not participating at the time of the investigation. The purpose of the study was to determine whether training in a horizontal body position or in a vertical body position resulted in a significant difference in the ability to perform the flutter kick in relationship to kicking speed, velocity of the legs and ankle flexibility.

Speed was determined by the stopwatch method while velocity and ankle flexibility were calculated from a frame analysis of motion picture film. A 70 H. R. Bell and Howell sixteen millimeter camera was used with Tri-X film. Pictures were taken at a shutter speed of 1/288 second and at the rate of thirty-two frames per second.

The control group trained in a traditional horizontal position, while the experimental group trained in a vertical position. The subjects practiced for fifteen minutes, five days a week for three weeks, rested for one week, and practiced for an additional two weeks. Both groups performed an identical repetition interval training program at the same time, with body position being the only variable.

Groups were equated on the basis of the average kicking time for three trials of kicking twenty-five yards. The four groups were the competitive-vertical, competitive-horizontal, ex-competitive-vertical, and ex-competitive-horizontal. The training program for the ex-competitive group was less stringent than that of the competitive group.

Kicking tests of twenty-five yards were administered 1) during the first session, 2) at the conclusion of the first three week practice block, 3) after the rest period of one week, and 4) at the conclusion of the second practice block of two weeks. Data collected from the kicking speed test were analyzed with a three-factor mixed design with repeated measures on one factor.

Films were taken at the first session and at the conclusion of the first three week practice block. Data collected from a frame analysis of the film were analyzed with a two-factor mixed design with repeated measures on one factor.

Significant F-ratios were found regarding kicking speed. The interaction term of trials by positions was significant at the .005 level. The main effect of trials was significant at the .005 level while the main effect of groups was significant at the .05 level. Scheffe's Test of All Possible Comparisons was used to determine the significant differences among means. The competitive vertical group made a significant improvement at the .05 level between trials one and two. The ex-competitive vertical group made a significant improvement at the .01 level between trials one and three. No significant changes occurred in the horizontal groups.

A t-test of mean differences for related measures indicated that for a first to fourth trial comparison, the competitive vertical group and the ex-competitive vertical group both made a significant improvement at the .05 level. Combining the results of both vertical groups for a first to fourth trial comparison resulted in a "t" significant at the .002 level. No significant changes occurred in the horizontal groups.

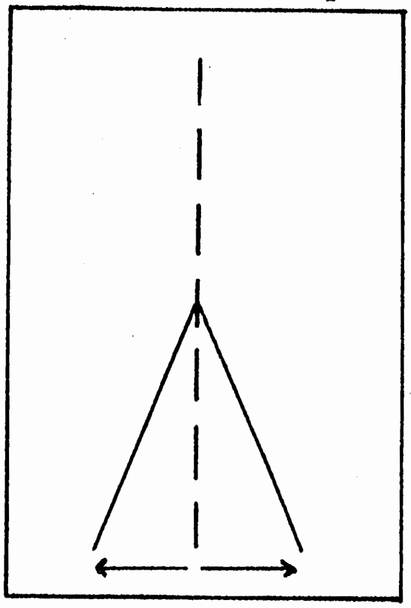
An analysis of the film data indicated that no significant changes occurred in plantar-flexion-inversion or plantar-flexion for either of the vertical groups. A significant F ($p > .05$) was found for velocity of the legs over trials for both vertical groups.

On the basis of the findings from the analysis of variances, two of the three null hypotheses stated in Chapter I were accepted. The main effect of position indicated there was no significant difference in speed of performing the flutter kick when comparing a horizontal and a vertical body position for practice as measured by the stop watch method. There was no significant difference in ankle flexibility as a result of practicing in a vertical position as measured by a frame analysis of motion picture films. However, a significant difference did occur in the velocity of the legs as a result of practicing in a vertical position as measured by a frame analysis of motion picture film.

Discussion

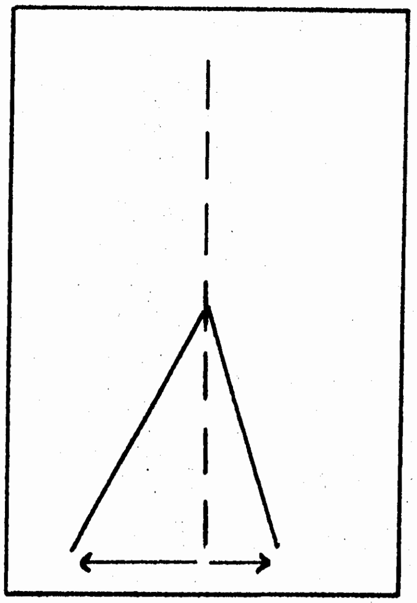
Authorities do not agree on the relative importance of the downbeat and upbeat of the flutter kick. When training in a horizontal position, the downbeat is aided by gravity and the upbeat is working against gravity. The investigator assumed that training in a vertical position would equate the effect of gravity. Illustration 4 indicates the hypothetical movement of the legs while kicking in a vertical position. Illustration 5 indicates, however, a pattern more similar to that observed by the investigator while conducting the film analysis. While training in the vertical position a forward movement of the leg is comparable to the downbeat and a movement of the leg backward is comparable to the upbeat. It appeared, therefore, that to maintain balance in a vertical position an emphasis was placed on the backswing of the legs. Training to perform the flutter kick in the vertical position appeared to stress that portion of the kick that is comparable to the upbeat in a horizontal position.

Illustration 4. Hypothetical Assumption



Hypothetically, the forward swing and back swing would be equal distances from perpendicular.

Illustration 5. Film Analysis Observation



Actually, the backswing for most subjects was almost twice the distance of the forward swing.

While authorities do not agree on the relative importance of the downbeat and upbeat of the flutter kick, the current trend is to emphasize the upbeat. Principles of overload and overtraining indicate the importance of fatiguing muscles and moving them beyond the range of their intended use. In the horizontal position it is not possible to overpractice the upbeat as the feet and legs come out of the water and a flapping kick results. The investigator assumed that training in a vertical position would allow an overpractice of the upbeat (backswing in the vertical position). The film analysis not only supported this assumption, but indicated that the backswing was emphasized more than the forward swing.

It appeared in the analysis of the film that while the majority of the subjects obtained maximum plantar flexion at the beginning of the forward movement of the legs, several of the subjects seemed to achieve maximum plantar flexion at the completion of the forward swing. Moore[1] states that the normal range of motion for plantar flexion at the ankle is forty-five degrees when the foot begins at zero degrees from the anatomical position forming a right angle with the leg. At the beginning of the forward movement of the legs the foot looked as if the water pressure forced the toes beyond a position that could be achieved in a dry land measurement unless an external force were applied to the foot. Thus, the ankle flexion-inversion and plantar flexion measurements obtained from the film analysis may be greater than those that would be found in ankle flexibility studies of swimmers in which dry land measurements are used.

It appeared also in the analysis of the film that while the majority of the subjects obtained the greatest velocity at the beginning of the forward movement of the legs, several subjects seemed to achieve the greatest leg velocity at the completion of the forward swing. The completion of the forward swing might be comparable to the whiplike action for the summation of forces at the completion of the downswing

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[1] Margaret Lee Moore, "The Measurement of Joint Motion," The Physical Therapy Review, XXIX (June, 1949), 264.

in the horizontal position. Measurements were taken, however, at the beginning of the forward swing in order to insure consistency in the point at which velocity was measured.

It is to be noted that the velocity of the legs for the competitive and ex-competitive groups training in a vertical position were similar and yet there was a significant difference between the kicking speed times. Velocity, however, does not necessarily denote efficiency of the kick. It is a common occurrence in "kicking only" drills for a swimmer to thrash vigorously with the legs and not achieve a corresponding amount of forward propulsion. In fact, if the swimmer is using a hooked kick or a flapping kick it is possible to kick energetically and remain in the same position or actually go backward from the intended direction. Efficiency of the kick may account for the similarity of leg velocity and yet the significant difference of kicking speed between the competitive and ex-competitive groups.

The competitive group for this investigation had been training for approximately ten weeks prior to the beginning of the experiment and was, therefore, considered to be at a base line level of conditioning. Because of the variance of physical conditioning, this assumption was not made for the ex-competitive group. As the competitive group entered the experiment at a base level of conditioning and the ex-competitive did not start at base level, the ex-competitive group was expected to be able to decrease kicking times more rapidly than the competitive group. An analysis of the mean scores, however, did not substantiate this assumption as both the competitive and ex-competitive groups appeared to improve at approximately the same rate.

Davis[1] used a two-week pre-conditioning program and Turkington[2] a three-week period to achieve a base level of performance. It was assumed by both investigators that if the subjects began the treatment at a base level of conditioning, changes that occurred in performance were a direct result of the treatment that had been administered. Their assumption was applied to this experiment. As the competitive group had kicked from 600-800 yards each workout for ten weeks using the kickboard technique, and as the horizontal group did not improve kicking speed significantly over the treatment period, the significant improvement achieved by the vertical group may be attributed to the training technique of the vertical position.

Winer[3] states that Scheffe's Test of All Possible Comparisons is the most conservative of all tests designed for comparisons of group means following an analysis of variance. Petrinovich and Hardyck[4] agree with Winer but state

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[1]M. Davis, p. 15. [2]Turkington, p. 8.

[3]B. J. Winer, <u>Statistical Principles in Experimental Design</u> (New York: McGraw-Hill Book Company, Inc., 1962), p. 88.

[4]Lewis F. Petrinovich and Curtis D. Hardyck, "Error Rates for Multiple Comparison Methods: Some Evidences Concerning the Frequency of Erroneous Conclusions," <u>Psychological Bulletin</u>, LXXI (January, 1969), 43-54.

further that while Scheffe's Test provides maximum protection against a Type I Error (erroneous rejection of the null hypothesis), it increases the possibility of a Type II Error. Scheffe's Test was chosen in light of the above statements to avoid a Type I Error.

In providing maximum protection against a Type I Error, however, it is possible that a Type II Error, erroneous acceptance of the null hypothesis, has occurred in this investigation. Lund[1] states a rule of thumb to test homogeneity: if the largest variance for any cell is six or more times greater than the smallest variance for any cell, the assumption for homogeneity of groups has been violated and a Type II Error is likely to occur. An analysis of Table 3 indicates that the variance for the ex-competitive vertical group on trial one was 55.06 which is nearly fifteen times greater than the variance of 3.68 for the ex-competitive horizontal group on trial four.

Assuming that the Type II Error has been made in this experiment, a more thorough analysis of the graphs is justified. Illustration 1 indicates that both of the vertical groups made rapid improvement during the first three week practice block. It should be noted again that the competitive group was at base level performance and the ex-competitive group was not, yet the pattern of improvement was

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[1]Lund, interview.

almost identical. During this same period of time, both horizontal groups became slower.

After the rest period all groups except the competitive vertical group showed a continued improvement in times. It should be noted, however, that three of the subjects in the competitive vertical group reported that they had been up most of the night prior to the test and had sore legs as a result of activities over spring vacation. Their scores were 1.267, 1.933 and 2.700 seconds slower than their scores on trial two. An examination of the remaining three scores for the competitive vertical group indicates a pattern similar to the remaining three groups. It was therefore assumed by the investigator that if normal testing conditions had existed for all subjects, the patterns over the rest period for the four groups would have been similar. This same increase in time for these three subjects accounted for the change from a significant F ratio between trials one and two as compared to the non-significant F ratio obtained between trials one and three for the competitive vertical group as indicated by Scheffe's Test in Table 5.

It is a common coaching practice to have teams continue training during vacation periods. Coaches should perhaps consider the findings of this study before continuing that procedure. Cherry and Boehm[1] indicate that fatigue often

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[1]John K. Cherry and Walter W. Boehm, "Modern European Controlled Interval Method of Distance Training," Scholastic Coach, XXVI (March, 1957), 24.

accumulates when using an interval training technique. The body is forced into a deficit as the work load exceeds the ability of the body to recuperate. Perhaps this phenomena was present in this study and the rest period allowed the body to reduce the deficit, as well as to counteract staleness from continual training.

After the rest period all four groups began to improve again, however, the vertical groups were improving more rapidly than the horizontal groups. Improvement during the last two week practice block did not reach a level of significance for any group. However, when the two vertical groups were combined for the last two week practice block a comparison of trials three and four resulted in a "t" of 2.1927 which approached significance at the .05 level. A "t" of 2.201 was needed for significance.

Motivation is an important factor in any training program. Rilea[1] concluded that when comparing swimmers who were training in a fatigue or a non-fatigue condition, the swimmers training in the non-fatigue group were bored. Turkington[2] concluded that when comparing swimmers who were training in a traditional method with those in an interval program, the swimmers reported that the interval method was more interesting and more motivating than the traditional method. Davis[3]

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[1]Rilea, p. 14.

[2]Turkington, p. 28.

[3]M. Davis, p. 37.

concluded that when comparing swimmers who were training in a traditional part-whole method with those in a whole method, the part-whole method is considered more difficult by the swimmers. Subjects in this experiment counted the repeat intervals and were aware of the number of repetitions to be completed. During the last two week practice block members of the vertical groups formed a circle and talked during the workout period. A method of training similar to the Fartlek method occurred during the longer intervals as the subjects took turns in attempting to raise the body as far out of the water as possible. This game would not have been possible if the subjects had been working to full capacity. In the vertical position it is necessary to work at a level sufficient to support body weight as one sinks if a constant amount of pressure is not applied against the water. This is not true of the horizontal position.

Burdeshaw[1] indicated that the majority of studies conducted in competitive swimming used male subjects and that the results may not be applicable to women swimmers. Kingston[2] and Collins[3] also made reference to sex differences and questioned the results obtained from male subjects being

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[1] Dorothy Burdeshaw, "Learning Rate of College Women in Swimming in Relation to Strength, Motor Ability, Buoyancy and Body Measurements" (unpublished Ed. D. dissertation, University of Texas, 1966), p. 6.

[2] Kingston, pp. 69, 98.

[3] P. Collins, p. 6.

applied directly to women. Lietuvietis[1] states that as women's shoulder strength is not as great as men's, the kick may be more important to the total stroke for women than for men, while the kick is not deemed as important as the pull for forward propulsion in executing the whole stroke, the kick may be more important for women swimmers not only because of a lack of shoulder girdle strength but also because of the additional weight women have in the hips and legs.

Fox,[2] Karpovich,[3] and Hewitt[4] used the "dead start" technique in their investigations, while Moyle,[5] Lopin,[6] and Puolos[7] recommended that the subject achieve maximum velocity before the time trial was started. Although the dead start technique was used in this study, the investigator would recommend the use of the constant velocity method. Several subjects, particularly those in the ex-competitive groups, appeared to have difficulty in obtaining traction for forward propulsion. The investigator observed that a subject might kick three to six beats before forward motion was noticeable. This delay in forward motion may partially account for the larger variance of scores within each subject's score for the ex-competitive group.

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[1]Lietuvietis, p. 1. [2]Fox, p. 233.

[3]Karpovich, "Propelling Forces," p. 49.

[4]Hewitt, p. 171. [5]Moyle, p. 4.

[6]Lopin, p. 7. [7]Puolos, p. 3.

In a study investigating training methods for speed swimming, Murray[1] included a rest period of one and one-half weeks during the treatment period, however, no analysis was given regarding the effects of the lay-off. Mathews and Fox[2] state that no loss in strength or flexibility occurred as a result of a one week lay-off period. This study would support those conclusions. The investigator suggests, however, that if tests regarding the effect of rest periods are included in a study, it will not be a valid procedure to conduct tests the first day the subjects return to the campus.

Twenty-five yards kicking appeared to be too great a distance for some of the lesser skilled ex-competitive swimmers. Two of the subjects had difficulty completing the last five yards of each trial. This finding agrees with Moyle[3] and Allen[4] who suggest a distance of ten yards for trials. However, the investigator recommends the twenty-five yard distance for skilled swimmers.

It is difficult to construct a land drill to practice a kicking skill. Kiphuth[5] states that the same amount of

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[1]Murray, p. 8.

[2]Donald K. Mathews and Edward L. Fox, The Physiological Basis of Physical Education and Athletics (Philadelphia: W. B. Saunders Company, 1971), p. 77.

[3]Moyle, p. 5.

[4]Allen, p. 4.

[5]Kiphuth, p. 92.

strength cannot be developed in the water as on land in the same amount of time. Clark[1] states that a position and activity similar to the desired skill obtains the best results. Strength and flexibility development are specific to the muscle group and joint. Kingston[2] agrees with the concept of specificity of exercise and states that the most effective method of improving swimming skills is to practice swimming. Murray,[3] however, states that land exercise or weight training in addition to swimming is an effective method. The review of literature revealed only three methods for increasing resistance while kicking. Counsilman[4] suggests the use of heavier kickboards than those used for beginning swimmers. Thrall[5] and Wallace[6] state that swimming fins may be used to increase the weight of the feet. Sproule[7] developed a resistance device from a gallon plastic jug that may be attached to the swimmers waist by means of a belt. Kicking in a vertical position may meet the criteria of both

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[1]Clark, p. 2.

[2]Kingston, p. 99.

[3]Murray, p. 104.

[4]Councilman, Science of Swimming, p. 218.

[5]Thrall, p. 45.

[6]Wallace, p. 56.

[7]J. P. Hugh Sproule, "Inexpensive Swimming Resistance Devices," Journal of Physical Education, LXVII (July, 1970), 161.

specificity of exercise and overload by progressive weight resistance while the subject is in the water.

The vertical method of practicing to perform the flutter kick suggests several advantages. The values of training in the vertical position are: no equipment is necessary, large groups are accommodated in a relatively small space, application of the overload and progressive weight training is automatic, motivation is increased as immediate awareness of success (lift in the water) is obvious to the swimmer, the criterion of making kicking drills competitive is fulfilled, and ineffective kicks such as a hooked or flapping kick are eliminated.

Conclusions

The following conclusions appear to be justified by the results of this study:

1. There appeared to be a significant improvement in flutter kicking speed for twenty-five yards as a result of practicing a repetition interval training program in a vertical position.
2. There appeared to be no significant improvement in flutter kicking speed for twenty-five yards as a result of practicing a repetition interval training program in a horizontal position.
3. There appeared to be no significant difference in ankle flexion-inversion or ankle flexion as a

result of practicing a repetition interval training program in a vertical position.

4. There appeared to be a significant difference in the velocity of the legs as a result of practicing a repetition interval training program in a vertical position.
5. There appeared to be a significant difference in the times of competitive and ex-competitive swimmers for a twenty-five yard kicking trial.
6. It appeared that competitive and ex-competitive groups perform in a similar pattern over trials as a result of practicing a repetition interval training program in a vertical and a horizontal position.

Recommendations for Further Studies

The following recommendations are suggested for further research on the topic of flutter kicking:

1. A replication of the study using highly skilled competitive swimmers as subjects.
2. A replication of the study using male subjects.
3. A replication of the study to determine where the plateau effect would occur relative to the length of the treatment period.
4. A replication of the study using only the vertical position and comparing back flutter and prone flutter changes in time.

5. A replication of the study in which the flexibility and velocity measurements were correlated on the basis of kicking speed.
6. A replication of the study using the vertical position as a teaching method for beginning swimmers.
7. A descriptive film analysis to determine changes, if any, that occur in the mechanics of the leg action while kicking in a vertical position as compared to a horizontal position.

APPENDIXES

APPENDIX A

SWIMMER'S DATA SHEET

_______ Test Group   Rank Order Within Classification _____

Name ______________________________
(Last)   (First)

College Address ______________________________

Phone ________________ Age _____ Year in School __________

Major ____________ Minor __________ Height _______ Weight _______

Competitive Experience in Swimming ______________________

____

When did you last train with a competitive team? ____________

What did (do) you consider your best stroke? ____________

Additional Physical Activity During Spring Semester 1971:

Physical Education Classes: (Days & Time) ____________

Other Physical Activities Done Regularly ____________

Classification for Study: _____ Competitive _____ Ex-competitive

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Time trials:

First Test: 1. _______ 2. _______ 3. _______ Average _______

Second Test: 1. _______ 2. _______ 3. _______ Average _______

Third Test: 1. _______ 2. _______ 3. _______ Average _______

Fourth Test: 1. _______ 2. _______ 3. _______ Average _______

Fifth Test: 1. _______ 2. _______ 3. _______ Average _______

Assigned to __________ Vertical __________ Horizontal Group

Film Subject: _______ Yes _______ No

APPENDIX B

INSTRUCTION AND INFORMATION SHEET FOR THE FLUTTER KICK EXPERIMENT

Purpose: The purpose of this study is to determine whether training in a horizontal or a vertical body position makes a significant difference in the ability to perform the flutter kick in relationship to speed, power and ankle flexibility.

Procedures: The training program is a times interval technique. Statistical treatment of the data requires that you receive the same amount of practice under the same conditions. If you are late to practice your training experience will not be identical to others in the experiment. Practice will take only fifteen minutes. Practice time is 5 PM Monday, Wednesday and Friday, and 5:30 PM on Tuesday and Thursday.

For the experiment, please conform to the following:

1. Attend practice daily, Monday through Friday.
2. Be on time.
3. Perform with maximum effort throughout the practice period. (No motivation techniques or corrections will be given to either group.)
4. Avoid ANY practice of the flutter kick other than the fifteen minute practice period. You may swim, but do not practice the kick by itself. (Arrangements have been made with your teachers and coach so that you are not expected to participate in any "legs only" work in class or at team practice.)

Vertical Group:

1. Concentrate to maintain the mechanics of the flutter kick as similar as possible to those used in a horizontal position.
2. Do not change the action of the joints in an effort to remain above the surface of the water. If the mechanics of the flutter kick remain the same as in the horizontal position you will stay afloat readily.
3. Do not increase the width of the flutter kick--too wide a kick may cause a scissor action.
4. Stand as erect as possible in the water.
5. Do not use your hands in a sculling action. Keep your hands in contact with your thighs.
6. Attempt to raise the body as far out of the water as possible by the force of the flutter kick.

Whistle Commands: Series of three whistles.

1. Start kicking on the first whistle.
2. Ex-competitive swimmers stop on the second whistle.
3. Competitive swimmers stop on the third whistle.

APPENDIX C

TESTING, FILMING, AND WORKOUT SCHEDULE

	Monday	Tuesday	Wednesday	Thursday	Friday	
March 11-12				11 Test & Film 1	12 Test & Film 1	Testing
March 15-19	15 Make-up Tests Workout 1	16 Workout 2	17 Workout 3	18 Workout 4	19 Workout 5	Week 1
March 22-26	22 Workout 6	23 Workout 7	24 Workout 8	25 Workout 9	26 Workout 10 (One Trial Test)	Week 2
March 29-31 April 1-2	29 Workout 11 (Test Make-ups)	30 Workout 12	31 Workout 13	1 Workout 14	2 Workout 15 Test & Film 2	Week 3
April 5-9	5 Workout 16 Test & Film Make-ups	6 Workout 17	7 VAC	8 VAC	9 VAC	Week 4
April 12-16	12 VAC	13 VAC	14 Workout 18 Kicking Test 3	15 Workout 19 Test Make-ups	16 Workout 20	
April 19-23	19 Workout 21	20 Workout 22	21 Workout 23	22 Workout 24	23 Kicking Test 4	Week 5*
April 26	26 Test Make-ups					Testing

*The week for lay-off is not counted in the workout schedule.

APPENDIX D

WEEKLY TREATMENT PROGRAM BY WORK-REST INTERVALS AND TOTAL INTERVALS BY GROUPS

The following are the work-rest intervals and total interval times (work and rest combined) for the repetition interval training program based on mixed sets, broken sets, and locomotive type progressions used as the treatment for the competitive and ex-competitive groups in this investigation. The work-rest intervals for the ex-competitive groups are listed first, the intervals for the competitive group listed below.

	Work-Rest Intervals in Seconds	Total "Interval Sequence" in Seconds	No. of Repeats	Total "Set Sequence" in Minutes
	WEEK ONE - MARCH 15-19			
Ex-Com. Com.	10 x 10 15 x 5	20	3	1
Ex-Com. Com.	15 x 25 30 x 10	40	6	4
Ex-Com. Com.	10 x 10 15 x 5	20	3	1
	Pattern sequence was repeated twice with a three minute rest between repeats.			
	WEEK TWO - MARCH 22-26			
Ex-Com. Com.	15 x 15 20 x 10	30	2	1
Ex-Com. Com.	20 x 20 30 x 10	40	3	2
Ex-Com. Com.	25 x 35 40 x 20	60	1	1
Ex-Com. Com.	20 x 20 30 x 10	40	3	2
Ex-Com. Com.	15 x 15 20 x 10	30	2	1
	Pattern sequence was repeated twice with a one minute rest between repeats.			

APPENDIX D--Continued

	Work-Rest Intervals In Seconds	Total "Interval Sequence" in Seconds	No. of Repeats	Total "Set Sequence" in Minutes
WEEK THREE - MARCH 29-31; APRIL 1-2				
Ex-Com. Com.	15 x 15 20 x 20	30	2	1
Ex-Com. Com.	25 x 20 30 x 10	45	2	1½
Ex-Com. Com.	30 x 30 40 x 20	60	2	2
Ex-Com. Com.	25 x 20 30 x 15	45	2	1½
Ex-Com. Com.	15 x 15 20 x 10	30	2	1
	Pattern sequence was repeated twice with a one minute rest between repeats.			
WEEKS FOUR AND FIVE - APRIL 5-6 & 14-16; 19-22				
Ex-Com. Com.	15 x 15 20 x 10	30	3	1½
Ex-Com. Com.	25 x 20 30 x 15	45	2	1½
Ex-Com. Com.	30 x 30 45 x 15	60	1	1
Ex-Com. Com.	25 x 20 30 x 15	45	2	1½
Ex-Com. Com.	15 x 15 20 x 10	30	3	1½
	Pattern sequence was repeated twice with a one minute rest between repeats.			

APPENDIX E

EXPLANATION OF THE WORKOUT PATTERN SEQUENCE SHEETS

Key to Terms:

W - Work interval
R - Rest interval
s - Start of interval sequence
W-1 - First whistle of interval sequence
W-2 - Second whistle of interval sequence
W-3 - Third whistle of interval sequence
Ex-C - Ex-competitive group
Comp. - Competitive group
Watch - Stop watch time

An "interval sequence" refers to a time sequence for a series of three whistles.
A "set sequence" refers to a series of intervals of the same length of work and rest intervals.
A "pattern sequence" refers to the series of set sequences used for one basic pattern sequence. (The daily workout consisted of one pattern sequence repeated twice.)

The "Basic Pattern" column gives a comparison of the work and rest intervals in seconds used by the ex-competitive and competitive groups, e.g., the first work period for the ex-competitive group is 10 seconds as compared to 15 seconds for the competitive group, with the first rest periods being 10 and 5 seconds respectively. The sets are separated by a horizontal double line. The time listed in minutes at the end of the column indicates the rest period allowed between pattern sequence repeats for the day.

The "Watch" column indicates the time within each interval sequence for the starting whistle, marked with the small "s," and the two stop whistles, the first for the ex-competitive group and the second for the competitive group, e.g., the whistle was blown on "0" to start both groups kicking, the whistle was blown at a reading of ten seconds on the watch for the ex-competitive group to stop kicking, and at 15 seconds for the competitive group to stop. Five seconds later the entire group started again when the whistle was blown at a clock reading of 20 seconds.

The double columns under the days of the week were used to keep an accurate account of the times for the workout. As the whistle was blown at each reading a check mark was placed in the appropriate square. When the bottom of the column was reached, the rest period between pattern repeats (found at the bottom of the basic pattern column) was allowed. The same check-off procedure was used for the second pattern sequence for the day.

The "W-1, W-2, and W-3" columns indicate the reason for each whistle. The columns correspond to the watch column as explained above. These columns provided a double check against the possibility of errors in the "Watch" column. Rest periods in relation to the whistle are shown in the small horizontal space at the end of each sequence pattern, e.g., after the stop whistle (W-2) the ex-competitive group had 10 seconds rest before the next start whistle and the competitive group had 5 seconds rest after their stop whistle (W-3) before the next start whistle.

APPENDIX E--Continued

WORKOUT PATTERN SEQUENCE - WEEK ONE - MARCH 15-19

	Basic Pattern Ex-C.	Basic Pattern Comp.
W	10	15
R	10	5
W	10	15
R	10	5
W	10	15
R	10	5
W	15	30
R	25	10
W	15	30
R	25	10
W	15	30
R	25	10
W	15	30
R	25	10
W	15	30
R	25	10
W	15	30
R	25	10
W	10	15
R	10	5
W	10	15
R	10	5
W	10	15
R	10	5
3 min. rest		

Watch 0	s	Mon.	Tue.	Wed.	Thu.	Fri.	W-1 Start	W-2 Ex-C.	W-3 Comp.
10								10stop	
15									15stop
							Rest	10	5
20	s						start		
0								10stop	
5									15stop
							Rest	10	5
10	s						start		
20								10stop	
25									15stop
							Rest	10	5
0	s						start		
15								15stop	
0									30stop
							Rest	25	10
10	s						start		
25								15stop	
10									30stop
							Rest	25	10
20	s						start		
5								15stop	
20									30stop
							Rest	25	10
0	s						Start		
15								15stop	
0									30stop
							Rest	25	10
10	s						start		
25								15stop	
10									30stop
							Rest	25	10
20	s						start		
5								15stop	
20									30stop
							Rest	25	10
0	s						start		
10								10stop	
15									15stop
							Rest	10	5
20	s						start		
0								10stop	
5									15stop
							Rest	10	5
10	s						start		
20								10stop	
25									15stop

APPENDIX E--Continued

WORKOUT PATTERN SEQUENCE - WEEK TWO - MARCH 22-26

	Basic Pattern Ex-C.	Comp.
W	15	20
R	15	10
W	15	20
R	15	10
W	20	30
R	20	10
W	20	30
R	20	10
W	20	30
R	20	10
W	25	40
R	35	20
W	20	30
R	20	10
W	20	30
R	20	10
W	20	30
R	20	10
W	15	20
R	15	10
W	15	20
R	15	10
1 min. rest		

Watch O	s	Mon.	Tue.	Wed.	Thu.	Fri.	W-1 Start	W-2 Ex-C.	W-3 Comp.
15								15stop	
20									20stop
							Rest	15	10
0	s						start		
15								15stop	
20									20stop
							Rest	15	10
0	s						start		
20								20stop	
0									30stop
							Rest	20	10
10	s						start		
0								20stop	
10									30stop
							Rest	20	10
20	s						start		
10								20stop	
20									30stop
							Rest	20	10
0	s						start		
25								25stop	
10									40stop
							Rest	35	20
0	s						start		
20								20stop	
0									30stop
							Rest	20	10
10	s						start		
0								20stop	
10									30stop
							Rest	20	10
20	s						start		
10								20stop	
20									30stop
							Rest	20	10
0	s						start		
15								15stop	
20									20stop
							Rest	15	10
0	s						start		
15								15stop	
20									20stop
							Rest	15	10

APPENDIX E--Continued

WORKOUT PATTERN SEQUENCE - WEEK THREE - MARCH 29-31 - APRIL 1-2

	Basic Pattern	
	Ex-C.	Comp.
W	15	20
R	15	10
W	15	20
R	15	10
W	25	30
R	20	15
W	25	30
R	20	15
W	30	40
R	30	20
W	30	40
R	30	20
W	25	30
R	20	15
W	25	30
R	20	15
W	15	20
R	15	10
W	15	20
R	15	10
1 min. rest		

Watch O	s	Mon.	Tue.	Wed.	Thu.	Fri.	W-1 Start	W-2 Ex-C.	W-3 Comp.
15								15stop	
20									20stop
							Rest	15	10
0	s						start		
15								15stop	
20									20stop
							Rest	15	10
0	s						start		
25								25stop	
0									30stop
							Rest	20	15
15	s						start		
10								25stop	
15									30stop
							Rest	20	15
0	s						start		
0								30stop	
10									40stop
							Rest	30	20
0	s						start		
0								30stop	
10									40stop
							Rest	30	20
0	s						start		
25								25stop	
0									30stop
							Rest	20	15
15	s						start		
10								25stop	
15									30stop
							Rest	20	15
0	s						start		
15								15stop	
20									20stop
							Rest	15	10
0	s						start		
15								15stop	
20									20stop
							Rest	15	10

APPENDIX E--Continued

WORKOUT PATTERN SEQUENCE - WEEKS FOUR AND FIVE
APRIL 5-6 & 14-16; APRIL 19-22

	Basic Pattern Ex-C.	Comp.
W	15	20
R	15	10
W	15	20
R	15	10
W	15	20
R	15	10
W	25	30
R	20	15
W	25	30
R	20	15
W	30	45
R	30	15
W	25	30
R	20	15
W	25	30
R	20	15
W	15	20
R	15	10
W	15	20
R	15	10
W	15	20
R	15	10
	1 min. rest	

Watch O	s	Mon.	Tue.	Wed.	Thu.	Fri.	W-1 Start	W-2 Ex-C.	W-3 Comp.
15								15stop	
20									20stop
							Rest	15	10
0	s						start		
15								15stop	
20									20stop
							Rest	15	10
0	s						start		
15								15stop	
20									20stop
							Rest	15	10
0	s						start		
25								25stop	
0									30stop
							Rest	20	15
15	s						start		
10								25stop	
15									30stop
							Rest	20	15
0	s						start		
0								30stop	
15									45stop
							Rest	30	15
0	s						start		
25								25stop	
0									30stop
							Rest	20	15
15	s						start		
10								25stop	
15									30stop
							Rest	20	15
0	s						start		
15								15stop	
20									20stop
							Rest	15	10
0	s						start		
15								15stop	
20									20stop
							Rest	15	10
0	s						start		
15								15stop	
20									20stop
							Rest	15	10

APPENDIX F

ORIENTATION AND TESTING PROCEDURES

I. Purpose: The purpose to this study is to determine whether training in a horizontal body position or a vertical body position makes a significant difference in your ability to perform the flutter kick in relationship to kicking speed, leg velocity and ankle flexibility.

II. General Procedure: Today you will be tested for three trials of flutter kicking for one length of the pool. Instructions for the testing procedures will be given in a few minutes. On the basis of the kicking time you will be divided into two groups, one control and one experimental. The control group will kick in a horizontal position, holding onto the edge of the pool; while the experimental group will kick in the experimental vertical position. The experimental group will also be filmed briefly from two different views while in the vertical position. The films will be analyzed later to determine leg velocity and ankle flexibility while kicking in a vertical position.

Practice will be held daily for fifteen minutes, Monday through Friday at 5 PM. The entire group, both control and experimental, will be kicking at the same time performing the same kicking progressions. The only difference between the two groups will be the body position. Because the training program is a timed interval training technique, it is very important for all of you to be here on time and be ready to start together. If you are late to practice your training experience will not be identical to the remainder of the group and thus affect the statistical findings. As a subject for the experiment, it will be necessary for you to attend practice daily, to be on time, and to perform with maximum effort throughout the practice time. You will practice daily for five weeks.

The day before Easter recess you will be re-tested on the kicking trials and the experimental group will be re-filmed. The day you return from Easter recess you will be re-tested for flutter kicking to determine if one week of not training causes a significant loss in kicking speed. There are two alternat plans after the testing. The dissertation committee will decide which plan will be used.
(1) If a significant loss has not occurred, the experiment will be over. If a significant loss has occurred you will practice until the loss has been recovered. This may take from one to four additional weeks. You will be re-tested at the end of each week to determine when the original (baseline) level has been regained. Or, (2) you will continue to practice and be re-tested at the end of the fifth and sixth weeks of practice (first and second weeks after Easter recess).

III. <u>Testing Procedure for Today</u>:

1. Fill out the data card that you received when you arrived.

2. Notice the number "one" or "two" in the upper left-hand corner of the card.
3. Report to the deep end of the pool if there is a "one" on your card, to the shallow end if there is a "two."
4. Line up in any order at the end of the pool.
5. Hand your card to the timer before your first trial.
6. Retain the same testing order for trials two and three.
7. Assume the testing position in the water when it is your turn:
    a. Lower yourself into the water.
    b. Assume a prone floating position.
    c. Hold the water polo ball with one hand placed directly on each side of the ball.
    d. Fully extend the arms overhead. Let the ball float as much as possible. Do not push downward on the ball.
    e. Keep your legs fully extended and place the end of your big toes against the edge of the pool. An assistant will hold your ankles lightly to keep your toes against the wall.
8. The testing commands will be "one," "two," "go." Counts will be even in rhythm to avoid differences in reaction time.
9. On the counts "one" and "two," take a deep breath.
10. On "go," the assistant will have released your ankle. On "go," lower your face into the water and begin kicking

as rapidly as you can. Lower your head until the water level is about even with your eyebrows.

11. Do not breathe any more than necessary. When you do breathe, do not push downward on the ball as water resistance against the ball will reduce your speed. Lift your head up to breathe, inhale and put your face back in the water.
12. Keep kicking until the ball touches firmly against the end (edge) of the pool.
13. Wait your turn and follow the same procedures for trial two and three.
14. At the completion of the time trials, you will be assigned to the control or experimental group according to a rank order based on your average time for the three trials. Those in the control group are through for the day.
15. Filming of the experimental group:
    a. Report to be marked for filming.
    b. Enter the water and move in front of the underwater observation window.
    c. Face the wall. Hold onto the edge of the pool with both hands.
    d. On command, release your hands from the edge of the pool and place the palms of your hands on the lateral sides of your thighs.
    e. Maintain an upright position and flutter kick as rapidly as possible.

f. Concentrate to maintain the flutter kick as similar as possible to that used in a horizontal position. Do not change the action of the joints in an attempt to remain above the surface of the water. If your mechanics of the flutter kick remain the same as in the horizontal position you will stay afloat readily.

g. Do not release your hands from your thighs until told to stop kicking. At the command to "stop," place your left (right) hand on the edge of the pool and turn your right side to the observation window.

h. On the command "go" place your hands on the lateral sides of your thighs and begin flutter kicking.

i. On the command "stop," your testing and filming period has been completed.

APPENDIX G

TESTING AND ORIENTATION EQUIPMENT AND PERSONNEL

Equipment for the Testing Sessions:

35 pencils

35 Swimmer's Data Sheets (15 marked in red, 20 in blue ink)

2 playground balls measuring seven inches in diameter

2 stop watches

1 package cotton balls

1 pint alcohol

1 Eberhard Faber MARKette felt marking pen (black ink)

10 towels

1 70 H.R. Bell and Howell camera with tripod

3 rolls of 100' Tri-X Reversal Type black and white 16mm film

Personnel:

30 testees

1 tester

1 assistant tester

1 assistant for the first session only

1 cameraman

APPENDIX H

INSTRUCTIONS FOR TESTING PERSONNEL

Tester:

Receive the data card from the subject.

Explain the starting position and instructions.

Check to see that the body is in the correct position.

Wait for the assistant tester's command of "ready."

Commands of "one," "two," "go."

Retain the same rhythm in giving the three commands.

Start the stop watch as the swimmer's legs begin to kick.

Stop the watch as soon as the ball makes contact with the edge of the pool opposite the starting position.

Record the time in the appropriate space on the data card.

Keep the data cards in order for the second and third trials.

Assistant Tester:

Keep the subject's big toes in contact with the edge of the pool by holding lightly onto the ankles.

Check to see that the feet are at the upper level in relationship to the remainder of the body.

Check to see that the subject's knees and elbows are fully extended.

When the subject is in the correct position say "ready" to the tester.

Release the subject immediately on the command "go."

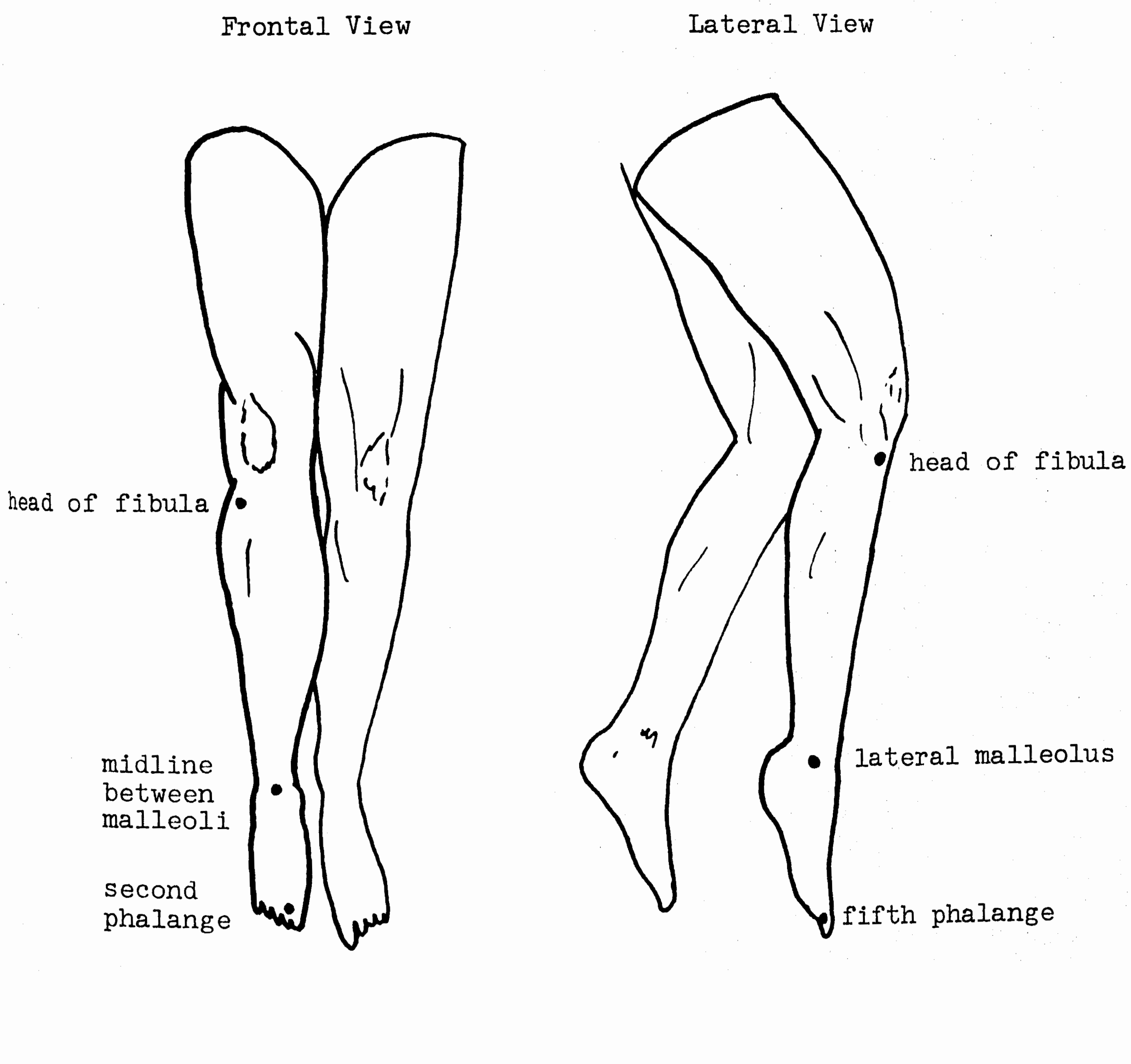
Second Assistant:

Compute the average time of the three trials. Arrange the cards in rank order, fastest on the top. Assign the rank order number in the upper right hand corner of the card.

Relay start and stop commands from the cameraman to the test subject for filming.

APPENDIX I

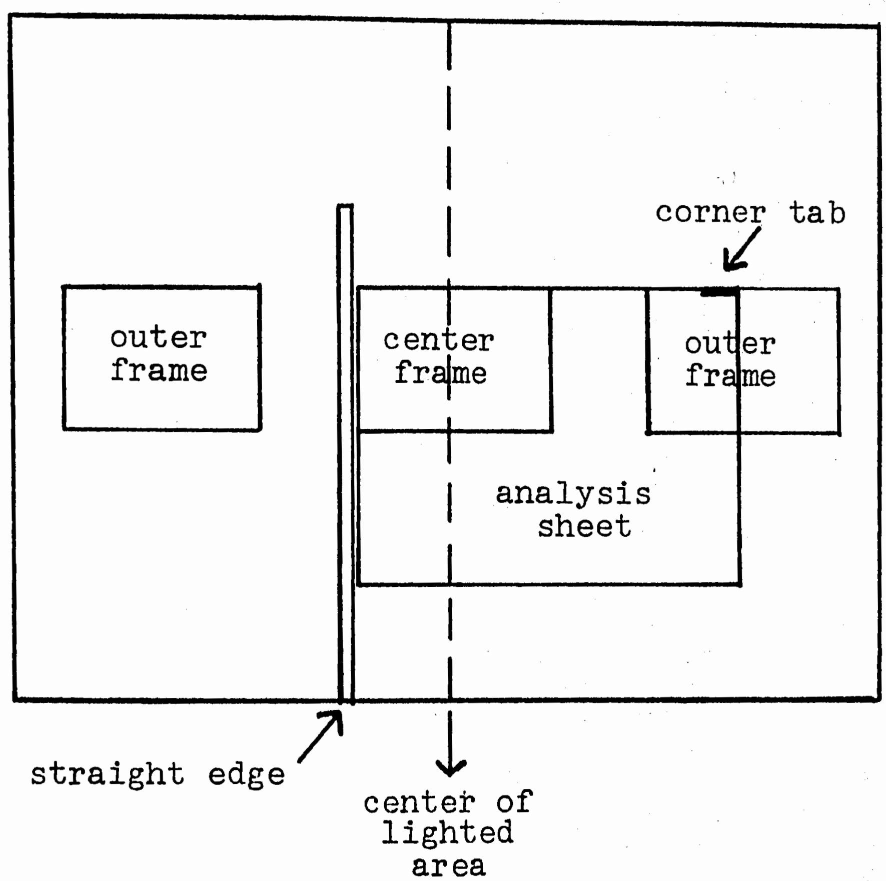
MARKING OF SUBJECTS FOR FILMING



APPENDIX J

FILM READER PROJECTION PROCEDURES

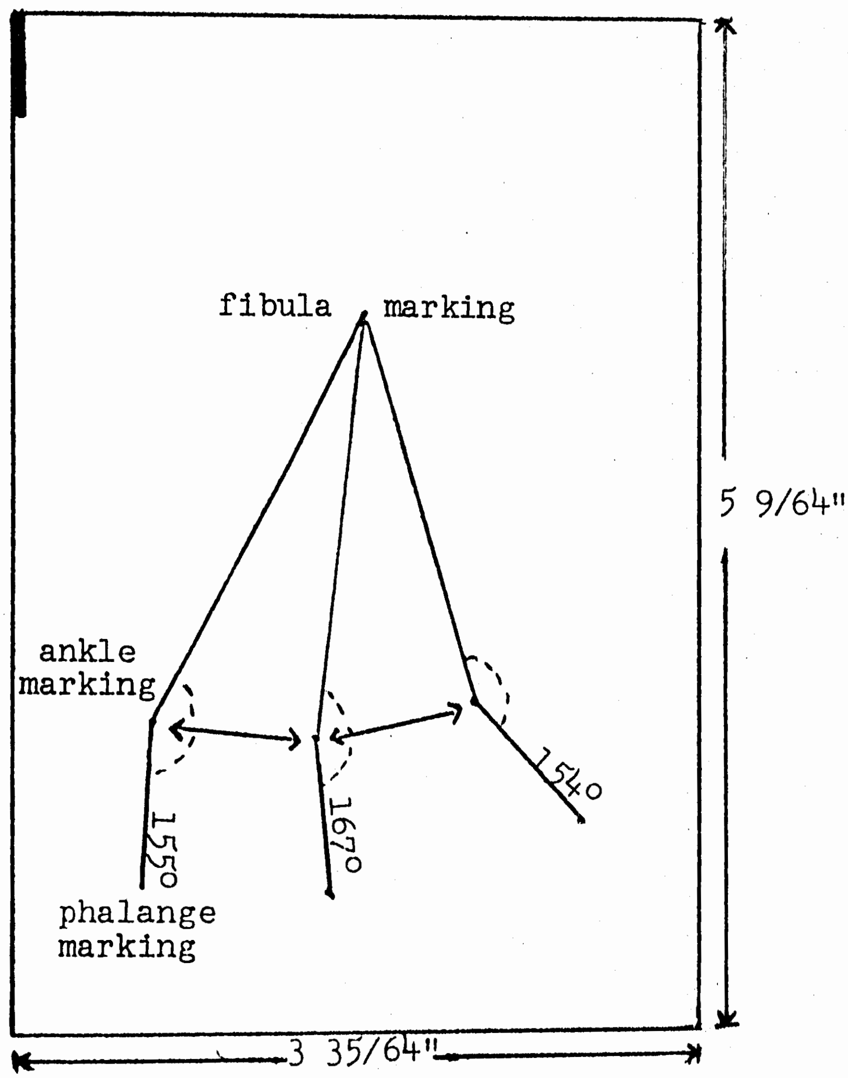
Lighted Area Produced by Projector



APPENDIX K

FRAME ANALYSIS SHEET

Lateral View



1) Three markings for one velocity measurement

2) Greatest angle for one ankle flexibility measurement

APPENDIX L

RAW SCORES:
AVERAGE TIMES FOR TWENTY-FIVE YARD KICKING TRIALS

Subject	Trials 1	Trials 2	Trials 3	Trials 4	Differences 1-2	Differences 2-3	Differences 3-4	Differences 1-4
Competitive-Vertical								
1	22.900	21.100	21.566	20.766	-1.800	+0.466	-0.800	-2.134
2	26.466	24.133	26.833	23.966	-2.333	+2.700	-2.867	-2.500
3	26.466	24.500	26.433	25.933	-1.966	+1.933	-0.500	-0.533
4	28.366	25.466	23.566	24.400	-2.900	-2.000	+0.834	-3.966
5	28.500	28.433	27.900	28.600	-0.067	-0.533	+0.700	-0.100
6	34.600	31.033	32.300	30.500	-3.567	+1.267	-1.800	-4.100
Competitive-Horizontal								
1	23.400	22.700	22.933	23.200	-0.700	+0.233	+0.267	-0.200
2	24.900	25.366	23.866	23.566	+0.433	-1.500	-0.300	-1.367
3	27.866	26.266	26.700	27.066	-1.600	+0.434	+0.366	-0.800
4	28.266	31.366	29.333	27.933	+3.100	-2.033	-1.400	-0.333
5	28.566	30.400	29.266	29.133	+1.834	-1.134	-0.133	+0.567
Ex-Competitive-Vertical								
1	27.566	27.700	27.266	25.166	+0.134	-0.434	-2.100	-2.400
2	29.433	29.533	28.966	29.566	+0.100	-0.567	+0.600	+0.133
3	29.600	27.933	27.700	26.066	-1.677	-0.233	-1.634	-3.534
4	31.600	29.533	29.633	29.200	-2.067	+0.100	-0.433	-2.400
5	43.166	39.700	37.333	34.266	-3.466	-2.367	-3.067	-8.900
6	44.200	38.800	37.933	38.400	-5.400	-0.867	+0.467	-5.800
Ex-Competitive-Horizontal								
1	27.600	27.666	27.900	28.833	+0.066	+0.234	+0.933	+1.233
2	28.500	29.500	27.300		+1.000	-2.200		
3	29.200	27.800	27.966	26.266	-1.400	+0.166	-1.700	-2.934
4	30.700	33.533	31.100		+2.833	-2.433		
5	33.466	33.000	31.300	31.066	-0.466	-1.700	-0.234	-2.400

RAW SCORES LATERAL VIEW: VELOCITY OF THE LEGS MEASURED TO THE NEAREST SIXTY-FOURTH INCH PER ONE-EIGHTH SECOND FROM A FILM ANALYSIS OF THE VERTICAL GROUP

	Pre-Test 1st Meas.					Pre-Test Retest					Post-Test 1st Meas.					Post-Test Retest				
Subj.	1	2	3	Avg.	Const.*	1	2	3	Avg.	Const.*	1	2	3	Avg.	Const.*	1	2	3	Avg.	Const.*
1	57	71	72	66.7	5.2109	57	71	72	66.7	5.2109	99	98	97	98.0	7.6563	101	107	96	101.3	7.914
2	116	103	97	105.3	8.2266	120	108	93	107.0	8.3599	118	131	125	124.7	9.7422	110	134	120	121.3	9.976
3	79	67	74	73.3	5.7266	77	75	66	72.7	5.6797	75	79	91	81.6	6.3750	78	77	85	80.0	6.250
4	102	73	75	83.3	6.5078	104	67	75	82.0	6.4063	106	99	115	106.7	8.3359	98	96	110	101.3	7,9141
5	88	86	82	85.3	6.6641	92	85	86	87.7	6.8516	88	90	94	90.7	7.0859	93	92	91	92.0	7.187
6	92	103	96	97.0	7.5788	91	101	96	96.0	7.5000	68	85	78	77.0	6.0156	72	85	80	79.0	6.171
1	81	95	113	96.3	7.5234	81	103	113	99.0	7.7344	108	105	120	111.0	8.6719	110	109	122	113.7	8.8828
2	67	74	94	78.3	6.1192	73	77	97	82.3	6.4297	100	97	105	100.7	7.8672	99	92	109	100.0	7.8125
3	74	90	89	84.3	6.5859	72	89	89	83.3	6.5028	125	80	89	98.0	7.6563	125	84	90	99.7	7.7891
4	73	82	85	80.0	6.2500	75	83	87	81.7	6.3828	64	61	57	60.7	4.7422	59	65	57	60.3	4.7109
5	102	95	95	97.3	7.6016	102	103	103	102.7	8.0239	142	119	113	104.7	9.7422	141	120	112	124.3	9.7109
6	61	80	83	74.7	5.8125	59	70	90	73.0	5.7031	103	102	72	92.3	7.2109	103	110	75	96.0	7.50

*The average times for three were multiplied by a constant of five to convert the measurements to normal size. The obtained figure would be multiplied by 8 to convert the measurement to inches per second.

APPENDIX L--Continued

RAW SCORES LATERAL VIEW: PLANTAR FLEXION MEASURED TO THE NEAREST DEGREE FROM A FILM ANALYSIS OF THE VERTICAL GROUP

	Pre-Test 1st Meas.				Pre-Test Retest				Post-Test 1st Meas.				Post-Test Retest			
Subjects	1	2	3	Avg.*	1	2	3	Avg.*	1	2	3	Avg.*	1	2	3	Avg.*
Competitive																
1	176	182	181	179.7	177	178	174	176.3	172	174	167	171.0	174	172	163	169.7
2	181	160	171	170.7	184	165	171	173.3	169	163	169	167.0	170	165	163	166.0
3	173	177	169	173.0	176	174	164	171.3	177	178	170	175.0	176	179	172	175.7
4	171	177	174	174.0	170	176	174	173.3	172	180	181	177.7	177	180	184	180.3
5	165	162	164	163.7	165	165	165	165.0	174	171	171	172.0	176	171	172	173.0
6	173	173	173	173.0	173	174	173	173.3	168	161	171	166.7	165	166	168	166.3
Horizontal																
1	169	174	170	171.0	168	174	169	170.3	170	171	172	171.0	170	171	171	170.6
2	174	175	177	175.3	176	175	176	175.6	175	174	169	172.9	176	175	170	173.7
3	182	184	185	183.7	184	186	186	185.3	187	186	189	187.3	183	183	184	183.3
4	170	179	178	175.7	167	175	178	173.3	161	167	168	165.3	157	165	166	162.7
5	177	171	173	173.6	169	174	175	172.6	169	170	173	170.7	171	171	175	172.3
6	166	168	172	168.7	163	167	173	167.7	168	159	161	162.7	169	158	161	162.7

*The average times for three trials were used for computation.

APPENDIX L--Continued

RAW SCORES FRONTAL VIEW: PLANTAR FLEXION-INVERSION MEASURED TO THE NEAREST DEGREE FROM A FILM ANALYSIS OF THE VERTICAL GROUP

	Pre-Test 1st Meas.				Pre-Test Retest				Post-Test 1st Meas.				Post-Test Retest			
Subjects	1	2	3	Avg.*	1	2	3	Avg.*	1	2	3	Avg.*	1	2	3	Avg.*
Competitive																
1	166	169	160	165.0	161	164	160	161.7	170	156	168	164.7	170	156	168	164.7
2	129	129	127	128.3	127	126	128	127.0	135	136	147	139.3	132	143	149	141.3
3	166	161	161	162.7	166	157	161	161.3	159	156	152	155.7	161	159	149	156.3
4	155	157	148	153.3	153	155	145	151.0	158	161	158	159.0	155	157	155	155.7
5	153	157	155	155.0	157	160	154	157.0	146	151	149	148.6	149	149	145	147.7
6	158	156	144	152.7	145	158	141	148.0	150	140	151	147.0	145	143	154	147.3
Horizontal																
1	167	174	164	168.3	167	168	160	165.0	151	157	157	155.0	149	165	161	158.3
2	151	155	151	152.3	151	155	151	152.3	159	165	165	163.0	158	165	164	162.3
3	146	152	150	149.3	145	151	151	149.0	159	160	158	159.0	163	158	155	158.7
4	136	133	135	134.7	136	131	139	135.3	135	156	146	145.7	141	155	146	147.3
5	140	166	166	157.3	142	165	162	156.3	168	156	162	162.0	168	156	159	161.0
6	163	160	161	161.3	165	162	162	163.0	157	152	144	151.0	153	157	141	150.3

*The average times for three trials were used for computation.

APPENDIX M

FORMULAS USED IN ANALYSIS OF DATA

I. Standard Deviation[1]

$$SD = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{N}}{N-1}}$$

X = raw score

N = number of scores

II. Standard Error of the Mean[2]

$$\frac{SD}{\sqrt{N}}$$

SD = standard deviation

N = number of scores

III. t-Test of Difference Between Means[3]

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{Sp^2 \left(\frac{1}{N_2} + \frac{1}{N_2}\right)}}$$

$\bar{X}$ = mean
Sp^2 = pooled variance
N = number of scores

IV. Sp^2 for Samples of Unequal Numbers[4]

$$Sp^2 = \frac{(N_1 - 1)S_1^2 + (N_2 - 1)S_2^2}{N_1 + N_2 - 2}$$

N = number of scores
S = standard deviations
Sp^2 = pooled variance

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[1]James L. Bruning and B. L. Kintz, Computational Handbook of Statistics (Atlanta: Scott, Foresman and Company, 1968), p. 5.

[2]*Ibid*., p. 6.

[3]Marilyn Hinson, private interview held at the Texas Woman's University, Denton, Texas, April, 1971.

[4]*Ibid*.

V. Sp^2 for Samples of Equal Numbers[1]

$$Sp^2 = \frac{S_1{}^2 + S_2{}^2}{2}$$

S = standard deviation

Sp^2 = pooled variance

VI. Scheffe's Test of All Possible Comparisons[2]

$$F = \frac{(M_1 - M_2{}^2)}{MS_w \left(\frac{1}{n_1} + \frac{1}{n_2}\right) (K-1)}$$

M = mean
MS_w = mean square within
n = number in group
K = number of groups

VII. t-Test of Mean Differences for Related Measures[3]

$$t = \frac{\bar{D}}{\frac{SD}{\sqrt{N}}}$$

$\bar{D}$ = mean of differences between trials for groups

$$SD = \sqrt{\frac{\Sigma x^2 - \frac{(\Sigma x)^2}{N}}{N-1}}$$

X = difference between trials for each subjects time

[1]*Ibid*.

[2]Roscoe, p. 240.

[3]Hinson, interview.

BIBLIOGRAPHY

BIBLIOGRAPHY

Books

American Red Cross. Swimming and Diving. Philadelphia: Blakiston Company, 1938.

Armbruster, David A.; Allen, Robert H.; and Billingsley, Hobert Sherwood. Swimming and Diving. 5th ed. St. Louis: C. V. Mosby Company, 1968.

Armbruster, David A.; Allen, Robert H.; and Harlan, Bruce. Swimming and Diving. 3rd ed. St. Louis: C. V. Mosby Company, 1958.

Armbruster, David A., and Morehouse, Lawrence E. Swimming and Diving. 2nd ed. St. Louis: C. V. Mosby Company, 1950.

Bartels, Robert. Swimming Fundamentals. Columbus, Ohio: Charles E. Merrill Publishing Company, 1969.

Beach and Pool. Training Competitive Swimmers. New York: Hoffman-Harris Inc., 1949.

Broer, Marion R. Efficiency of Human Movement. 2nd ed. Philadelphia: W. B. Saunders Company, 1966.

Bruning, James L., and Kintz, B. L. Computational Handbook of Statistics. Glenview, Illinois: Scott, Foresman and Company, 1968.

Bunn, John W. Scientific Principles of Coaching. New York: Prentice-Hall, Inc., 1955.

Carlile, Forbes. Forbes Carlile On Swimming. London: Pelham Books, Ltd., 1963.

Corbett, Martin, and Racster, J. Swimming. London: George Bell & Sons, 1891.

Collins, Gilbert. The Newest Swimming. London: Windmill Press for William Heinemann, Ltd., 1937.

Colwin, Cecil M. "Crawl-Stroke Leg Action." Teaching Beginners to Swim. Edited by Beach and Pool. New York: Hoffman-Harris, Inc., 1949.

Corsan, George H., Sr. The Diving and Swimming Book. New York: A. S. Barnes & Company, 1929.

Counsilman, James E. The Science of Swimming. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968.

Cureton, Thomas Kirk, Jr. How to Teach Swimming and Diving. New York: Association Press, 1934.

Daviess, Grace Bruner. Swimming. Its Teaching Management, and Program Organization. Philadelphia: Lea & Febiger, 1932.

English Schools' Swimming Association. Swimming and Diving. Great Britain: William Heinemann, Ltd., 1963.

Faulkner, John A., ed. What Research Tells the Coach About Swimming. Washington, D. C.: American Association for Health, Physical Education and Recreation, 1967.

Greenwood, Frances A. Bibliography of Swimming. New York: The H. W. Wilson Company, 1940.

Handley, L. de B. Swimming for Women. New York: American Sports Publishing Company, 1931.

Handley, L. de B. Swimming and Watermanship. New York: Macmillan Company, 1925.

Harris, Marjorie M. Basic Swimming Analyzed. Boston: Allyn and Bacon, Inc., 1969.

Hayes, William L., and Winkler, Robert L. Statistics: Probability, Inference and Decision. Vol. I. New York: Holt, Rinehart and Winston, Inc., 1970.

Juba, Bill (W. J.). Instructions to Young Swimmers. London: Museum Press Limited, 1956.

Juba, Bill (W. J.), ed. Swimming as Taught by Experts. New York: Arco Publishing Company, Inc., 1961.

Juba, Bill (W. J.), and Madders, Max. "The Front-Crawl." Swimming and Diving. Edited by the English Schools' Swimming Association. Great Britain: William Heinemann, Ltd., 1963.

Kinnear, Bert. "A System of Training." Swimming as Taught by Experts. Edited by Bill (W. J.) Juba. New York: Arco Publishing Company, Inc., 1961.

Kiphuth, Robert J. H. Swimming. New York: A. S. Barnes & Company, 1942.

Kiphuth, Robert J. H., and Burke, Harry M. Basic Swimming. New Haven: Yale University Press, 1950.

Klugh, Henry E. Statistics--The Essentials for Research. New York: John Wiley & Sons, Inc., 1940.

Mackenzie, M. M., and Spears, Betty. Beginning Swimming. Belmont, California: Wadsworth Publishing Company, Inc., 1963.

Mathews, Donald K., and Fox, Edward L. The Physiological Basis of Physical Education and Athletics. Philadelphia: W. B. Saunders Company, 1971.

Plato. The Dialogues of Plato. Vol. II. Translated by B. Jowett. New York: Random House, 1892.

Rajki, Béla. The Technique of Competitive Swimming. Translated by Làsglò Göndör. Budapest, Hungary: University Printing House, 1956.

Reichart, Natalie, and Brauns, Jeanette. The Swimming Workbook. A Manual for Students. New York: A. S. Barnes & Company, 1937.

Roscoe, John T. Fundamental Research Statistics for the Behavioral Sciences. New York: Holt, Rinehart and Winston, Inc., 1969.

Scholey, Ray. "Front Crawl." Edited by Bill (W. J.) Juba. Swimming as Taught by Experts. New York: Arco Publishing Company, Inc., 1961.

Scott, M. Gladys. Analysis of Human Motion. 2nd ed. New York: Appleton-Century-Crofts, 1963.

Sheffield, Lyba, and Sheffield, Nita. Swimming Simplified. Rev. and Enlarged ed. New York: A. S. Barnes & Company, 1927.

Sinclair, A., and Henry, W. Swimming. 2nd ed. London: Longmans, Green & Company, 1894.

Smith, Ann Avery. Skillful Swimming. Ann Arbor, Michigan: J. W. Edwards, Publisher, Incorporated, 1954.

Smith, Ann Avery. Swimming and Plain Diving. New York: Charles Scribner's Sons, 1930.

Thomas, Ralph. Swimming. 2nd ed. London: Sampson Low, Marston & Company, 1904.

Torney, John A. Swimming. New York: McGraw-Hill Book Company, Inc., 1950.

Ulen, Harold S. and Larcom, Guy, Jr. The Complete Swimmer. New York: Macmillan Company, 1949.

Weissmuller, Johnny. Swimming the American Crawl. Collaborated with Clarence A. Bush. Boston: Houghton, Mifflin Company, 1930.

Wells, Katharine F. Kinesiology. 3rd ed. Philadelphia: W. B. Saunders Company, 1960.

Winer, B. J. Statistical Principles in Experimental Design. New York: McGraw-Hill Book Company, Inc., 1962.

Periodicals

Adrian, Marlene J.; Singh, Mohan; Karpovich, Peter V. "Energy Cost of Leg Kick, Arm Stroke, and Whole Crawl Stroke." Journal of Applied Physiology, XXI (November, 1966), 1763-66.

Alley, Louis E. "An Analysis of Water Resistance and Propulsion in Swimming the Crawl Stroke." Research Quarterly, XXIII (October, 1952), 253-70.

Barrows, Duane. "Basic Components of the Freestyle." Scholastic Coach, XXXV (December, 1965), 16, 37.

Barrows, Duane. "General Principles of the Competitive Strokes." Scholastic Coach, XXXV (October, 1965), 52-53, 69.

Batterman, Charles. "Mechanics of the Crawl Arm Stroke." Scholastic Coach, XXXIII (October, 1963), 46-49, 78-79.

Bush, Clarence A. "An Analysis of the Swimming of Borg and Weissmuller." The Athletic Journal, VI (March, 1926), 19, 22-23.

Cherry, John K., and Boehm, Walter W. "Modern European Controlled Interval Training Method of Distance Training." Scholastic Coach, XXVI (March, 1957), 20-24, 74-78.

Counsilman, James E. "Forces in Swimming Two Types of Crawl Stroke." Research Quarterly, XXVI (May, 1955), 127-39.

Counsilman, James E. "Interval Training Applied to Swimming." The Athletic Journal, XLII (September, 1961), 20, 80-84.

Counsilman, James E. "Principles of Training." The Athletic Journal, XXV (March, 1955), 40-44, 54-56.

Counsilman, James E. "The Crossover Kick in the Crawl." Junior Swimmer, I (November, 1960), 6-7.

Counsilman, James E. "Theory of the Flutter Kick." Beach and Pool, XXIV (June, 1949), 124-25.

Cureton, Thomas Kirk, Jr. "Elementary Principles and Techniques of Cinematographic Analysis." Research Quarterly, X (May, 1939), 3-24.

Cureton, Thomas Kirk, Jr. "Flexibility as an Aspect of Physical Fitness." Research Quarterly, XII (May, 1941 Supplement), 381-90.

Cureton, Thomas Kirk, Jr. "Mechanics and Kinesiology of Swimming--The Crawl Flutter Kick." Research Quarterly, I (December, 1930), 87-121.

Cureton, Thomas Kirk, Jr. "Review of a Decade of Research in Aquatics at Springfield College, 1929-1939." Research Quarterly, XI (May, 1940), 68-79.

Cureton, Thomas Kirk, Jr. "The Stop Watch Method for Testing Speed." Beach and Pool, IV (February, 1930), 15, 17-19, 32-34.

Davis, Jack F. "The Effect of Weight Training on Speed in Swimming." The Physical Educator, XII (March, 1955), 28-29.

Doherty, Ken. "Interval Training." Scholastic Coach, XXV (February, 1956), 18-20, 48.

Doherty, Ken. "Interval Training--Part II." Scholastic Coach, XXV (March, 1956), 20-24, 79.

Dunlap, James E. "The Swimming-Stroke of the Ancients." Art and Archaeology, XXVI (July-August, 1929), 26-35.

Fox, Margaret G. "Swimming Power Test." Research Quarterly, XXVIII (October, 1957), 233-37.

Gray, Norman A. "Training and Conditioning for Competitive Swimming." The Athletic Journal, XXXII (February, 1952), 14-15, 40.

Heffner, Fred. "Training for Swimmers." The Athletic Journal, XXXVIII (February, 1958), 46-48, 61-62.

Hewitt, Jack E. "Achievement Scale Scores for High School Swimming." Research Quarterly, XX (May, 1949), 170-79.

Karpovich, Peter V. "A Mathematical Analysis of the Crawl." Scholastic Coach, VII (December, 1937), 22-24.

Karpovich, Peter V. "Analysis of the Propelling Force in the Crawl Stroke." Research Quarterly, XXXV (May, 1935 Supplement), 49-58.

Karpovich, Peter V. "Swimming Speed Analyzed." Scientific American, CXLII (March, 1930), 224-25.

Karpovich, Peter V. "Water Resistance in Swimming." Research Quarterly, IV (October, 1933), 21-28.

McVicar, J. W. "A Brief History of the Development of Swimming." Research Quarterly, VII (March, 1936), 56-67.

Maglischo, Ernest W. "Overload Principle in Swimming Conditioning." Scholastic Coach, XXXIV (September, 1964), 66, 68, 112.

Matthews, Dave. "Interval Training in Swimming." Scholastic Coach, XXVIII (November, 1958), 42-43, 61.

Mohr, Dorothy R. "Needed Aquatics Research." Journal of Health, Physical Education and Recreation, XXVIII (May, 1957), 23.

Moore, Margaret Lee. "The Measurement of Joint Motion." The Physical Therapy Review (June, 1949), 256-264.

Mosterd, W. L. and Jongbloed, J. "Analysis of the Stroke of Highly Trained Swimmers." Arbeitsphysiologie, XX (June, 1964), 288-93.

Petrinovich, Lewis F., and Hardyck, Curtis D. "Error Rates for Multiple Comparison Methods: Some Evidence Concerning the Frequency of Erroneous Conclusions." Psychological Bulletin, LXXI (January, 1969), 43-54.

Robinson, Tom. "How Swimmers Use Their Legs." The Athletic Journal, XIII (January, 1933), 8-9.

Sanders, H. A. "Swimming Among the Greeks and Romans." The Classical Journal, XX (June, 1925), 566-568.

Scharf, Raphael J. and King, William H. "Time and Motion Analysis of Competitive Freestyle Swimming Turns." Research Quarterly, XXXV (March, 1964), 37-44.

Snyder, Alonzo (Al). "Hip-Knee-Ankle Foot-Propelling Drive Kick." Beach and Pool, XI (August, 1937), 7-8, 25, 27.

Sproule, J. P. Hugh. "Inexpensive Swimming Resistance Devices." Journal of Physical Education, LXVII (July, 1970), 161.

Swegan, Donald B. and Thompson, Hugh L. "Experimental Research in Swimming." Scholastic Coach, XXVIII (August, 1959), 22.

Tallman, John, "The Modern Two Beat Crawl." Swimming World, VII (May, 1966), 4, 47.

Thompson, Hugh L. and Stull, G. Alan. "Effects of Various Training Programs on Speed of Swimming." Research Quarterly, XXX (December, 1959), 469-85.

Timmons, Bob. "Championship Swimming and Diving Coaching Methods." Scholastic Coach, XXIX (February, 1960), 46-49, 60-61.

Walters, C. Etta. "Scientific Foundations of the Over-Load Principle." Scholastic Coach, XXVII (April, 1958), 20-22, 57.

Wilson, Colin Theodore. "Coordination Tests in Swimming." Research Quarterly, V (December, 1934), 81-88.

Young, Leonard. "Characteristics of In-Water Training." Scholastic Coach, XXXIV (September, 1964), 64, 102-5.

Unpublished Materials

Allen, Robert H. "A Study of the Leg Stroke in Swimming the Crawl Stroke." Unpublished Master's thesis, State University of Iowa, 1948.

Alteveer, Robert G. J. "A Natographic Study of Various Swimming Strokes." Unpublished Master's thesis, Springfield College, 1958.

Bandy, Janis Allen. "A Study of the Relationship of the Front Crawl Flutter Kick and the Drag." Unpublished Master's thesis, State University of Iowa, 1951.

Burdeshaw, Dorothy. "Learning Rate of College Women in Swimming in Relation to Strength, Motor Ability, Buoyancy and Body Measurements." Unpublished Ed. D. dissertation, University of Texas, Austin, 1966.

Clark, David F. "The Effect of Prescribed Isometric Exercises on Strength, Speed and Endurance in Swimming the Crawl Stroke. Unpublished Master's thesis, Central Michigan University, 1965.

Collins, Patricia A. "A Film Analysis of Selected Swimming Stroke Kicks." Unpublished Ph. D. dissertation, University of Iowa, 1968.

Davis, Michael Gary. "Relative Effects of Two Types of Training on Speed Swimming." Unpublished Master's thesis, The Pennsylvania State University, 1965.

Essick, Raymond Brooke. "The Training Habits of the 1956 United States Men's Olympic Swimming Team." Unpublished Master's thesis, University of Illinois, 1958.

Foster, Margaret Virginia. "The Development of a Method of Swimming Instruction Based on Efficiency of Propulsion Including a Comparative Study of Fear Reduction." Unpublished Master's thesis, University of Wisconsin, 1963.

Hairabedian, Ara. "Kinetic Resistance Factors Related to Body Positions in Swimming." Unpublished Ed. D. dissertation, Stanford University, 1964.

Healey, John H. "A Comparative Study to Determine the Relationship Between Plantar Flexion at the Ankle Joint and Success in Selected Skills in Swimming." Unpublished Ph. D. dissertation, University of Utah, 1970.

Hockey, Robert. "Flexibility Changes Following Participation in a Three Week Swimming Program." Unpublished Master's thesis, University of Oregon, 1965.

Jacobson, Richard Lee. "An Experimental Study of Flexibility and Its Retention in Competitive Swimmers." Unpublished Master's thesis, University of California at Los Angeles, 1967.

Jaeger, Lee Daehn. "Resistance of Water as a Limiting Factor of Speed in Swimming." Unpublished Master's thesis, State University of Iowa, 1937.

Kingston, Margaret. "The Effects of Two Training Programs on Swimming Speed, Physiological Efficiency, and Strength of College Women." Unpublished Master's thesis, University of North Carolina at Greensboro, 1961.

Lawrence, Lee Woods. "Practices in Conditioning of Competitive Swimmers." Unpublished Master's thesis, Springfield College, 1965.

Lewis, Helen B. "A Preliminary Study of the Relationship of the Factors of Propelling Force and Body Build to the Ability of Women to Develop Speed in Swimming the Front Crawl." Unpublished Master's thesis, University of Oregon, 1941.

Lietuvietis, Kaija. "The Effect of Isotonic and Isometric Leg Exercises on Selected Swimming Kicks." Unpublished Master's thesis, State University of Iowa, 1958.

Lopin, Vito. "A Diagnostic Test for Speed in Swimming the Crawl Stroke." Unpublished Master's thesis, State University of Iowa, 1947.

Moore, Kenneth. "The Effects of Warm-Up Exercises on the Flexibility of Boys Twelve, Fourteen and Sixteen Years of Age. Unpublished Master's thesis, University of Oregon, 1953.

Moyle, William J. "A Study of Speed and Heart Size as Related to Endurance in Swimming." Unpublished Master's thesis, State University of Iowa, 1936.

Murray, John L. "Effects of Precisely Prescribed Progressive Resistance Exercises with Pulley Weights on Speed and Endurance in Swimming." Unpublished Master's thesis, The Pennsylvania State University, 1962.

Osborn, Lola Lee. "A Method of Analysis of Swimming Strokes with Relation to the Application of Force." Unpublished Master's thesis, University of California at Los Angeles, 1941.

Parchman, Linda Lou. "A Comparative Study of the Development of Leg Strength and Endurance of College Women in Basketball and Swimming." Unpublished Master's thesis, University of Illinois, 1961.

Pickens, William Lamar. "A Study of Flexibility in Swimmers." Unpublished Master's thesis, University of Oregon, 1950.

Poulos, George L. "An Analysis of the Propulsion Factors in the American Crawl Stroke." Unpublished Master's thesis, State University of Iowa, 1949.

Rilea, Rose Ellen. "The Application of the Overload Principle of the Improvement of Swimming Performance." Unpublished Master's thesis, Florida State University, 1960.

Robertson, David F. "Relationship of Strength of Selected Muscle Groups and Ankle Flexibility to the Flutter Kick in Swimming." Unpublished Master's thesis, State University of Iowa, 1960.

Sanders, Charles L. "A Photographic Analysis of Five Methods of Freestyle Swimming." Unpublished Master's thesis, North Carolina College at Durham, 1968.

Smith, Ronald George. "A Study of the Relationship Between Leg Strength and Swimming Speed Using the Flutter Kick in the Prone Position." Unpublished Master's thesis, Montana State University at Missoula, 1962.

Spangler, James R. "A Compilation and Analysis of Completed Research in Competitive Swimming and Diving in the United States from 1930 to 1963." Unpublished Master's thesis, University of Illinois, 1964.

Tews, Richard J. "The Relationship of Propulsive Force and External Resistance to Speed in Swimming." Unpublished Master's thesis, State University of Iowa, 1941.

Thrall, William Robinson. "A Performance Analysis of the Propulsive Force of the Flutter Kick." Unpublished Ph. D. dissertation, State University of Iowa, 1960.

Turkington, Harold David. "A Comparative Study of an Interval and a Traditional Method of Training for Competitive Swimming." Unpublished Master's thesis, State College of Washington, 1959.

Van Atta, William Davidson. "Techniques of Performing Basic Swimming Strokes." Unpublished Ph. D. dissertation, State University of Iowa, 1964.

Wallace, Lulu. "Swim Fins as an Aid in Teaching the Flutter Kick for the Front Crawl." Unpublished Master's thesis, Washington State University, 1960.

Wilson, Colin T. "Coordination Tests in Swimming." Unpublished Master's thesis, International Young Men's Christian Association College, Springfield, Massachusetts, 1933.

Persons

Hinson, Marilyn. Private interview. Texas Woman's University, Denton, Texas. April, 1971

Lund, Nick. Class notes, "Statistical Theories." Texas Woman's University, Denton, Texas. February, 1971.

Lund, Nick. Personal interview. Texas Woman's University, Denton, Texas. July, 1971.